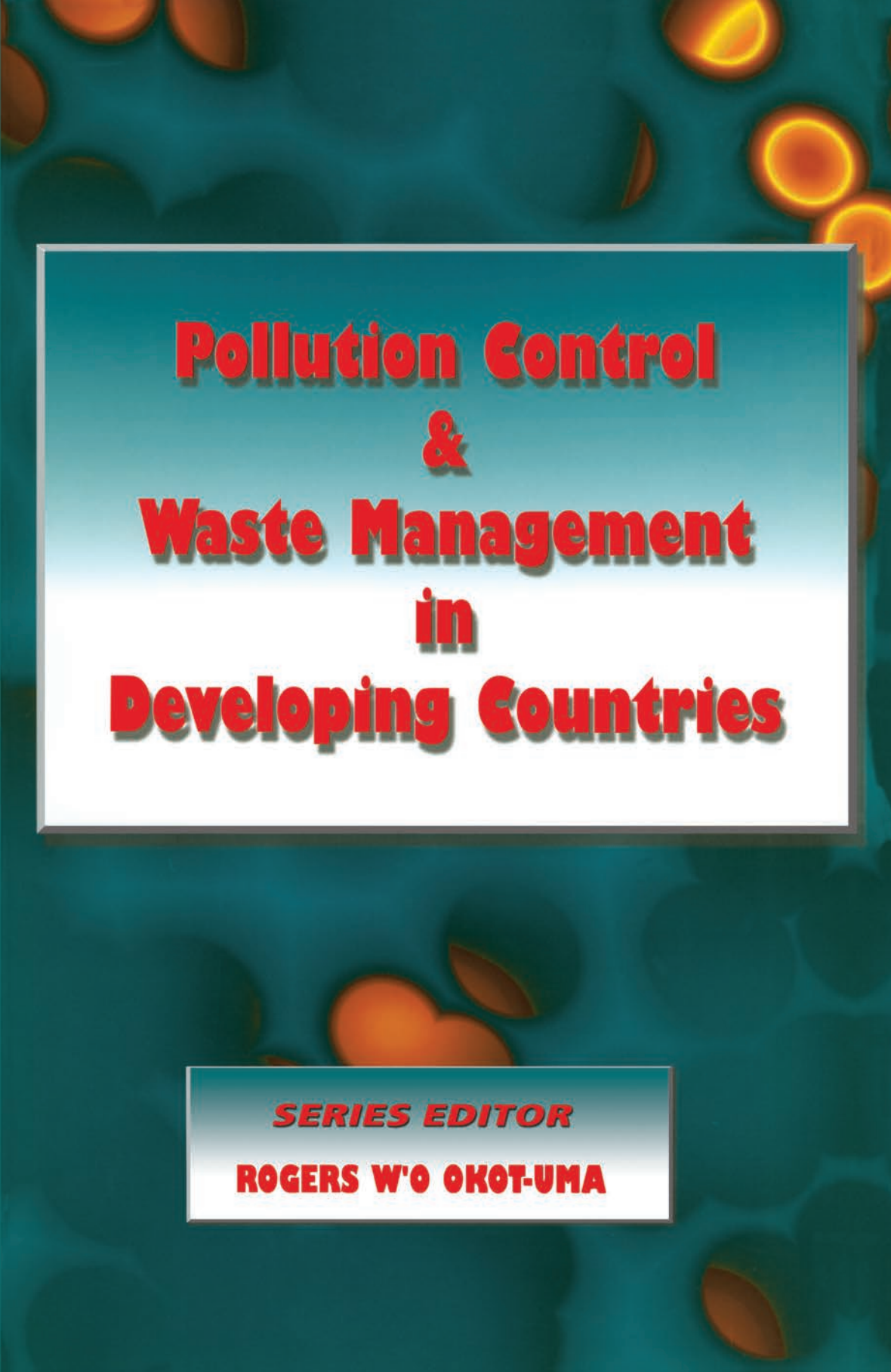




Pollution Control & Waste Management in Developing Countries

SERIES EDITOR

ROGERS W'O OKOT-UMA

**POLLUTION CONTROL
AND
WASTE MANAGEMENT
IN
DEVELOPING COUNTRIES**

**Edited by
ROGERS W'O OKOT-UMA
GEORGES E EKOSSE
YVONNE GOTLOP BOGATSU
KWESI DARKOH
OTLOGETSWE TOTOLO**



The Commonwealth Secretariat, London, UK
December, 2000

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Last but not least due tribute is paid to the several people who, individually and/or severally contributed to the content chapters that have resulted in the realisation of the publication. Some of the contributors have tirelessly continued to play the role of editing content areas of their choice.

Rogers W'O Okot-Uma
Georges Ekosse
Yvonne Gotlop Bogatsu
Kwesi Darkoh
Otlogetswe Totolo

PREFACE

The last 25-30 years has witnessed a significant surge and resurgence in public concern about Development and other anthropogenic activities as they relate to the status of the Environment in which we live. A number of international initiatives have contributed as precursor and antecedent, as provenant 'trigger' and provenant 'seeding' and as nurturing consequents in relation to *sustainability as a driving concept with respect to Environment and Development*. For individual countries and groups of countries, the realisation of sustainability will remain contingent upon the ability of the political agenda of the countries to effect a *paradigm shift* out of the *status quo*, namely, ability to develop a vision which is supported by commitment in the form of allocation of adequate financial resource to provide the necessary educational, institutional, organisational, legal and human resource development framework that will continue to nurture sustainability in all its manifestations.

The road to sustainability is long, The Stockholm UN Conference on Human Environment in 1977 marked a significant precursor to sustainability. Within 10 years of the Stockholm Conference, the Bruntland Report, *Our Common Future*, heralded, for the first time, the existence of an "unholy alliance" between Economy and Ecology on Planet Earth within the context of *Sustainability and Ecology* on the one hand, and *Development, anthropogenic activities and Economy*, on the other. The Rio Earth Summit in 1992, 5 years later (Bruntland + "5"), eloquently provided a consensus action plan for the 21st Century ("Agenda 21") *as an embodiment of commitment to sustainable development* in the years following the Earth Summit.

Five years after the Earth Summit ("Rio + 5"), an intergovernmental meeting convened to review progress towards the goal of sustainable development showed variable progress from the standpoint of three indicators comprising *Climate Change, Agenda 21* and *Sustainable Development*. While at Rio, Governments agreed to promote and co-operate on measures to reduce or prevent greenhouse gas emissions, global carbon emission reached a record of 6250 mt in 1996! Furthermore, the 1990s have been the hottest decade since records began. While at Rio, governments agreed to adopt Agenda 21 as the 'blueprint for sustainable development' covering some 20000 recommendations on arrange of environmental, economic and social issues, at "Rio + 5", Agenda 21 had raised government and public awareness, but had little effect on national policies.

Finally, while at Rio, developed countries committed to increase official development assistance (ODA) to 0.7% of GDP, at “Rio + 5”, official development assistance had decreased to 0.27% of GDP, the lowest level since 1970.

The publication *Pollution Control and Waste Management in Developing Countries* had its provenance in a series of training programmes implemented under the auspices of the Commonwealth Secretariat in Nigeria and in Botswana, respectively, during the five year period following the Rio Earth Summit. The publication represents an embodiment of modest initiatives aimed at giving drive to the Rio pronouncements from the standpoint of human resource skills development in an area of greatest significance to Environment, Development and Sustainability, namely, pollution and waste resulting from anthropogenic activities. It is my hope that the publication will provide a timely treatise that will find a timeless role in support of Agenda 21.

ROGERS W’O OKOT-UMA

London, December 2000

PART 1

1	Environmentally Sound Technologies: A Framework - Rogers W'O Okot-Uma	3
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CHAPTER 1

ENVIRONMENTALLY-SOUND TECHNOLOGIES: A FRAMEWORK

Rogers W'O Okot-Uma
Commonwealth Secretariat
Marlborough House
Pall Mall
London SW1Y 5HX

Tel.: +44 (0) 20 7747 6339 Fax.: +44 (0) 20 7747 6335
E-mail: r.okot-uma@commonwealth.int

Environmentally-Sound Technologies: A Framework

Introduction

This chapter presents the three entities *Environment, Development and Technology* as a tripartite set, characterised by the interaction between the *ecological* cycles in Nature and the *economic ‘cycles’* resulting from the effect of anthropogenic activities from technology use in the environment. The challenge of sustainability is postulated to lie with the ability of the humankind and the disposition of the ‘economic super-cycles’ to realise and promote the utilisation of environmentally sound technologies (EnSTs). Environmentally sound technologies are generically classified as ‘curative’ or ‘preventive’ with respect to *pollution and resource waste generation*. A paradigm shift from *end product focus to product life cycle* consideration is proposed, which postulates the use of a set of parameters for the (EnST) characteristic along the full product life-cycle. As constructs for eco-efficiency, the set of (EnST) parameters are perceived as integral components of the dichotomy of the “terms of exchange” between purchaser and seller of technology in the current international economic order. Eco-efficiency is predicate to play the role incorporating a measure of simultaneous effort to minimise the ecological burden while maximising the economic value of products, goods and services.

Environment, Development and Technology

In the context of environmentally-sound technologies, the term *environment* will be predicated to mean any component of the atmosphere, lithosphere, hydrosphere, or biosphere perceived as inseparable components.

Development will be taken to mean “development of human beings”, namely, a process of *satisfaction of basic human needs and welfare* (Table 1.1), leading to the concept of needs-oriented development. *Technology* will be taken to mean modifier of the environment on the one hand and as a negotiable commodity with a given set of “terms of exchange” on the other.

Table 1.1: A Simple List of Basic Needs and Welfare

Material Needs	Material Satisfiers	Non-Material Satisfiers
Physiological Individual	Food, Water, Clothes, Shelter	Creativity Identity

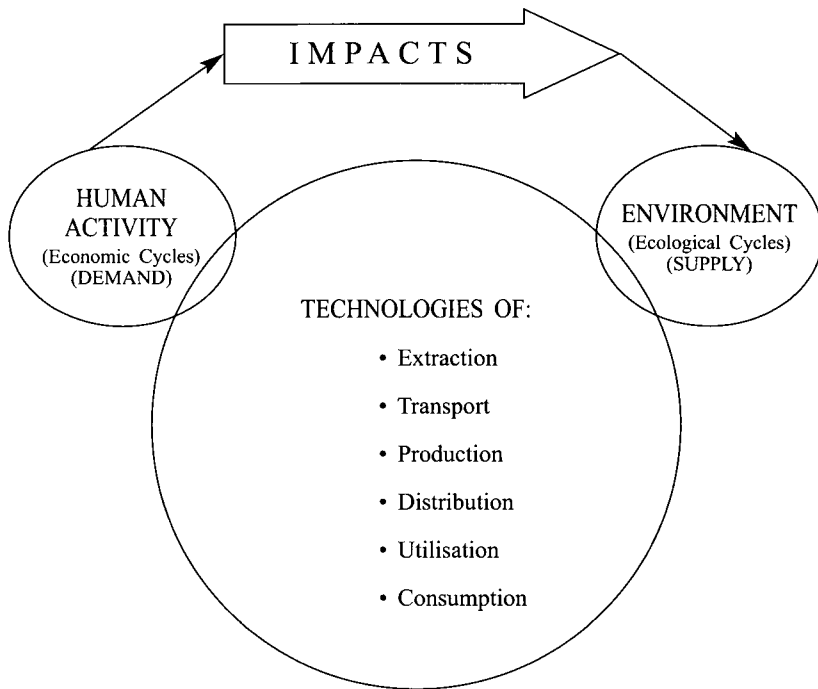


FIGURE 1
Impacts Model of Anthropogenic
Economic Cycles on Ecological Cycles

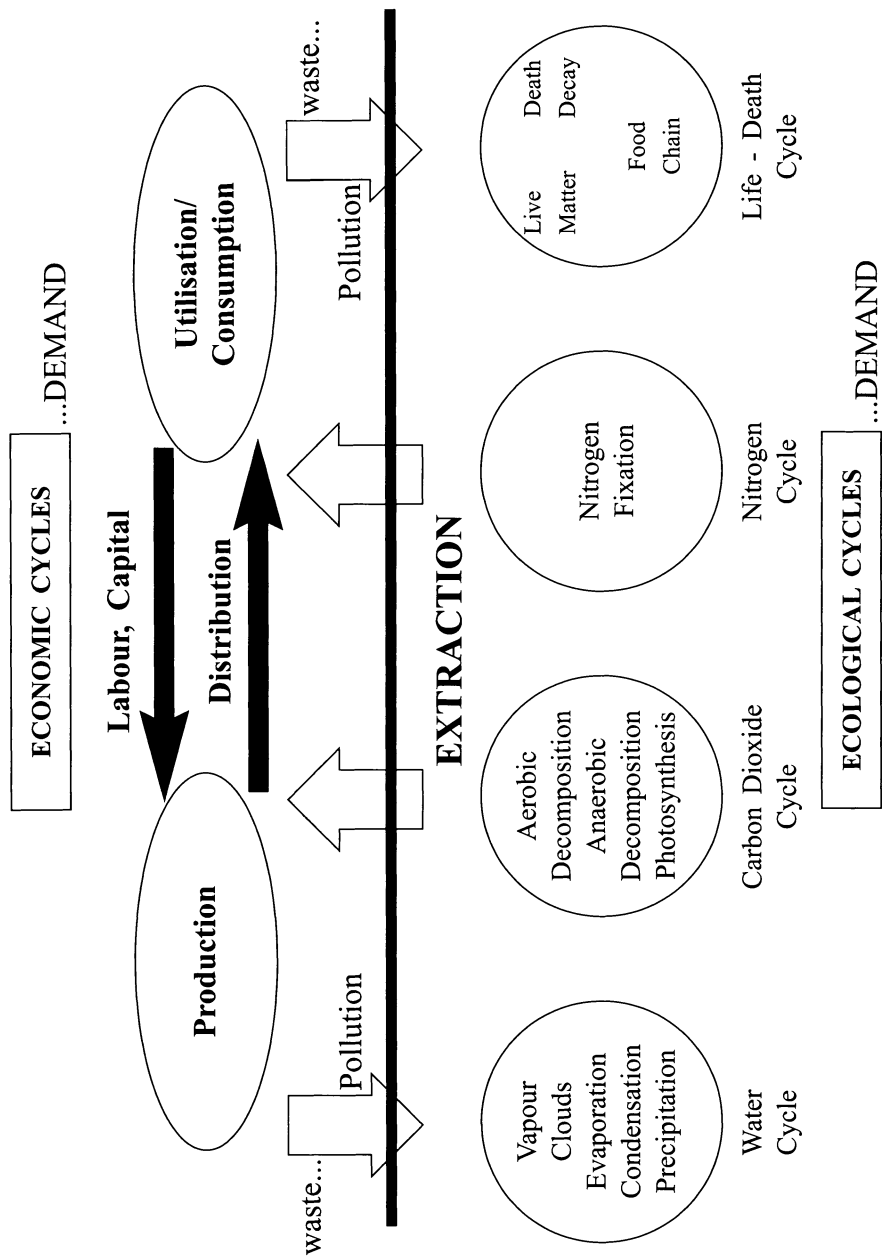


FIGURE 2
Model of Economic Cycle - Ecological Cycle Interaction

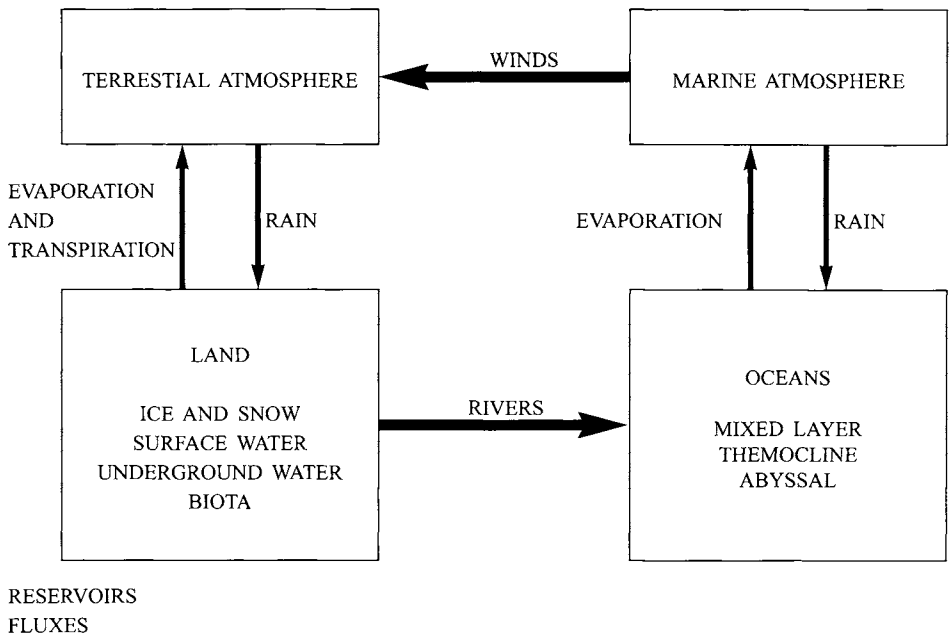


FIGURE 2 (a)(i)
Model of the Global Water Cycle

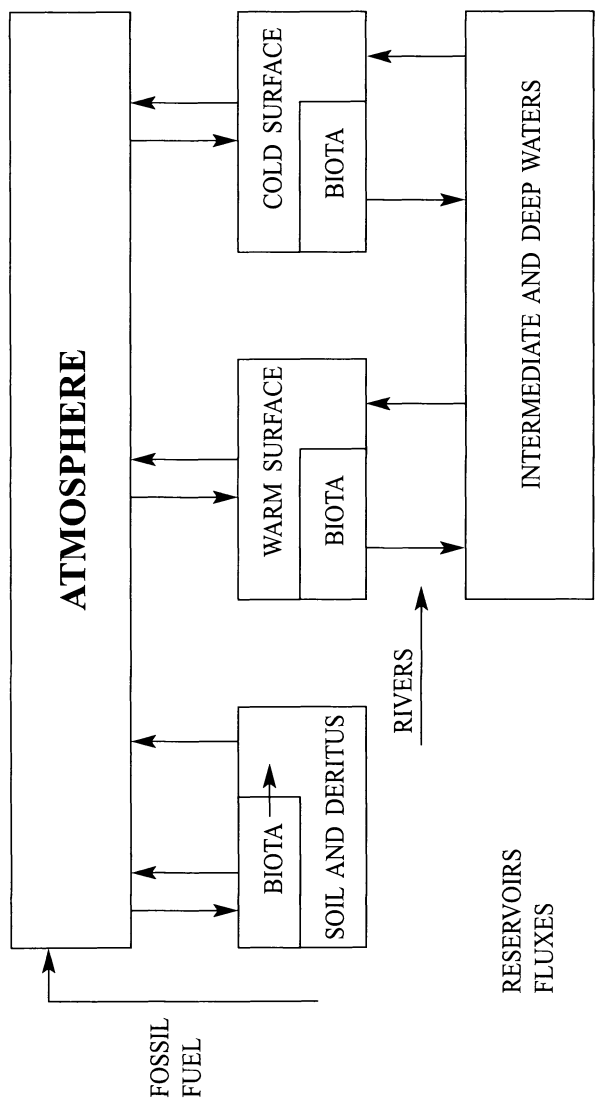


FIGURE 2 (b)(i)
Model of the Global Carbon Cycle

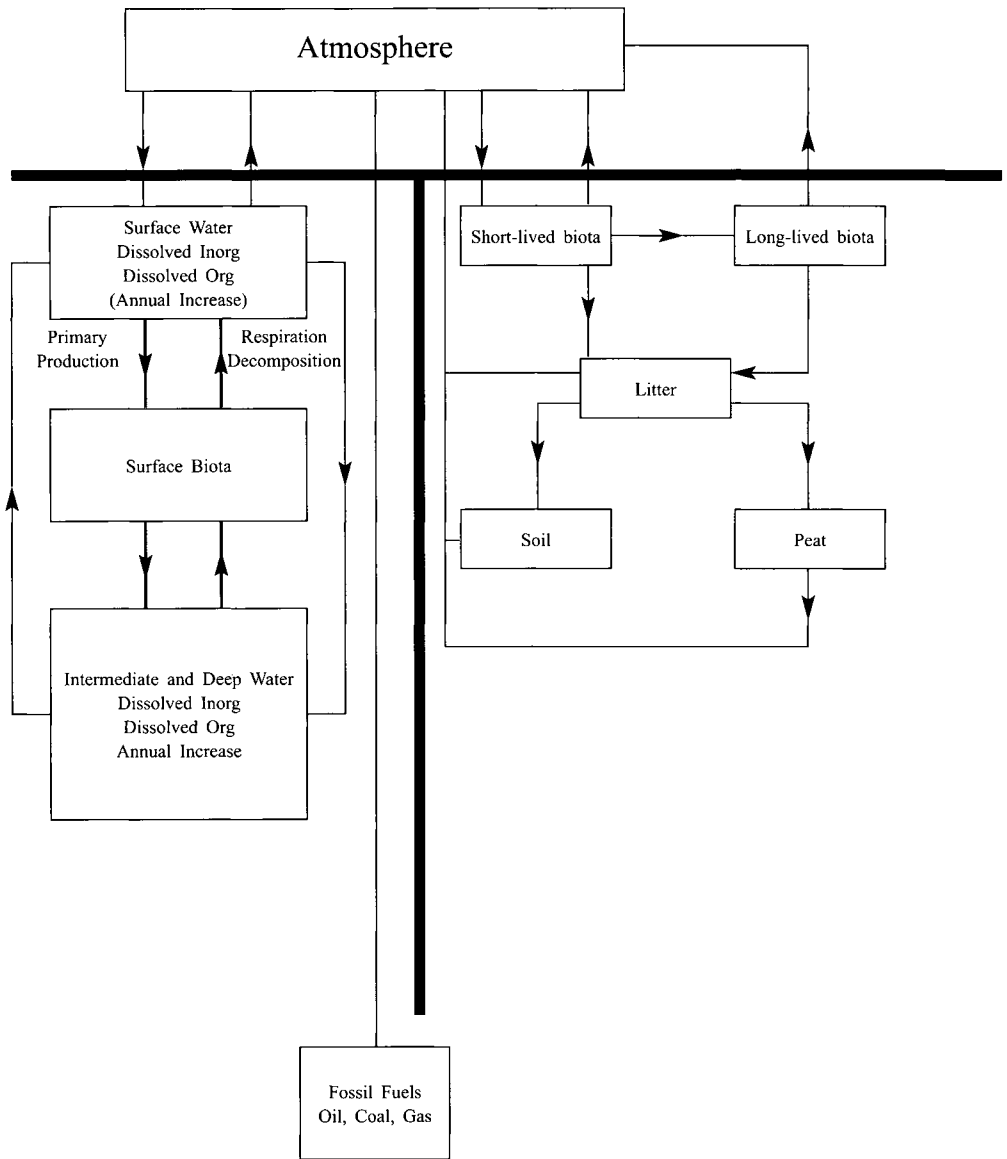


FIGURE 2 (a)(ii)
Model of the Global Carbon Cycle

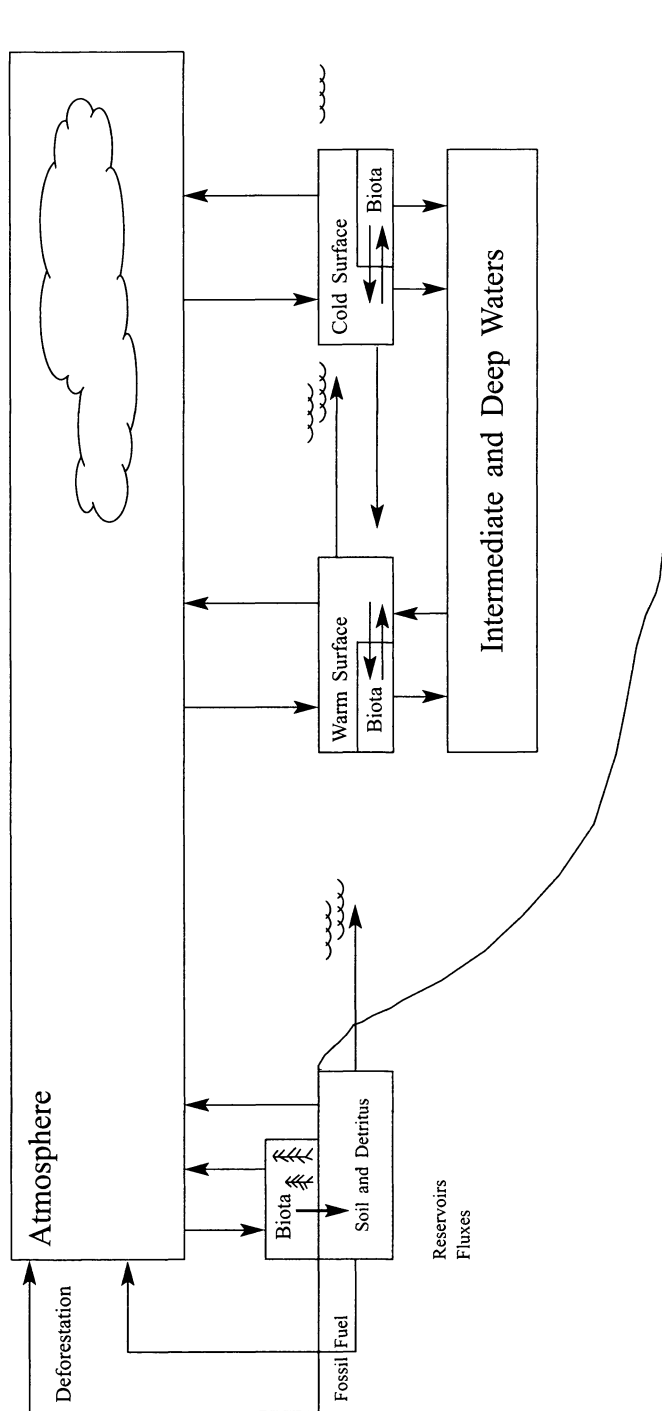


FIGURE 2 (b)(iii)
Schematic of the Global Carbon Cycle

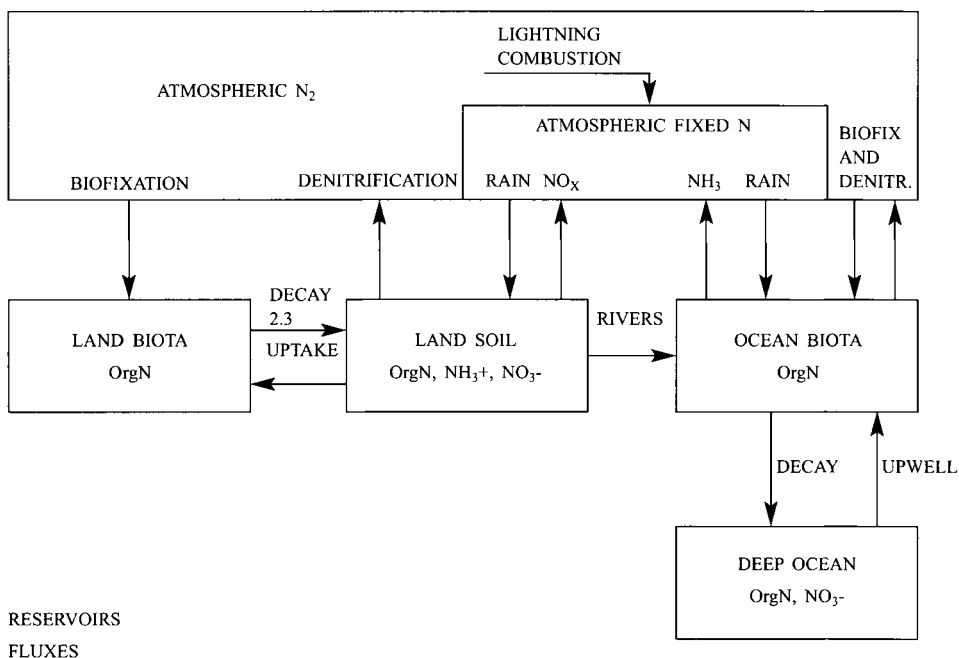


FIGURE 2 (c)
Model of the Global Nitrogen Cycle

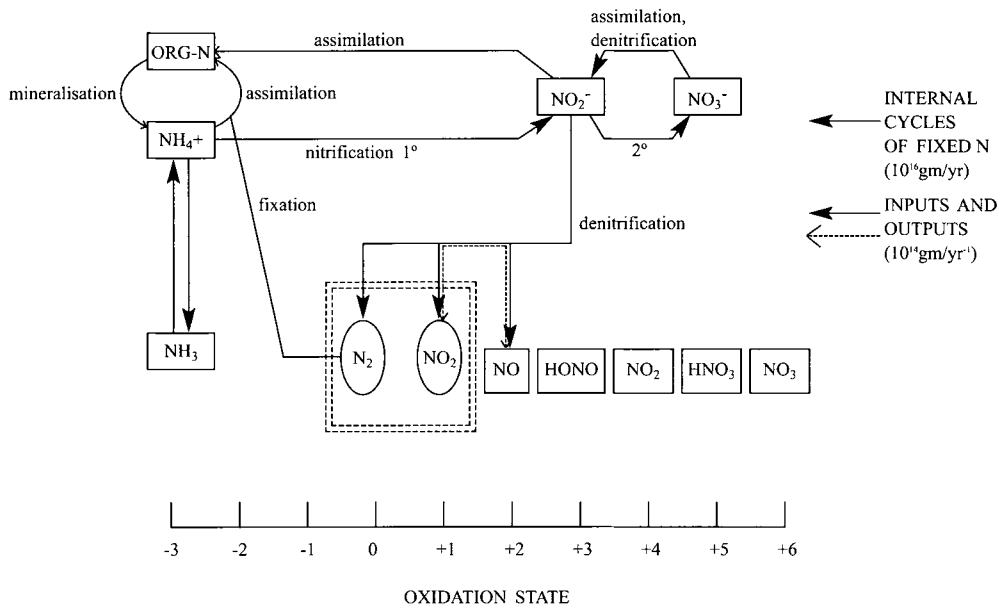
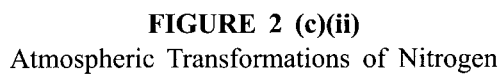


FIGURE 2 (c)(i)
Biological Transformations of Nitrogen



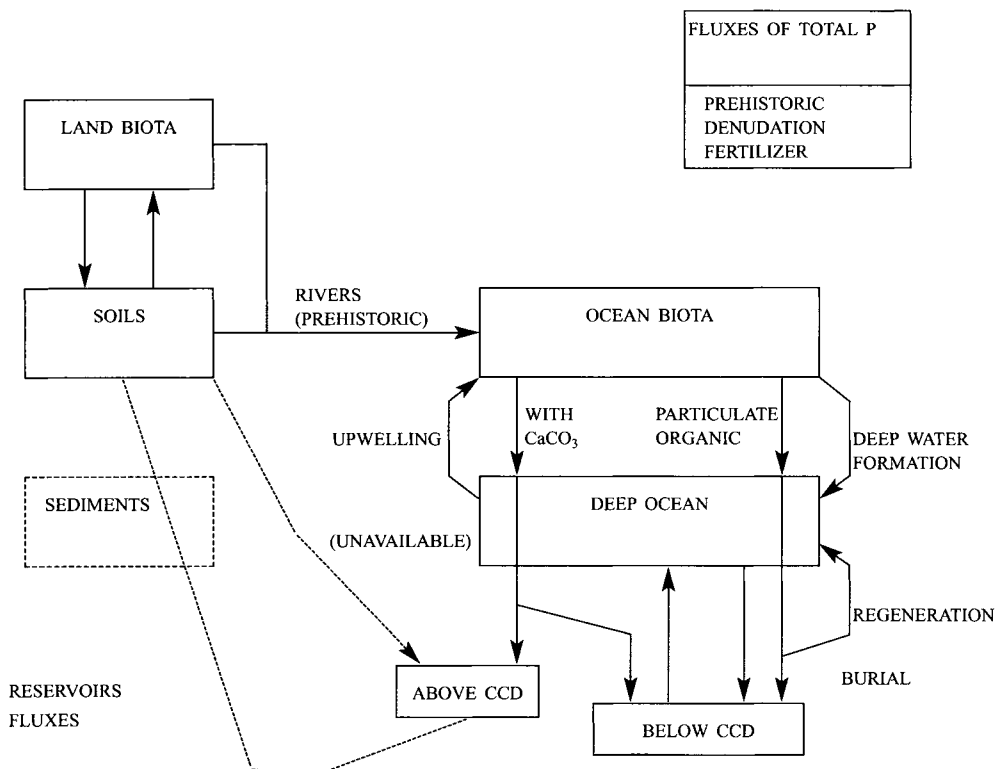


FIGURE 3
Global Cycle of Chemically Available Phosphorus

Group/Family	Medical Care	Autonomy
Health	Civil Protection	Somatic State
Safety	Schools	Non-Violence
Education	Free Movement	Schooling
Freedom/Equity		Self-Fulfilment

Ecological and Economic Cycles

Nature is replete with *Ecological Cycles*, whereby matter, organic or inorganic, is transformed from one state to another, predominantly cyclically, sometimes non-cyclically. The humankind, on the other hand, is able to construct what may be conceived as *Economic Cycles*, which almost invariably involves the extraction and transportation of raw material from nature's available natural resource; production; distribution; and consumption of the products and services from the processed raw material. This is illustrated in Figures 1.1 and 1.2, which show:

- (i) Impacts Model of Anthropogenic Economic Cycles on Nature.
- (ii) Model of Economic Cycle and Ecological Cycle interaction.

A model of the Global Water Cycle is illustrated in Figure 2(a); that of the Global Carbon Cycle is shown in Figure 2(b) (i) and Figure 2(b) (ii), of the Global Carbon Cycle is shown in Figure 2(b) (i) and Figure 2(b) (ii), together with a corresponding schematic in Figure 2(b) (iii)

A model of the Global Nitrogen Cycle is shown in Figure 2(c), together with the corresponding schematic for biological and atmospheric transformation mechanisms for nitrogen, Figures 2(c) (i) and (ii)

Figure 3 summarises a model on contents of major phosphorous reservoirs and transfers between them. Phosphorous is abundant in the crust of the earth where it exists principally in the form of insoluble minerals (apatite, iron phosphates) or as absorbed phosphate. These compounds are not available for biological uptake, and phosphorous is often a limiting nutrient in soils, in lakes, and in marine systems. Atmospheric transfer processes are unimportant for phosphorous, in contrast to carbon, nitrogen and sulphur. Key exchanges are with dissolved and particulate transport in rivers, with weathering processes and with diagenesis in soils and sediments.

Figure 4 summarises flux transfer mechanisms of sulphur compounds to and from the atmosphere. Sulphur compounds are present in all living materials. Reduced sulphur gases are emitted primarily as the result of biological processes in ocean surface water and in salt and fresh-water marshes and in volcanoes.

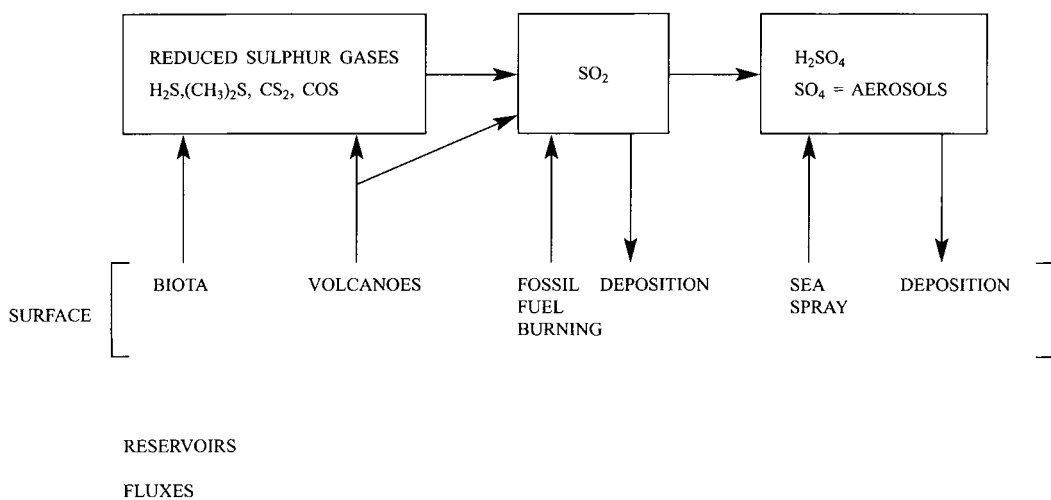


FIGURE 4
Tropospheric Sulphur Budget Model

Technology as Modifier of Nature's Ecological Cycles

Technology may be perceived to be a manifestation of the discrepancy between natural ecological cycles and anthropogenic economic cycles. A consequence of this is that the challenge of sustainability lies with the ability by both Nature and Humankind to (...) *meet the needs of the present generation without compromising the ability of future generations to meet their own needs*. A distinctive feature of the perceived challenge points to a possible relationship between technology and social challenge, namely the imperative to making and using technology to degrees that are commensurate with the social state or level of society, whether primitive, developing, developed, or emerging.

Perceived Impacts of Anthropogenic Economic Cycles

Extraction: The impacts of the anthropogenic economic cycles at extraction include the following:

- ☐ Natural Resource Exploitation, Land;
- ☐ Desertification, Biodiversity and Genetic Resource; and
- ☐ Loss and Depletion; Pollution; and Man-made Disasters.

Production, Transportation/Distribution and Utilisation/ Consumption:

The impacts at these phases of the economic cycles include the following: Transborder Pollution; Global Warming; Ozone Layer Depletion; and Ecosystem Degradation.

In generic terms, the impact of anthropogenic economic cycles may be perceived to comprise the following forms:

- ☐ **Perturbance of Nature's Dynamic Eco-Equilibrium**, namely, Acceleration/Retardation of Ecological Cycles; Eco-Material Transfer and Transportation; Exploration, Degradation, Depletion and Loss.
- ☐ **Pollution**, namely, Incidence into Environment of By Products of the Economic Cycle Activities.

Other Metaphors of Technology

Many metaphors of technology exist, the various factors, depending on perspectives, beliefs, or even the nature of the social status of individuals, groups or even communities:

- ☐ Source of well-being;
- ☐ Instrument of Power to Dominate Nature and Society;

- ❑ Enslaver of Humankind;
- ❑ Destroyer of Jobs, Environment, and Social Values;
- ❑ Cause of Human-made Disaster

Environmentally Sound Technologies (*Environmental Technologies*)

Environmentally - Sound Technologies (EnSTs) may be defined in terms of the *sustainability* concept as technologies whose use or application can be said, or demonstrated to, “... meet the needs of the present generation without compromising the ability of future generations to meet their own needs” promoting the *use technology assessment* as a tool for the development and application of environmentally sound technologies constitutes environmentally sound technology assessment (EnSTA)

The Economic Super-Cycle

A particular aspect of the **challenge of sustainability** lies with the ability of countries in their roles as economic entities and drivers of their own destinies, for their respective future generations, to survive a phenomenon that may be described as an *economic super-cycle*, perceived to involve international control ‘centres’ *processing problems into decisions, raw capital into investment capital, science into technology, and technology into technology transfer*. The Economic Super-Cycle can be recognised in embodiments of transitional corporations (MNCs), the Bretton Woods Systems, Donor and aid Agencies and in corresponding “networks” of bilateral and multilateral arrangements between and within countries and not least in the IGOs and the emerging Global Corporations (GCs) of the new information era.

Perceived Impacts of the Economic Super-Cycles

The Economic Super-Cycles provide an illustration of what may be termed the centre-periphery social structure, which essentially comprises an imposition, by design, by the north (“centre”) on the South (“periphery”) on the mode of exploitation, processing and utilisation of the natural resources of the South, perceived as the essence of the current international economic order. The result is building of a strategic alliance of imbalance of power and social reformation between the North and the South, which can be:

- ❑ *Exploitative* in the “terms of exchange”; in the context that technology is a negotiable commodity;
- ❑ *Dependency-creating*, in the nature of North-South relationship;
- ❑ *Fragmenting*, unless supported by a definitive environment strategy;
- ❑ *Marginalising*, unless recipient is non-succumbing to external dictates of

- the economic super-cycles;
- ❑ *Dichotomous*, in the nature of differential mode of development between the North and the South.

Economic Super Cycle and Technology Transfer

Technology as a concept may be perceived to comprise the following components:

Technology = Technique + Structure,

where:

(a) **Technique** can be represented by combinations of the following entity types:

- ❑ Tools, Equipment, Machines, Vehicles, Physical Facilities (Technoware);
- ❑ Skills, Experience, Knowledge, Know-How, Creativity (Humanware);
- ❑ Procedures, Specifications, Standards, Guidelines, Theories, Observations (Infoware); and

(b) **Structure** can be represented as an Organisational Framework, a Cognitive Management Practices, Institutional Linkages, and Networks within which techniques become meaningful (Orgaware). *This component is often overlooked in the technology transfer process. It is essential that the structure that accompanies technology transfer is adequately negotiated in the “terms of transfer” to reflect appropriate and relevant organisation framework in the environment of the receiver of the technology*

It is convenient to identify the following modes of the Technology Transfer Process:

Object-Embodied *Technology (Technoware)* and transfer Human-Embodied Technology (*Humanware*) and transfer; Document-Embodied *Technology (Infoware)* and transfer; Institution-Embodied Technology (*Orgaware*) and transfer.

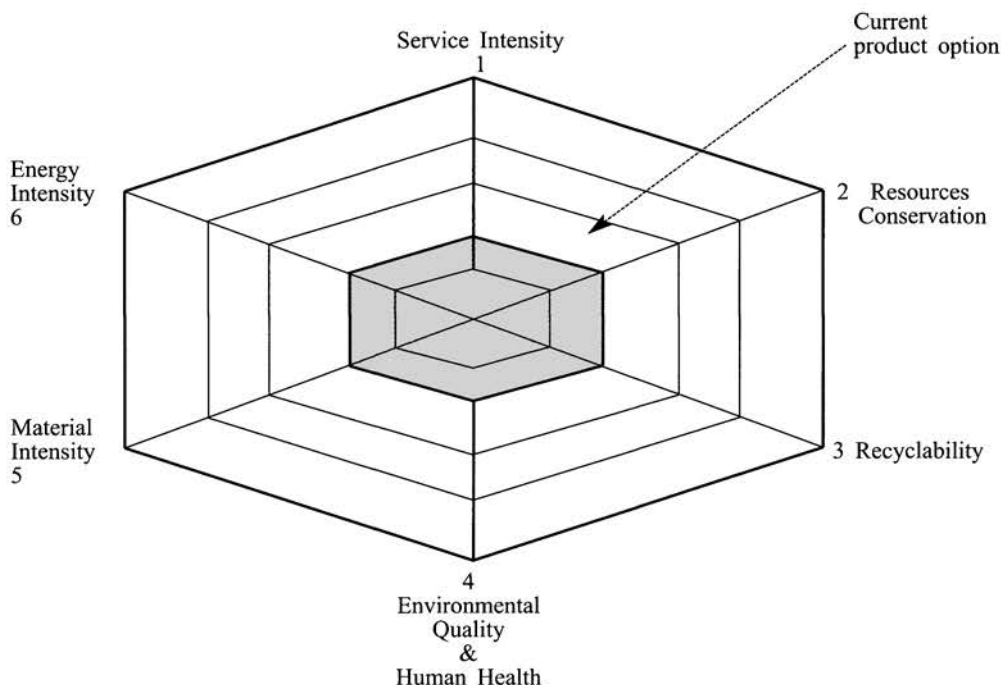


FIGURE 5
The Six Components of Ecoefficiency

Environment Technologies: Generic Classifications

“Curative” Technologies

“Curative” technologies comprise those environmental technologies whose utilisation will variously result in the mitigation of the factors of environmental pollution or resource waste generation:

- ☐ **Pollution Control/Abatement Technologies**
- ☐ **Waste Control Technologies**, including: Waste Treatment and Disposal; and Waste Recycling and Utilisation
- ☐ **Energy Conservation Technologies**, including Waste Energy Recovery; and Waste Utilisation for Energy Generation.

“Preventive” Technologies Pollution Free/Low Pollution Technologies; Energy Efficient (or Energy Saving) Technologies through the promotion of Non Conversion Sources of Energy Efficient Energy Supply through Conversion Generation of Energy.

Environmentally Sound Technology Assessment (EnSTA)

Environmentally Sound Technology Assessment (EnSTA) is based on the *sustainability concept*, perceived as a triple balance of securities:

- ❑ **Ecological Security**, a condition on environmental resource quantity, for the current capacity of the environment to support living and non-living resources without compromising the ability of future generations to meet their own needs;
- ❑ **Socio-economic Security**, a condition for human education, health and technological progress to meet the needs of the present generation without compromising the ability of future generations to meet their own needs;
- ❑ **Resource Security**, a condition on environmental resource quality, for the current capacity of the environment to sustain living and non-living resource quality.

EnSTA and Eco-Efficiency

Eco-Efficiency represents a measure of Simultaneous Effort to minimise etc while maximising the economic value of Products, Goods and Services (human needs and welfare, quality of life, among others). A result of the Eco-Efficiency concept is the need for the paradigm **shift** from the end-use product consideration in any attempt to computer Eco-Efficiency metric.

The **components** of Eco-Efficiency are varied and various and include the following:

- ❑ Material Intensity
- ❑ Energy Intensity
- ❑ Service Intensity
- ❑ Environmental Quality and Human Health
- ❑ Recyclability
- ❑ Resource Conservation

The six components of Eco-Efficiency may be represented as in Figure 5 above.

EnSTA and Eco-Efficiency Criteria in the Total Life Cycle of a Product

Production: Material Intensity; Energy Intensity; Renewable Resource Input;

Waste Intensity; Refusal Rate; Transport Intensity; Packaging Intensity; Hazardous Effluent and Intensity; Longevity; Surface properties (cleaning losses and duration due to mechanical stress); Anti Corrosivity; Repairability; Structure and Ease to Disassemble (maintenance, repair); Durability; Reliability; Likelihood of Material Fatigue; Adaptability to Technical Progress and Technology Upgradation.

Use, Consumption: Material Throughout; Energy Input; Self-Optimisation; Multi-functionality; Potential for Subsequent (different) Uses; Potential for joint (e.g. several families) Users; Size; Area Coverage; dispersive Hazardous Material Outputs.

After Use: Material Consumption and Complexity; Re-usability; Multi-purpose Usability; Remanufacturing Potential for Same Use; Combustion Potential (usable energy outputs); Potential for Composing; Impact on environment after Disposal.

Special Focus on Living Resources: Conservation Strategy Objectives

Conservation strategies for living resource in the environment functionally depend on the **renewable characteristic** of the biotic resources.

Maintain essential **ecological processes** and life support systems through rational planning, allocation, and management of biotic resources;

Preserve **genetic diversity** through the collection and banking of genetic material:

Ensure sustainable utilisation of **ecosystem** through knowledge and understanding of productive capacities and measures to ensure that resource utilisation does not exceed resource regeneration capacity.

Figure 6 depicts what is known as the *Holdridge Life-Zone Classification System* for the earth's geographical biodiversity regions.

Conservation Strategies: National Perspectives

Strategic Review: Review of national development objectives in light of the conservation strategies.

Analysis: In-depth analysis of practices and identification of areas for change.

Action Planning: Proposal of means of supplying the economic, social, and political resources necessary to meet the conservation objectives. It is important that conservation strategies aim to do the following, among others: integrate conservation and development goals; compensate for knowledge gap by retaining options including information data on absorptive capacity and productive regenerative qualities of environment; address prevention as well as cure options; and address causes as well as symptoms.

“The Road to Sustainability Is Long”

The road to sustainability is long. Sustainability by nature is a long-term process and can only be realised after a long time horizon. This is rendered manifest by the realisation that as an international agenda, *sustainability as a concept* in the international area has existed for quite some time. Below (**Table 2 on page 26**) is **listed** a number of international initiatives since the late 1960s that may be considered pertinent to sustainability.

A number of the initiatives can be perceived as precursor in relation to sustainability.

For individual countries and groups of countries, the realisation of sustainability will be contingent upon the ability of the political agenda of the countries to effect a *paradigm shift* out of the *status quo*, namely, the ability to develop a vision which is supported by commitment in the form of allocation of adequate financial resource to provide the necessary drive for the vision.

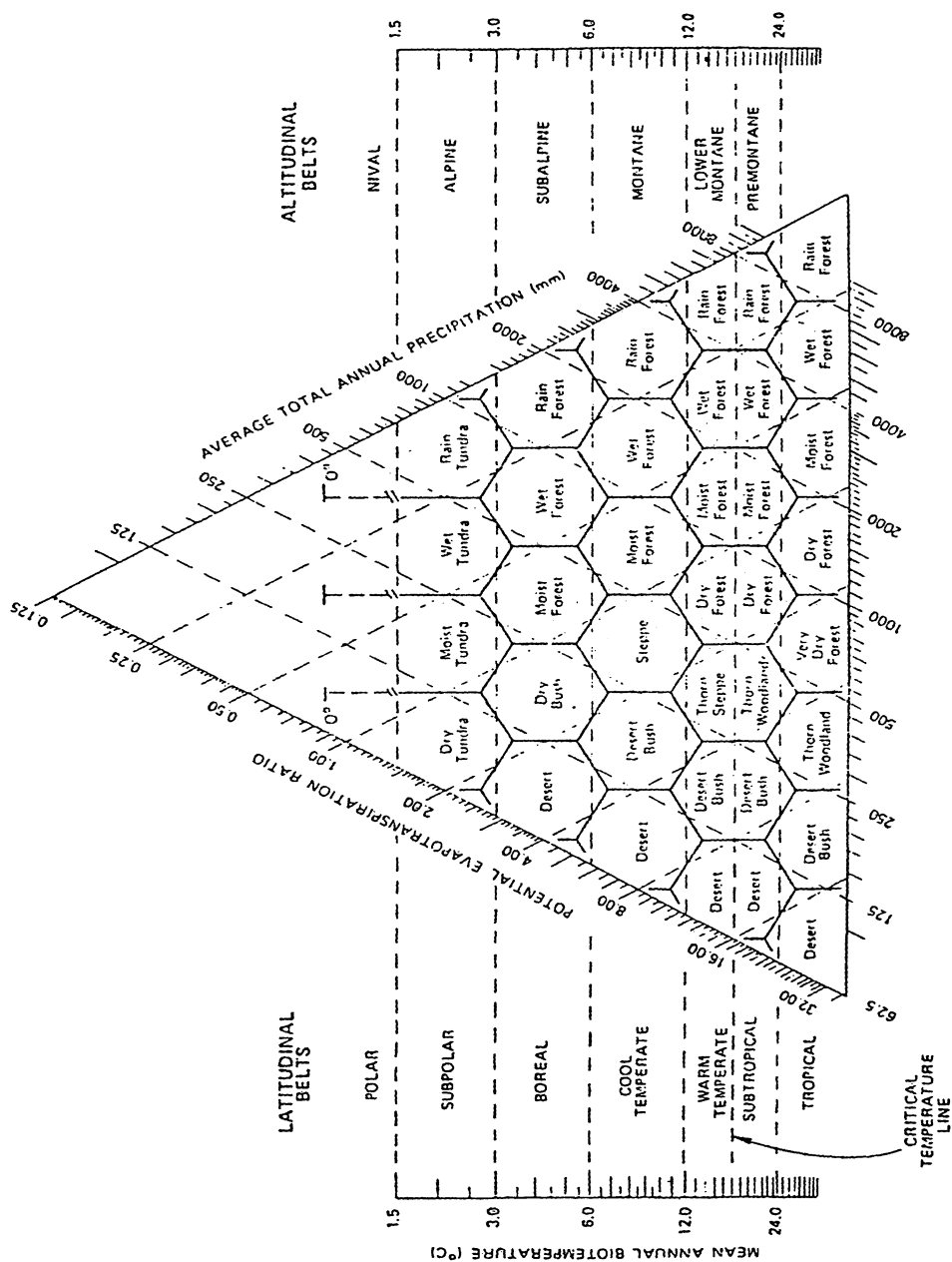


FIGURE 6: The Holdridge LifeZone Classification System

Table 2: A Chronology of Initiatives on the Environment

1968 Paris **Biosphere** Conference – **Environmental** Education first fully recognised.

1975 Belgrade – Belgrade Charter – framework for **environmental education**.

1977 Stockholm UN Conference on **Human Environment**

1977 Tbilisi First InterGovernmental Conference on **Environmental Education**

1987 Moscow - Another Conference on **Environmental Education**

1987 Bruntland report. “Our Common Future”, an exposition heralding marriage of **Economy and Ecology** on planet Earth.

1992 Rio Earth Summit. “Agenda 21”, a consensus action plan for 21st century – commitment to realising **sustainable** development.

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CHAPTER 2

MOBILISATION OF THE COMMUNITY ON ENVIRONMENTAL MANAGEMENT

K. Nthomang

Department of Environmental Science
University of Botswana
Private Bag 0022
Gaborone, Botswana

Phone: 267-3552524 Fax: 267-356591
E-mail: nthomang@noka.ub.bw

Mobilisation of the Community on Environmental Management

Introduction

This chapter discusses how communities can be mobilised to manage their environment. The chapter begins with a brief discussion of the key terms *community mobilisation, involvement and participation*. It is very important for the public to understand the conceptual basis of these terms since they are value loaded. Sometimes they are used interchangeably by both scholars and practitioners, thereby making it difficult for one to understand their differences and similarities.

The chapter also reflects on the ongoing efforts by various actors geared towards *better use, protection and conservation of the environment*. The chapter observes that it is through extensive dialogue that we can appreciate the significance of community mobilisation in environmental management. It must be understood that community mobilisation as a model is generally easier said than done. The challenge is to find better ways of making community mobilisation in environmental management an achievable goal.

Background

Traditional Tswana Societies

For many years, Botswana have maintained a living balance with their natural environment and resources on which they depend. They maintained an intimate organic relationship with nature, characterised by a high degree of sensitivity and respect for the workings of natural ecosystems and a sense of duty to conservation. Controls and taboo systems were a manifestation of this sense of close relatedness between Botswana and their surroundings. It is true, therefore, that a thorough understanding of nature leads to a sensible and sustainable attitude towards the use of its resources.

Post-Independence Tswana societies

Development as manifested in rapid economic growth and expansionist tendencies disturbed this harmonious relationship between Tswana tribal people and nature by imposing ever-increasing demands on natural resources. It introduced large scale industries, agriculture and began massive deforestation to construct roads and dams. Intensive mining operations began too, as “western notion of development” ushered Botswana into an era of resource-intensive use. The cumulative effect of land misuse, deforestation, pollution and desertification has resulted in extensive damage to the environment.

The ecological degradation that followed “development” has had a devastating effect on both rural and urban dwellers in Botswana. The most acute environmental problems facing this country are *overgrazing* (due to increased commercialisation of both arable and pastoral agriculture) and *pollution* (due to increased industrialisation and population growth).

The problems outlined above are continuing to grow. Hence, the need to be creative, imaginative and come up with effective strategies to address them. There is a growing concern at both national and local levels about the deteriorating environmental conditions. To remedy the situation and put Botswana back on the path to sound environmental management, sensitivity and recovery, most efforts should centre around mobilisation of the community in managing their own environment. It is no exaggeration to say that the struggle against all environmental problems as stated above will be won and lost at household, community and council level.

Community: Definitional Issues

There is no universal definition of the term “community”. Some commentators have used the term to refer to pre-industrial societies when there existed *strong kinship bonds and a spirit of communalism or communitarianism*. The term has also been used to refer to people living within specific geographical boundaries. Clarke (1975) traces the evolution of the definition community as including among others, *community as locality, as a social activity and as consisting of interest groups with different missions and sometimes conflicting agenda*.

Today, it is apparent that talk about community is an acknowledgement of the negative impact of industrialisation on social relationships in society.

The term community in this chapter shall refer to:

A group of individuals who have a consciousness of common social problems or interests, and a commitment to address these commonalities collectively (Rankopo, 1993: 34-35)

This definition of community places emphasis on the social factor or boundaries in the determination of a community. It is envisaged that this definition could be relevant for understanding and managing the environment, for communities are located within certain environments which they must protect and conserve.

Community Involvement, Participation and Mobilisation

As indicated earlier, these terms are often used interchangeably. A commonly held view is that for communities to participate in any social activity, they must

be mobilised, i.e., be organised, get involved and by so doing take part in social development efforts. Used in this manner, it is presumed that people will have a natural desire to take part in activities that they identify with and directly affect them.

Community involvement

This concept implies a sense of commitment on the part of a community. For a community to be involved means that *“the people will have a right and duty to participate actively in decisions concerned with solutions of their problems, and they would have greater responsibilities in assessing the needs, mobilising resources, and suggesting new solutions as well as creating and maintaining local organisations”* (Oakely and Marsden, 1986:19). Critics, however, argue that the word “involve” can note that it is the state which has the authority to involve people in social development. It is important to note that the state is a very powerful institution which determines when and under what conditions should ordinary people be involved in social development.

Community Participation

This concept means to *“sensitise people and thus to increase their receptivity and ability to respond to local development programmes, as well as to encourage local initiatives”* (Uma Lele, 1975). It is argued further that participation is “essentially a political act” in which the people voluntarily contribute to one or more public programmes designed to contribute to national development. However, they are not expected to take part in shaping the programme or to criticise its content (Oakely 1980:10; Oakely and Marsden, 1986:19).

Community Mobilisation

GoB/UNICEF (1989:226) define social mobilisation as *“increasing the capacity of individuals and communities to identify, evaluate and respond to their problems and opportunities within their own capacity and to seek assistance from elsewhere when necessary”*. Today, it is generally believed that community mobilisation is one of the most effective mechanisms of changing people's behaviour and creating sensitivity to community issues. The adoption of this orientation may lead to the creation of environmental programmes which are more “appealing” or “acceptable” to the people.

It is also important to note that in the same vein, community mobilisation presupposes that local people and their leaders, and organisations are so weak

that they cannot on their own partake in local social development activities without external motivation. Consequently, there is a need for external agents to stimulate and motivate local people to participate in environmental programmes and projects. It is at this point that professionals will assume the roles of catalysts, educators and organisers. The major limitation of this model is that it emphasises the weakness and not strength of the community.

An important thing to note is that in seeking to mobilise the community one should not lose sight of the dynamics that may prevent the community from achieving their goals. These may include unscrupulous politicians taking advantage of the mobilisation process to promote their political agenda or for political expediency. This is dangerous as it is short term and it is likely to bring tension among people as they realise that they are being taken for a ride. Such dynamics, if left unchecked, could undermine even the best of intentions.

Current Efforts By Government

The government of Botswana, through different ministries is trying to confront the above problems head-on. Ministries involved include the Ministry of Education - Health Education Unit, Ministry of Health - Environmental Health Unit and Ministry of Local Government Lands and Housing - National Conservation Strategy Agency (NCSA). The latter plays a pivotal role as it is charged with the overall responsibility for policy, research, education and co-ordinating in an integrated manner the activities of other government ministries, departments concerned and to some extent NGOs focusing on environmental issues. Major activities include management and disposal of solid wastes, pollutants, littering, environmental education, research and policy formulation.

Despite government efforts, environmental problems continue unabated. The government also embraced the notion of community mobilisation in implementing its programmes but given the nature of its bureaucracy, the concept has not worked. Many explanations have been given for this unfortunate state of affairs, the most plausible one being the centralised or top-down nature of government programmes. The Botswana Government always wants to retain the power and responsibilities for formulation, planning and implementation at central level, treating communities as grateful beneficiaries and recipients rather than participants. This phenomenon may be termed paternalistic fallacy.

Limitations of Government Centralised Approaches

While a centralised bureaucratic approach may be appropriate for provision of national level enabling structures and strengthening of national level institutions,

it is certainly not suitable for selecting and implementing environmental projects and activities at village or community level. If a village level environmental project, e.g., littering campaign is spearheaded and determined by government (central or local) rather than communities themselves, there is a high possibility that the community will not identify with the project. This brings into the surface a fundamental question of ownership in that communities tend to perceive such projects as having been imposed from outside. They may consequently be indifferent, less committed, make less efforts, generally participate less, and in some cases, might even concentrate their efforts on criticising the government's efforts or become resigned to dependency on government provision.

The gap between planning and implementation has also been a major limitation. Government programmes are often said to be in the pipeline and many times communities have been asking, just how long is the pipeline as it takes a long time to implement programmes. For example, current efforts by government, NGOs and private sector on controlling litter have failed not because people were unwilling but because of government failure to provide dustbins in public places and where provided, failure to collect and empty them. This obviously kills the morale of the community resulting in indiscriminate disposal of litter.

Forstering Community Participation

Given the concerns over poor performance of current strategies, there have been calls to revive the old or come up with new strategies and initiatives on how best communities could manage their own environment. Today, it is often argued that emphasis must be placed on what Ul Hag (1976) would refer to as *"building of developments around people rather than people around development"*.

Mobilising the community to participate in managing the environment means ensuring that the people are able to act in ways that improve their own surroundings; in ways that will help not only to preserve but to enhance its future use. It means ensuring that policies and practices are in place to provide Botswana with a healthy environment at home, school, work or wherever they may be. Mobilising people and encouraging community participation also means helping people to assert control over the factors which affect their environment. We must equip and enable people to act in ways that preserve, improve and manage the environment. By creating a climate that favours community participation, we can channel the energy, skills and creativity of community members into the national effort to achieve healthy environments.

In the national quest for healthy environments, people constitute a major resource, both individually and in groups. Our experience confirms that people understand and are interested in the circumstances and events that influence

their environments. It is generally known that they are seeking opportunities to take responsibility.

The enduring impact of community participation is often witnessed during world environmental day celebrations. It is amazing just what can be achieved in one day. The enthusiasm displayed on this particular day can help us respond to one of our leading challenges mobilising people and enhancing their capacity to cope. The conclusion reached here is that community participation is not only valuable but essential for all Botswana.

Suggested Strategies for Community Mobilisation

A variety of strategies are suggested to assist in initiating and sustaining community mobilisation, involvement and participation. The focus is on helping communities to realise their potential for organising themselves, assembling and analysing their own information base, and developing and implementing their own priorities and plans. This potential is often masked by problems of dependency and lack of experience, education and skills (Community Based Strategy for Rural Development, 1977).

Community Empowerment

Empowerment is conceptualised as *the discovery of a community's strengths, the attainment of participatory competence, and an element of claiming resources from the state*. In terms of environmental management, empowerment generally refers to the *transfer of knowledge, initiatives, control, ownership of resources and decision-making responsibilities* to the participants (i.e. those affected by the problem). This can bring about change in the nature of people's role in development from passive dependent beneficiaries to active participants in managing the environment.

CBSRD report 1997:8 states:

In most instances the first step towards empowerment is to increase people's awareness and mobilise and build their participation and support. Government development programmes can contribute to empowerment by helping communities to establish capacity to organise and take on development activities at grass-root level, and by affording communities' discretion over the choice of activities and the way they are pursued.

Community-based Environmental Programmes

These should involve decentralised or bottom-up strategies. Many such

strategies are premised on the principle of empowerment and have been advocated mainly by NGOs e.g. Tlhokomelo Tikologo-Environment Watch, Botswana. This is an attempt to move away from the traditional top-down approaches to a more community-based. It represents a strategy which believes in promoting a more participatory mode of development by giving communities control over formulation, planning and implementation of decisions regarding in this case their environment.

The role of the government is to *facilitate community's efforts*, e.g., by making available technical expertise through its extension services. *These approaches generally entail democratisation and shifting of accountability to local level because of the belief that local people have ideas, skills and leadership qualities to manage their own affairs.* Such approaches are important to any activity requiring significant inputs of local knowledge, leadership and participation e.g. environmental management.

A critical requirement of this strategy is to secure participation of people in the community. This generally requires that there should be transparent and democratic structures for consultation and decision-making within the community. This could be done by strengthening and giving power to local institutions e.g. VDC, VHC, VET and PTA.

Co-ordination

It is important to co-ordinate the activities of various actors involved so that each knows what the other is doing. Together, they should ensure the attainment of one goal. There is need to establish an effective administrative mechanism and related institutional capacity to provide simple, effective channels of communication and decision making between central, district and community/village level, including NGOs, private sector and other mechanism. Though there are risks of frictions, conflicts and ambiguities between roles of different participants as well as duplication of efforts, it is hoped that a co-ordinated effort will minimise these problems. Politicians, notably the opposition often take advantage of these ambiguities to dismiss government programmes.

In addition, a well co-ordinated effort will ensure that people know the issues very well e.g. littering, costs and benefits involved and the resulting damage from neglect of environment. With the spirit of team work and mutual support it is likely that environmental issues will be discussed, especially with the youth. Targeting the youth is essential for it ensures continuity in human resource mobilisation for proper use and care of the environment. This could involve role plays, videos, theatre and television adverts as some of the projects to embark upon to dramatise environmental concerns.

Community Development Organisations (CDOs)

This refers to a *community leadership structure responsible for mobilising the community as well as directing and monitoring the community based development activities*. The CDO's could be considered as the specialist organ of the VDC concerned with community based projects. It could also be the umbrella organisation co-ordinating development activities for a community pursuing a common interest e.g. an environment protection and management project in a particular community.

For this strategy to work one needs community workers not office workers. That is, people who can effectively mobilise the community through the kgotla and other channels i.e. focused groups. It will also be charged with the responsibility to encourage networking and coalition building among village institutions and extension staff.

Conclusion

In conclusion, it is necessary to re-emphasise that community mobilisation is easier said than done. Governments (both central and local) responsible for policy formulation often design plans, programme and implementation strategies which are not in line with Botswana views and aspirations in terms of their traditions, values and experiences. This has resulted in the failure of many environmental projects. There is need to review both governmental, private sector and NGO's policies in order to accommodate the needs of local communities in managing the environment.

Protection and management of the environment cannot occur unless the decisions and actions which lead to both come from the people who are directly affected. Control by communities over resources can instill a sense of ownership and encourage their conservation.

From the foregoing the following recommendations can be made:

- ☐ There is need to begin to develop policies that are pragmatic and recognise that people are an important resource to be exploited and put to good use.
- ☐ Government should be fully committed to adopting a purely participatory approach to development.
- ☐ Responsibilities of government and those of the civil society must be clearly spelled out.

- ❑ There is need to launch a national environmental civic educational campaign. This should also form part of the education system and should be taught to children from an early age.
- ❑ Planning and implementation capacity must be built into National Development Plans.

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CHAPTER 3

PERCEPTIONS AND ATTITUDES IN POLLUTION CONTROL AND ENVIRONMENTAL MANAGEMENT

Raban Chanda, PhD

**Department of Environmental Science
University of Botswana
P/B 0022, Gaborone, Botswana**

**Phone: 267-3552524 Fax: (267) 3552784
E-mail: chandar@noka.ub.bw**

Perceptions and Attitudes in Pollution Control and Environmental Management

Introduction

This Chapter focuses on Perceptions and Attitudes in Pollution Control and Environmental Management. The view is taken that technical approach alone may be and is often inadequate in dealing with some environmental issues. This view has been validated now and again by various studies (cf. Mensah and Whitney, 1991; Blaikie and Bookfield, 1991; Chanda, 1996). This Chapter will attempt to illustrate this position with Case Study data from Botswana.

Concepts

Four main concepts will form the basis of the chapter, namely, perception, attitude, pollution and environmental management.

a) Perception

Perception refers to the image or intuition formed in one's mind about some perceived phenomenon or object. To perceive is to be aware of something through the senses through direct or indirect contact with it. For example, an individual may be asked whether he/she is aware of various environmental quality problems in his/her town or community. An affirmative answer can indicate awareness while a negative response will suggest lack of perception. Where many individuals are interviewed in this manner, it becomes possible to identify issues that command greater or lower perception in an area. For instance, in a survey conducted in 1994 in Gaborone, Botswana, of perceptions of environmental quality issues the following levels of awareness, shown in Table 2.1, emerged.

Clearly, residents of Gaborone were more aware of problems of litter and public urination than other environmental quality issues.

Perception is influenced by both past experience and present context as defined or circumscribed by the perceiver's values, mood, beliefs, socio-economic circumstances and expectations. Since experiences and present contexts of individuals vary greatly, there cannot be standard perceptions; variations can be expected among individuals, between professional groups, between cultural groups and even for the same individual over time and in different contexts. Again Gaborone survey data are illustrative of this point. In addition to the 19

environmental quality issues in Table 3.1, the survey instrument included nine socio-economic issues deemed of relevance to Gaborone.

Table 3.1: Respondents rating environmental quality issues as serious-very serious in Gaborone, Botswana (July 1994) (N=250)

Issue	% rating: issue as serious-very serious
Paper/plastic litter	65.6
Can litter	65.2
Public urination	61.6
Bottle litter	56.0
Dust	49.6
Inadequate recreational parks	48.4
Noise	38.4
Garbage dumps	37.6
Cockroaches	34.8
Crowding	34.8
Untidy public open spaces	34.4
Air pollution	28.4
Flooding	28.4
Street erosion	28.0
Rodents	25.2
Unkempt	24.6
Uncollected garbage	18.8
Sewage disposal problems	11.6
Water shortage	5.6

Source: Adapted from Chanda (1995b)

The purpose of this inclusion was to gauge how the perception of environmental quality issues fared in relation to other problems of the urban milieu, especially with reference to the low and medium/high income groups of the city. The results (Table 3.2) clearly indicate that environmental quality issues were more widely perceived among the relatively well-off residents of the city while socio-economic issues ranked high among the poorer residents (cf. Chanda, 1995a&b).

Table 3.2: Top 10 concerns among low and medium/high income residents of Gaborone (July 1994) (N=250). Issue cited as serious-very serious

Low income	% citing issue	Medium-High Income	% citing issue
Unemployment	87.2	Crime	80.9
Cost of living	77.6	Can litter	77.7
Low income	72.4	Cost of living	74.4
House shortage	71.2	Paper/plastic litter	72.3
Public urination	62.2	Bottle litter	64.9
Paper/plastic litter	61.5	Public urination	60.6
Crime	59.6	Few recreational parks	58.5
Can litter	57.7	Dust	55.3
Bottle	50.6	House shortage	54.3
Too many foreigners	49.4	Untidy open spaces	52.1

Source: Chanda (1995a)

Thus, a phenomenon may conjure up different images in people with different experiences and in different socio-economic circumstances and cultural settings. This in effect means that perceptions are: (i) subjective views about phenomena, as opposed to being objective and verifiable facts, (ii) subject with changes in circumstances, experience and expectations.

b) Attitude

Attitude refers to an individual's feeling(s) and beliefs about some phenomenon which consequently would influence his/her behaviour toward that phenomenon. Attitudes are invariably conditioned by perceptions and vice versa.

Attitudes have three interrelated components: the affective, cognitive and behavioural components which are characterised as follows:

i) Affective Component: The Affective Component describes an individual's feelings towards/about something. It therefore addresses people's emotions towards things. For example, residents in a given city reacting to the statement "solid waste pollution poses the greatest risk to human health", on an attitudinal scale ranging from "strong agree" to "strongly disagree", would be expressing their feelings towards solid waste pollution and its relation to health.

ii) Cognitive Component: The Cognitive Component describes what an individual thinks or believes about something. For example, most respondent in the Gaborone survey who answered the question "Where in the city are

environmental quality problems most serious?" cited low cost residential areas (Table 3.2). Similarly, in a study of environmental degradation in the Boteti area of north-central Botswana, it was found that most agropastoralists interviewed thought that the primary cause of environmental problems was drought and that their solution lay in more regular rainfall events and government intervention (Tables 3.4 & 3.5) (Chanda 1994, 1996).

Table 3.3: Gaborone residents' spatial allocation of some environmental quality problems (% citations*)

Issue	Where Most Serious				
	(N**)	Rich Areas	Poor Areas	Pub. Areas***	Everywhere
Noise	43	0	51	25.6	13.9
Can litter	76	0	48.7	21	28.9
Paper/plastic litter	77	0	42.9	22.1	32.5
Bottle litter	57	0	56.1	17.5	24.6
Cockroaches	33	0	48.5	42.4	
Public urination	48	0	14.6	16.7	68.8
Crowding	43	0	86	0	11.6

*May not always add up to 100 because of the "no idea" responses

**N = number of returns on the question

***Pub. areas = public and shopping areas

Source: Chanda (1995)

Table 3.4: Perceived causes of resource use related environmental problems in the mid-Boteti area: a classification based on percent citation frequencies (in brackets)* (N=47)

Resource Use Type	Significance of Classification of Causes		
	Primary (>40)	Secondary (10-39)	Minor (<10)
a) Cultivation	Drought(60)	No floods(38) Pests(17)	Wind erosion(9) Poor soils(6) Weeds(4)
b) Livestock	Drought(60)	Range Degradation(17) Overstocking(15) No floods(15) Disease(15) Predation(15)	Veld fires Poor fencing(4) Crop damage by wildlife(4) Late fence material(2) Late seeds(2) Road works(2) Overpopulation Costly supp.feed(2) Unfair BMC grading(2) Road works(2) Saline water(2) Maun rice project(2)
c) Veld Product	Drought(45)	Overpop.(38) Commercial exploitation(17)	Veld fires(9) Overgrazing(2) Game reserves(2) Wind erosion(2) Saline water(2) Cold winters(2)

*Due to non responses and/or multiple responses, per cent citations will not add up to 100.

Source: Chanda (1994)

Table 3.5: Perceived solutions to resource use problems in mid-Boteti
(% citations) (N=47)

Solution	Cultivation	Livestock	Veld products Solution base
Government assistance*	51	16	15
External			
Rainfall/floods	57	47	32
External			
Fence fields	9	-	-
Local			
Cattle herding	6	2	-
Local			
Abandon cultivation	4	-	-
Local			
Landuse zoning	2	-	-
External/local			
Reduce/remove game reserve	2	6	-
External			
People-govt caucus for solutions	2	-	-
Local/External			
Re-empower chiefs	2	-	-
External			
Plant hedges around fields	2	-	-
Local			
Encourage horticulture	2	-	-
Local			
Kin assistance	2	-	-
Local			
Beer brewing	2	-	-
Local			
Supplementary feeding	-	15	-
Local			
Increase off-take	-	6	-
External/local			
Destock	-	6	-
External/Local			
Open game reserves up to cattle	-	2	-
External			
Kill predators	-	2	-
External			
Rotational grazing	-	2	2
Local			
Deconcentrate cattle posts	-	2	-

Local			
Plant trees	-	-	32
Local/external			
Stock commercial exploitation	-	-	11
External			
Substitute preferred fuelwood species	-	-	4
Local			
Substitution of energy sources	-	-	2
Local			
Build modern houses	-	-	2
Local/external			
Grow grass	-	-	2
Local			
Return land to Basarwa	-	-	2
External			
Build houses without reinforcing poles	-	-	2
Local			
Open access to game reserves	-	-	2
External			
No idea/no solution	15	23	21

*The commonest requests were for irrigation and game reserve boreholes, food, planting trees and employment.

Source: Chanda (1996)

iii) Behavioural Component: The Behavioural Component describes how an individual acts towards a given object, obviously influenced by the affective and cognitive components.

In considering attitudes, it is important to recognise the existence of cognitive versus behavioural dissonance and hierarchy of attitudes. The former refers to a situation where an individual's overt behaviour is at variance with his/her proclaimed beliefs: e.g. an individual preaching against solid waste pollution while privately contributing to littering in public places. To live with cognitive dissonance, individuals try to rationalise or justify their overt behaviour somehow as revealed in such statements as "the one piece of paper I threw in the park could not have caused much pollution, after all there was no garbage bin in sight". Hierarchy of attitudes, on the other hand, points to the existence of competing attitudes in people, some more dominant than others. For example, attitudes to environmental conservation/protection are assumed to be generally lukewarm in poor Third World countries in comparison to their attitudes towards economic growth. The contrasting ranking of environmental

quality and socio-economic issues among “rich” and “poor” residents of Gaborone shown in Table 3 provides another illustration of this concept.

Relevance to Pollution Control and Environmental Management

Both pollution control and environmental management are meant to curtail environmental degradation for various reasons. Most environmental problems (including pollution) are human-induced. Some pollution problems are easily amenable to technical solutions (eg. sulphur dioxide pollution, ozone layer depletion) because they are generated by identifiable industrial entities subject to direct government regulation.

Many other environmental problems, however, are less responsive to ‘technological fix’ interventions. Examples of the latter include solid waste pollution and rural livelihood related environmental degradation. These commonly involve many individuals, acting privately, often surreptitiously and at different and scattered points in time and space. The solution of these problems therefore requires intervention at the perceptual and attitudinal levels of actual and potential culprits. As Russell (1987) has observed for America, targets of efforts to improve the environment must shift from industry to the more widely dispersed sources, the control of which will depend on changing the behaviour of individual citizens (as cited in Gigliotti, 1992: 15-16). Similar observations have been made by other researchers. For example, from their study in Ghana, Mensah and Whitney (1991: 164) reached the following conclusion: “Urban waste problems such as littering cannot be solved by regulation alone - they are not likely to be obeyed - nor by just supplying disposal facilities like trash cans on the streets - they are not likely to be used. Motivation and attitudes must be considered.” In Botswana, one of the Natural Resources Officers at the National Conservation Strategy Agency made a similar observation: “... the nature of most environmental problems is such that it is the people’s actions that determine whether problems will be solved ... in many instances, the solutions lie with the people changing their attitudes toward the environment, ... (Botswana Daily News, Sept. 4, 1992: 3). The results of the Gaborone and Boteti perception studies cited in the previous section provide further illustration of the importance of gauging perceptions and attitudes of the public towards environmental problems for which solutions are needed. Data from the Gaborone study, for instance, suggest that poverty alleviation would have to be a major consideration in designing any environmental quality management strategy for low cost residential areas. The Boteti study points to the need for cognitive therapy to create a greater appreciation among the area’s agropastoralists of the role of human action in livelihood related environmental degradation and its solution or amelioration. Sustainable environmental management requires appropriately attuned human perceptions and attitudes.

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CHAPTER 4

ENVIRONMENTAL IMPACTS OF URBANISATION

Kwesi Darkoh

Department of Environmental Science
University of Botswana
Private Bag 0022
Gaborone, Botswana

Tel.: 267-355 2524 Fax.: 267-356 591
E-mail: darkohmb@noka.ub.bw

Environmental Impacts of Urbanisation

Introduction

An ever increasing number of people in Developing Countries are living in urban areas. By the new millennium almost half the world's population would be expected to be living in urban areas. Africa would experience the highest urban growth rate: an average of 4.5 per cent between 1995 and 2000 and 4.3 per cent thereafter. Latin America, already urbanised will not have such a large increase. Absolute growth will be in Asia, where cities have been projected to gain by the year 2000. Roughly 60 per cent of the GNP of less developed countries is urban-generated by about one-third of the population. Habitat II Secretariat projects that urban centres may account for as much as 80 per cent of GNP growth by the end of 2000. Despite the growing contributions to the economies of developing countries urban areas are being increasingly neglected and the quality of urban environment is suffering. Institutional structures are in decay. More and more people are living and working in some of the world's most degraded environments where the smells and pollution are unbearable. They *lack clean drinking water and rudimentary sanitation facilities.*

A very high proportion of the people live in *dilapidated and overcrowded houses*. Garbage lies rotting outside their makeshift shelters, restricting access along narrow unpaved pathways and clogging surface drains. *Pollution, waste disposal problems, inadequate and neglected infrastructural services, social unrest and other stresses of the environment are endemic.* Diarrhoea, typhoid and many other diseases are ever present menaces of life. *Urban-industrial impacts may well be the most serious of all types of land degradation in several Developing Countries.* A general overview of urban-industrial problems faced in human settlements, especially by the fast growing cities of the Developing World constitutes the central focus of this chapter. Urban degradation reflects underlying socio-economic and administrative problems that have bedevilled both municipal administrators and residents. In turn, these problems are most *maladministration in municipalities*. Human settlement problems are probably more easily identified and resolved at local rather than national level. A basic approach may be to empower both cities and towns of all sizes to make their own decisions and to raise their opportunities without undue constraints from central and regional authorities. More *innovative approaches and policy initiatives are required and a basic strategy incorporating critical areas needing attention in the creation of a sustainable urban living environment is outlined.* The solution of the urban environmental problems in developing countries is more than a task for technocrats. It is a fundamental challenge for the political and administrative leadership in these countries.

Changing Trends in Urbanisation and Industrialisation

The focus of this chapter is a general overview of the environmental impacts of urbanisation and industrialisation in the fast growing cities of the Developing World. Over the last half century, the world has experienced its fastest ever rate of urbanisation and by the year 2000, 46.7 per cent of the world's population would be living in urban areas, made up of 74.8 per cent of the population of Developed Countries and 39.5 per cent of the population of the Developing World. Africa would experience the highest urban growth rate: an average of 4.5 per cent thereafter. Latin America, already urbanised will not have such a large increase. Absolute growth would be expected to greatest in Asia where cities would reach 210 million people by the beginning of the new millennium. It is estimated that during the period 1950 to 2025, the absolute number of urban dwellers in the Developing World would have increased by a staggering fourteen times, from 300 million to 4 billion. It had predicted that by the beginning of the new millennium there would be two city dwellers in the Developing Countries for every one city dweller in the Developed World. United Nations statistics indicate that at the advent of the year 2000, the three largest cities in the world would be Mexico City, Sao Paolo and Shanghai, each with a population in excess of 23 million. This contrasts starkly with the 1950s, when the three largest conurbations were New York, London and the Rhine-Rhur (Table 4.1)

Table 4.1: The Largest Cities in the World, 1950 and 2000

Rank (1950)	City	Population (million)	Rank (2000)	City	Population (million)
1	New York	12.3	1	Mexico	31.0
2	London	10.4	2	Sao Paolo	25.8
3	Rhine-Ruhr	6.9	3	Shanghai	23.7
4	Tokyo	6.7	4	Tokyo	23.7
5	Shanghai	5.8	5	New York	22.4
6	Paris	5.5	6	Beijing	20.9
7	Buenos Aires	5.3	7	Rio de Janeiro	19.0
8	Chicago	4.9	8	Mumbai	16.8
9	Moscow	4.8	9	Calcutta	16.4
10	Calcutta	4.6	10	Jakarta	15.7
11	Los Angeles	4.0	11	Los Angeles	13.9
12	Osaka	3.8	12	Seoul	13.7
13	Milan	3.6	13	Cairo	12.9
14	Bombay	3.0	14	Madras	12.4
15	Mexico City	3.0	15	Buenos Aires	12.1

Developing Countries are also rapidly industrialising, *albeit* at variable regional growth rates and generally at a slower pace than the pace of urbanisation. During the colonial period, these countries were not encouraged to develop industry. They were mainly producers of primary products. Urbanisation during the colonial period denied people of the Developing Countries not only the opportunity of acquiring modern productive skills for processing the produce from their farms, forests and mines, but also the chance of learning organisational skills needed for ensuring the smooth flow and delivery of the produce to foreign markets.

However, with independence, and the burgeoning national governments' ardent interest in promoting industrialisation and the favourable climate provided by the New International Division of Labour, the situation has radically changed. Although the share of Developing Countries' manufacturing is still low (about 18.4% compared to 81.6%, in the developed countries in (1985), it is not surprising that it is in some of these countries that the fastest growth rates in manufacturing have been registered in recent years. The most rapid growth of industrial output has taken place in the Newly Industrialising Countries (NICs), particularly those that the World Bank refers to as the Asian Tigers (South Korea, Hong Kong, Singapore and Taiwan). More recently, this rapid growth has expanded to include China, Malaysia, the Philippines and Thailand. The rapid industrial growth of these South East Asian countries, with their 900 million consumers and economies growing at a rate several times faster than world average, is changing the structure of world business and industry.

In the period from 1960 to 1985, several of these NICs, equalled or exceeded Japan's annual growth rate. They also registered prodigious increases in manufacturing employment: 27 per cent in South Korea (between 1974 and 1985), 53 per cent in Taiwan, 43 per cent in Hong Kong and 75 per cent in Malaysia. The leading exporters in manufacturing in 1985 were South Korea, which accounted for 23.3 per cent of total manufactured exports of all developing countries, Hong Kong (16 per cent), Mexico (9.5 per cent) Brazil (9.0 per cent) and Singapore (7.1 per cent). Industrial development in these countries emphasise the production of high-value goods for both domestic and export markets, together with both resource-based and high technology industries.

While industrialisation may not yet be a significant factor in several countries outside of the NICs (for example, African countries), it has been estimated that roughly 60 per cent of Developing Countries' GNP is urban-generated by one-third of the population, involved in a wide range of mostly secondary and tertiary activities. There is speculation that urban centres may account for as much as 80 per cent of GNP growth by the end of the century (Habitat II Secretariat, 1994)

Urban Benign Neglect and Environmental Deterioration

Despite the growing contributions to the developing economies, *urban centres in several parts of the Developing World are environmentally suffering from benign neglect. The quality of the urban environment is deteriorating.* More and more people are living and working in some of the world's most degraded environments, where the smells and pollution are unbearable. They lack clean drinking water and rudimentary sanitation facilities. A very high proportion live in dilapidated and overcrowded houses. Urban expansion is all too often haphazard and unplanned and slums and squatter settlements are growing (see Table 4.2 which shows the extent of slums and uncontrolled settlements in African cities). Garbage lies rotting outside the makeshift shelters, restricting access along narrow unpaved pathways and clogging makeshift drains. Untreated sewage, uncontrolled industrial effluents and rapidly growing numbers of motor vehicles pollute air, water, coasts and croplands. Diarrhoea, typhoid, cholera, food poisoning and other diseases are ever present menaces of life. There is little or no protection for workers from unsafe work places, over-long working hours and extensive travel to and from home. Social unrest and other stresses of the environment are endemic.

Table 4.2: Extent of Slums and Uncontrolled Settlements in Some African Cities. (Source: Reconstructed from World Bank Reports)

Country	City	Year	Population	% in Unhealthy housing
Kenya	Nairobi	1984	959,000	23
	Kisumu	1984	163,000	73
Zambia	Lusaka	1981	650,000	50
Tanzania	Dar-es-Salam	1981	757,000	65
	Tanga	1978	103,000	60
Egypt	Ismalia	1978	175,000	50
Tunisia	Tunis	1975	925,000	33
Nigeria	Lagos	1975	1,220,000	83
	Ibadan	1970	736,000	75
Morocco	Casablanca	1971	1,445,000	70
Senegal	Dakar	1969	650,000	60
Ethiopia	Addis Ababa	1968	737,000	90
Somalia	Mogadishu	1967	206,000	77
Cote D'Ivoire	Abidjan	1964	437,000	60

Most of these problems are linked to the failure or inability of governments to provide effective regulations and planning frameworks to address the problems of poor citizens and protect the urban environment from contamination.

Urban-industrial impacts may well be the most serious of all types of land degradation in several developing countries, and for the rest of this Chapter focus will be given more closely on some environmental ramifications of urbanisation and industrialisation. The chapter will conclude by sketching a strategy for addressing the urban problems within the overall context of sustainable development of human settlements in the Developing World.

A pivotal theme identified by Potter (1996) is that the very different character of urbanisation and industrialisation is itself a critical and pressing issue. Taking a cue from Potter (1996), the Chapter will attempt to pursue two avenues, the first dealing with the relations between urban development and environmental circumstances and the second, exploring the links between industrialisation and urban environmental conditions and change.

Human settlements, in theory, are areas of opportunities – for production, investment, marketing, trade, education, communication and creativity. Yet, if unmanaged or badly managed and growing under uncontrolled conditions, they can harbour human misery alongside large scale environmental degradation, which goes unnoticed on account of the more pressing survival problems and lead to irreversible resource depletion. This is what is happening in many parts of the Developing World.

Urbanisation and Environment

It is contended that one of the primary reasons why towns and cities are such a disturbing factor in Developing Countries (particularly African countries) today is that they are *unable to provide sustainable living environments for their inhabitants*. The function of towns and cities is to centralise facilities, services and opportunities, both social and economic. As nodal points in networks of communication, towns and cities provide vital links for economic functioning of regions of all sizes. Large urban centres provide exceptionally fertile seed-beds for economic growth, and throughout history, these have offered distinctive environments for the development of human societies. Cities offer job opportunities in both formal and informal sectors, and where jobs exist, average wage rates increase progressively with city size (Hoch, 1972).

Human beings are the centre of concern for sustainable development of human settlements. In theory at least, it should be possible for Developing Countries to provide housing, water, sanitation, paved roads, transport systems

and recreational and open spaces at low units costs as well as job opportunities without prejudicing environmental and human health and well being in their cities.

All too frequently, however, *Developing Countries are marked by an unprecedented urban explosion, resources are insufficient, structural poverty is rife, the needs of city dwellers are not met, and the environment is deteriorating.* For example, more than 50 per cent of urban residents in the Developing World live in sub-standard dwellings and this has a direct bearing on their environmental circumstances. In Africa, some 60 million people were reported to be living in 1987, in squatter settlements and unhealthy housing conditions in cities (Munro 1987; see also Table 4.2). The rural landless poor living in unhealthy shelters and neighbourhoods were estimated to be 110 million. The numbers have been and are still increasing alarmingly day by day.

According to the World Bank (1992), less than 60 per cent of the urban population in Developing Countries have access to adequate sanitation and only 33 per cent are connected to a sewer system. It is also evident that 20 to 30 per cent of urban dwellers regularly purchase supplies of drinking water from mobile vendors (Hardoy *et al* 1992). Some sense of the magnitude of the problem can be gauged from a single city. With 6 million inhabitants, Hong Kong produces 23,300 tons of solid waste, 21 tons of floating refuse, 2 million tons of sewage and industrial waste per day, along with 100,000 tons of chemical waste per year. Many difficulties are now being experienced in finding adequate landfill sites (Chan 1994, Potter 1996). Other problems stem from noise pollution from vehicles, aircraft and construction and, as Chan (1994) and Potter (1996) have observed, it is the poor of Hong Kong who suffer the most as a result of the environmental degradation.

Although the best health facilities available in Third World cities are frequently as good as those found in Western cities, *pathogens in the environment* pose serious threats. The main scourges are diarrhoea, dysentery, typhoid and cholera, which disproportionately affect the poor. *Overcrowding in residential areas* means that diseases like tuberculosis, influenza, and meningitis once contracted, are easily transmitted. *There is also the need in all settings to look into the balance that exists between indigenous and foreign influences and modes of development.* An example is the direct link that exists between tourism, Aids and child prostitution in many Developing Countries.

In the Developing World (for example, in African and Latin American countries), *over-concentration of wealth in the big cities* is contributing to the abandonment of the rural areas and the small towns. Attempts to redress the situation are beset with difficulties in view of the low level of investment that has been available to inject into the rural areas from their existing level of deprivation or resource degradation as well as such structural issues like

institutional capacity and absence of meaningful intersectoral linkages. This has led to depletion of human resources and inability to maintain infrastructure and service provision.

In most African human settlements, large masses of people live in environments which are neither life-sustaining, nor conducive to positive development trends. Areas are poorly serviced and the inhabitants are susceptible to both man-made and natural hazards. These environmental hazards can be identified at different spatial scales of the settlement hierarchy (Saha, 1992).

At the very **local level**, millions of African peasant and urban slum dwellers are exposed to pathogens, with serious impacts on human health, e.g. pathogens from human excreta in water supplies and to smoke fumes from stoves which cause respiratory problems. The above problems are compounded at the next level, the *small town or neighbourhood level* where in addition, there would be added risks from toxic chemicals used in the workplace without adequate safeguards; disease causing agents, like rats and flies which feed on the uncontrolled garbage dumps and the dirty water pools which occur on accounts of inadequate sewage and drainage.

At the **city scale**, problems would centre on high levels of air pollution caused by poorly maintained vehicles on congested streets and high levels of lead additive in petrol used; high levels of water pollution on account of inadequate and strained systems, absence of drains and sewage treatment plants, inappropriate dumping practices and lack of enforcement, and inadequate environmental control on industry.

At the **subnational level**, problems arise from the interaction between cities and their rural hinterlands. Rural areas suffer from the impacts of city-based generated activities. Among common examples are the degradation of coastal fisheries as a result of water pollution from city-based enterprises. Other resource degradation would occur from over-intensified demand, say, for fuel wood.

There are several fundamental obstacles to the integration of environmental concerns into the management of living environments of human settlements in developing countries. As the experience of African countries show, to begin with, authority is weak generally on account of the shortage of personnel trained in the specific skills required to monitor environmental degradation and whatever skills exist would be concentrated in the Central Government organisations with inordinately large range of responsibilities. Then there is an absence of standards for pollution control measures; a shortage of analytical laboratory facilities and where the same do exist, many instruments are out of use on account of inadequate maintenance capacity. Legislation is out of date and often with a multitude of authority which often amounts to no authority at

all. There is also a lack of inventory on resources and very importantly, an absence of an integrating framework for decision making on intersectoral resource use priorities and a co-ordination mechanism for implementation of decisions once taken.

The relationship between the environment and development requires a comprehensive and integrated approach which can be obtained through National Environmental Action Plans. Several African countries are going through the process of a comprehensive environmental management approach with the collaboration of the World Bank. The pioneering countries and implementing Environmental Action Plans include Ghana, Kenya, Burkina Faso, Madagascar, Mauritius, Lesotho, Guinea and Rwanda.

Industrialisation and the Environment

Some effects of industrialisation are variously mentioned in connection with discussions on urbanisation and the environment. However, some significant issues remain to be highlighted if the environmental ramifications of urban-industrial development in Developing Countries are to be adequately comprehended.

First, in the context of the potential impacts of industrialisation, it is worth noting that the contribution of cities in the developing World to global environmental problem remains relatively small – *it is mainly the cities of the Developed World that are emitting greenhouse gases*. Thus the main threat from industry located in the Developing World cities is to the local population. Even so, Developing World cities are threatened by *global warming which may lead to more severe storms as well as sea-level rise* (Potter 1996).

Second, it ought to be noted that the New International Division of Labour is characterised by a *trend towards global divergence*, whereby, through the activities of multinational companies in particular, *patterns of ownership, capital accumulation and production are becoming more concentrated and diverse at the global level*. Multinationals, with their capital and technology, have the power to choose what they consider to be the ideal locations for their industries. This choice is often made at two levels: the most suitable country and the most suitable place within that country. The choice of a country usually depends upon political factors. Most governments, regardless of the level of economic development within their country, are prepared to offer financial inducements to attract multinationals which they see as providers of jobs and means of increasing exports.

The severe competition to attract multinationals by Developing Countries

means that the process of industrialisation is neither monitored nor managed very closely. Consequently, according to Potter (1996), Developing Countries are prepared to ignore health, safety and environmental issues in their search for investment and employment. The best example is the recent investment of Third World Countries in the reprocessing of highly toxic chemicals exported from developed nations. The trade is prompted by lower costs and lack of regulations in many developing countries. In the late 1980s of the 30 to 45 million tons of hazardous waste that crossed international borders, 20 million went to Developing Countries.

A third point to note is that, *in the arena of political economy, Developing Countries are lacking in power vis-a-vis the global multinational companies in whom industrial capital, technology and production are mainly concentrated.* They must accept the conditions offered by the Transnationals and other large companies. Moreover, they don't have the financial base to fight air pollution because they are mostly pre-occupied with finding jobs and ways to house and feed their growing populations. They are accordingly forced to accept investments or jobs, sometimes at any price. Governments of economically less developed countries, due to a greater economic need, are often prepared to impose fewer restrictions on multinationals because they often have to depend upon them to develop natural resources, to provide capital and technology (machinery skills, and transport), to create jobs and to gain access to world markets. Despite political independence, many poorer countries remain economically dependent (neo-colonialism) upon the large multinationals (together with international banks and foreign aid).

The Bhopal tragedy is one example of what can happen environmentally if the activities of multinationals are not controlled and if industrial development is allowed to proceed on the basis of a maximum return and insufficient monitoring and regulation. A report marking the tenth anniversary of the disaster highlighted the continuing suffering of many who survived facing breathlessness, dry coughs and chronic lung diseases.

Another example of the human and environmental consequences of unregulated industrial development is provided by the spate of fires which have claimed the lives of workers, particularly women, in factories in the developing countries. *The Guardian* on May 12, 1993, chronicled a case where a raging fire killed at least 200 workers and injured several hundred more in a toy factory in an industrial zone on the outskirts of Bangkok, Thailand.

The case of Mexico City illustrates some of the hazards rapid population growth and industrialisation can pose for a developing country. Mexico City in 1995 had a population of 23 million people – projected to expand to 31 million by the year 2000, perhaps making it the largest urban area in the world. Cars, buses, industry and power plants in the city emit hundreds of thousands of

metric tons of pollutants in the atmosphere each year. The city is at an elevation of approximately 2255 metres (7400 feet) in a natural basin surrounded by mountains – a perfect situation for a severe air pollution problem. It is becoming a rare day in Mexico City when the mountains can be seen, and physicians report that there has been a steady increase in respiratory diseases. Headaches, irritated eyes, and sore throats are common when the pollution settles in. Doctors advise parents to take their children out of the city permanently! Other large cities in developing countries with similar pollution problems include Dhaka (Bangladesh) and Kuala Lumpur (Malaysia)

Urbanisation and Sustainable Living Environments

It is apparent that the fundamental policy consideration in relation to urbanisation is how to manage human settlements in such a way as to create congenial and humane living conditions for human beings, a more healthy environment as well as caring resource use that would foster a better quality of life, higher productivity as well as a more sustainable environment in the longer term. Population growth in Developing Countries is unlikely to stabilise until well after the year 2000. Many regions in the Developing World have also their share of natural calamities, including, as in the case of Africa, *widespread drought, political conflicts and an ailing agricultural sector*, which, in addition to climatic factors, also suffers from a basic lack of inputs.

The dynamics of *human settlement growth* are made up, *inter alia*, of the interplay among several components: *regional planning, resource use, institutional and legal frameworks, human capacity, technological and financial resource, service delivery and management, energy, transport infrastructure and construction*. The management of certain key linkages among those components would go a long way towards the improvement of sustainability within the human settlements and their rural hinterlands. Such an approach calls for:

- ❑ A ***strong government commitment*** towards the improvement of environmental quality within the built-up and natural environment, a commitment to be made more visible and more tangible through the provision, *inter alia*, of an enabling environment, an intersectorial co-ordination mechanism and the enhancement of appropriate institutional capacity. The collaboration of the international community would be paramount in the light of the scale of the problem.
- ❑ A ***holistic view towards resource use***, resource conservation and the management of investment priorities, relationships amongst environmental quality, human health, productivity and long-term sustainability.
- ❑ A ***strong injection of spatial planning*** to complement

national economic planning and the pursuit of integrated land use planning at all levels. Such land use planning is to be targeted to the priority needs of the community.

- ❑ A ***sanitation and water supply response*** to address the basic needs of the poor and needy. There is need to focus on incremental approach and low cost technology.
- ❑ The ***equity issue*** need to address the problem of cost recovery and the need to stretch service delivery for water supply, sanitation, energy as well as transport to as many beneficiaries as possible. Environmental costs also need to be reflected in pricing so as to encourage the desirable and sustainable policy shifts.
- ❑ It is necessary to clarify ***property rights*** and resolve the ***gender issues*** which mitigate against long term sustainability in land development.
- ❑ A ***programme of public education and creation of environmental consciousness*** are essential.
- ❑ There is a need to enhance ***local community participation*** in all the decision making processes.
- ❑ The ***activities of multinationals*** should be closely monitored and controlled; and there is need to vigorously enforce all laws and regulations regarding pollution and land degradation.
- ❑ Human settlement problems are probably more easily identified and resolved at local rather than national level. There is therefore a need to ***empower cities and towns*** of all sizes to make their own decisions and generate their own revenues without undue constraints from central and regional authorities.
- ❑ There is a need for more ***highly focused environmental impact assessment*** and research on towns and cities as liveable environments.

The solution of the urban-environment problems in Developing Countries is more than a task for technocrats. It is a fundamental challenge for the political and administrative leadership in these countries.

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CHAPTER 5

ENVIRONMENTAL PROTECTION IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

Jaap Arntzen

**Department of Environmental Science
University of Botswana
Private Bag 0022
Gaborone, Botswana**

**Tel.: 267-3552524 Fax: 267-356591
E-mail: arntzenj@noka.ub.bw**

Environmental Protection in the Context of Sustainable Development

Introduction

Environmental protection refers to the deliberate maintenance of a certain level of *environmental quality*. This is done through *environmental management*. This chapter briefly discusses four aspects of environmental protection, namely:

- ☐ Why is it needed?
- ☐ What needs to be protected?
- ☐ How much should be protected?
- ☐ How should protection take place?

The concept of *sustainable development* offers a useful analytical framework to answer these questions. Although not entirely new, the World Commission on Environment and Development (WCED) gave sustainable development a new authority:

Meeting the demands of the present generation without jeopardising the ability to meet the needs of future generations (WCED, 1987).

The following description in the same book reflects the demanding nature of the concept:

A process of change in which the exploitation of resources, the direction of investments, the orientation of technological developments and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations (WCED, 1987).

In economic terms, sustainable development considers natural resources as production factors (at par with labour and physical capital). A society develops sustainably when it increases its production factors, or at least keeps them constant.

Sustainable development is not just an environmental concept; it has various dimensions. It cuts across traditional lines of sectoral organisation of policies - dominant in government structures - and traditional disciplinary lines - dominant in academic institutions. Few countries - if any at all - in the world can claim to develop sustainably. Nonetheless, the concept is useful in directing the general development path and as an analytical framework to improve existing projects and policies.

Reasons for Environmental Protection

Environmental protection is a limited concept in that it is only concerned with prevention of undesirable environmental changes. It gained prominence because of the growing environmental problems, resulting from past environmental neglect. As the environment provides key resources to society, its protection is essential to maintain a flow of essential goods and services.

Environmental decline may adversely affect such flows, either damaging future development or threatening human survival in the case of loss of life support functions. In particular, irreversible environmental changes deserve detailed examination before such changes are “accepted”. One needs to weigh the costs and the benefits of such actions, and in case of uncertainty planners may be well advised to apply the *precautionary principle*, i.e. do not implement actions until you are sure about their major consequences. The consequences of species losses are often very difficult to anticipate because of our limited understanding of complex ecological processes. Perhaps, we can do without a species such as the panda bear, but who knows the other consequences its disappearance might have? If you like, this utilitarian perspective on the environment is selfish, considering benefits to humankind as the ultimate criterion of every development or process. There are other normative - less anthropocentric - perspectives which consider humankind as only one of the natural resources and species. In such views, humans are not above the other species, and in fact have the responsibility to ensure their survival.

What Needs Protection?

Given ecological complexities, it is not sufficient to single out species in need of protection (e.g. through CITES). Environmental protection should focus on a wide range of interrelated levels such as *genes*, *species*, *ecological cycles* and *ecosystems*. For practical purposes, countries could concentrate their efforts on species or ecosystems which are particularly threatened and/or vulnerable to development. Certain ecosystems may be protected by giving them a special status (e.g. Park and Reserve Ramsar site). However, it is widely accepted that species protection cannot be restricted to special areas such as Parks or Reserves. Genes protection is particularly important in undisturbed areas hitherto not suffering from intensive, monoculture-biased, development. Species and genes diversity tend to be greatest in such areas (e.g. tropical rainforests).

Level of Protection

The level of protection can be identified in different ways. In reality, the most commonly selected level of environmental protection is environmental

management which does not significantly and adversely affect economic growth. An example of this approach is the Western growth model followed in the past. Where a trade-off exists between environmental protection and economic growth, the latter usually takes priority (protection is a luxury, which one can only afford later). Fortunately, the importance of environmental protection for long term economic growth is increasingly recognised, demonstrating that the tradeoff is not as common as generally believed (win-win situations, where both development and environment benefit).

Sustainable development offers clear guidelines as to the level of environmental protection. Two variations exist, each with their own recommended level of protection.

Strong Version of Sustainable Development

The *strong version of sustainable development* dictates that the *environmental quality must be maintained as far as renewable resources, biodiversity and pollution is concerned*. The optimal levels of environmental use and protection are:

- ☐ For *renewable resources*: the use of renewable resources should not exceed the regeneration renewable resources;
- ☐ For *pollution - emission and effluent discharge*: level of emission/discharge should not exceed the environment's absorption capacity;
- ☐ *Loss of biodiversity*: anthropogenic loss must not exceed the natural rate of loss.

Weak Version of Sustainable Development

For the *weak version of sustainable development* (the sum natural, human-made) no environmental losses are acceptable. On the other hand if all environmental losses can be compensated, then all environmental changes would be acceptable. It is problematic to identify the potential and extent of compensation. To what extent can machines and human skills substitute natural resources? Optimists argue that technology and human innovation will solve all problems. Pessimists argue that substitution is limited, and possibilities will run out.

Strictly adhering to the principle of strong version of sustainable development (the amount of natural capital should remain at least constant), extraction of non-renewable resources would not be allowed. Of course this does not make sense (why keep it forever?). The weaker version of sustainable development

offers two useful guidelines for the rate of depletion:

- ❑ Deplete non-renewable resources in such a way that renewable substitutes exist upon their depletion. This will minimise societal disruptions.
- ❑ Mineral revenues should only be used to strengthen human skills and/or the physical infrastructure. This would enhance the future productive capacity.

Interestingly, sustainable development extends protection guidelines to the human sphere. Environmental protection requires eradication of absolute poverty (i.e. people living below the poverty datum line) and efficient resource use by the middle and high income groups (households and countries). The former would enable the poor to invest in activities with long term environmental benefits. The latter would reduce resource pressure and create room for low income groups to access their fair share of natural resources.

Environmental economics adds to the sustainable development approach by incorporating cost concerns. Let us discuss the example of pollution. The problem of pollution arises because of market failures. Normally, pollution costs are external to the polluter, and therefore not incorporated in his/her decision-making process. The company increases its production level to the point where the extra revenues from an additional unit produced equal the extra production costs, i.e. the level where the marginal net private benefits are zero. Society incurs increasing pollution costs MEC, which lead to a situation where - from society's prospective - the company's production is too high, i.e. the level where the society's marginal costs exceed the marginal benefits. The optimal level of pollution is the environmental quality where the society's extra (or marginal) costs of pollution reduction equal society's extra benefits. If the costs of pollution control exceed the benefits, such control is uneconomic, and unwise. If on the other hand the gains exceed the costs, it is important.

Means of Environmental Protection

Environmental protection is the responsibility of all resource users, be it individuals (e.g. consumers, farmers), companies or government departments. Government - as the overall custodian of society's interests - should provide a "climate", an "enabling environment" conducive to environmental protection. Governments have three general instruments at their disposal:

- ❑ **Legislation**, comprising legal rules that seek to prescribe environmental use (command the control);
- ❑ **Economic instruments**, comprising charges, subsidies etc. aimed at

encouraging environmentally friendly behaviour and discourage undesirable resource use; and

- ❑ **Consultative instruments**, seeking negotiated or voluntary changes in resource user behaviour. For example, government may sit down with villagers to negotiate a sustainable development plan in the village area. The government may also sit down with the chemical companies to agree on an environmental action plan. Awareness raising and formal education are fundamental components of this approach.

Each type of instrument has its own strengths and weaknesses. Traditionally, *environmental policies* have heavily relied on regulations. While this has the potential advantage of detailed control over resource use, enforcement has proven to be difficult and costly. *Economic instruments* serve the dual purpose of fund raising for government activities with respect to environmentally management and of altering resource use by stimulating environmentally friendly behaviour. In practice, *economic instruments* are successful in fund raising but their environmental impacts are less clear. Among others, the environmental impacts depend on the price elasticity of demand. If this elasticity is close to zero, making resources more expensive will not change consumption patterns much. Finally, *consultative instruments* such as negotiations with villages or economic sectors can be used. Persuasion and environmental education also belong to this category of instruments. These instruments tend to be successful in terms of compliance as people and institutions have been consulted. However, it is not always possible to agree on relevant environmental targets. For example, an industrial sector may not be willing to reduce pollution sufficiently. Indonesia has been fairly successful with these instruments by making compliance or non-compliance with environmental standards public (with a time lag for defaulters of one year to allow time to improve their record).

Conclusion

It is recommended that a consistent package of all *environmental protection instruments* be put together to promote the desired resource utilisation. This requires radical changes as most countries apply instruments with diverging environmental impacts. For example, livestock subsidies lead to larger number of animals and rangeland rehabilitation. Subsidies actually hamper the chance of success of the latter projects. Both instruments have to be brought in line. Environmental impact assessments for both projects and government policies could reduce the occurrence of such inconsistencies.

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CHAPTER 6

POPULATION, POVERTY AND ENVIRONMENT IN AFRICA

John O Oucho

**Population and Sustainable Development
University of Botswana
Private Bag 0022
Gaborone, Botswana**

**Tel.: 267-355 2524 Fax.: 267-356 591
E-mail: ouchoj@noka.ub.bw**

Population, Poverty and Environment in Africa

Introduction

The African continent consists of four sub-regions, namely Eastern, Middle (also known as Central), Northern and Southern, which vary considerably in demographic, economic, developmental and environmental profiles. Generally, Northern Africa is excluded from analyses of Africa because of its geographic and socio-cultural affinities with the Middle East, thereby restricting focus to Sub-Sahara Africa which characterises the African region in many respects. In keeping with this tradition, This Chapter analyses the region's *population, poverty and environment as entities in themselves and in terms of their interrelationships in ensuring or undermining sustainable development.*

While the next section explains the setting of our analysis, the rest of the sections highlight population, poverty and environment, followed by concluding remarks.

General

Sub-Saharan Africa comprises 50 countries which are distributed as follows: 19 in Eastern Africa, 9 in Middle Africa, 5 in Southern Africa and 17 in Western Africa. These countries differ considerably in size, population, poverty, extent and levels, and environmental conditions. Moreover, some of the countries are sometimes classified or do consider themselves as part of different sub-regions from which they are classified. The best examples are the three countries in the Southern and Eastern Africa - Mozambique, Zambia and Zimbabwe - which, according to a variety of statistics, are part of Southern Africa. Another confusing issue is regional economic integration which places these countries together with Malawi, Mauritius, Tanzania and Angola within the *Southern African Development Community (SADC)*; all the Eastern African countries and Zaire within the *Common Market for Eastern and Southern Africa (COMESA)*; Anglophone and Francophone as either part of the *Economic Community of West African States (ECOWAS)* or member states of *Communate' de l' Afrique* - of the West African Economic Community (CEAO); the *Union Duaniere Economique de l'Afrique Centrale* - the Customs and Economic Community of Central Africa (UDAEC); some Eastern and Middle African states (Rwanda, Burundi and Zaire) as member states of the Economic Community of the Countries of the Great Lakes (CEPLG). Such fluid classification systems complicate attempts to make sub-regional generalisations or comparisons and shift residence to country-specific interpretations which in themselves are far from comparable.

Throughout this Chapter, the United Nations classification which apportions the SSA into the four sub-regions, has been adopted. Exceptions to this rule apply where a given phenomenon is best explained by a different classification.

Population: Basic Concepts

The term *population*, while commonly used, has been so misinterpreted in Africa by lay persons that it is misconceived as “Family Planning”, that is, a method of spacing or limiting births, or both. Clearly this is a gross misinterpretation of a concept which is on the lips of researchers, planners, policy and decision makers who scarcely share information in many SSA countries.

As the total number of people in a given place, the term population must of necessity address population dynamics whose components - **fertility** (a positive factor), **mortality** (a negative factor) and **migration** (having elements of either) - determine the growth and structure of population. *While the difference between fertility and mortality constitutes natural increase of population, the aggregate change due to the interplay of the three factors denotes population change.* Measures of **fertility** range from a *crude index* (crude birth rate) to a more refined, *total fertility rate*; of **mortality**, from crude death rate to *infant mortality rate* (IMR), *maternal mortality rate* and *life expectancy at birth* ; and of **migration**, from *gross migration* to *net out-migration* or *in-migration*, or *net emigration* or *immigration*.

In the context of population - area relationship, population distribution (configuration of population in a given space) and population density, either the number of persons per square kilometres (arithmetic density) or the number of persons per square kilometre of arable land (physiological density) point to whether population size exceeds and therefore exerts pressure on resources; the optimum population which economists often underscore, is an idealistic condition because it presupposes an equilibrium between population and resources.

Finally, the *concept of population pressure on resources*, notably land, has far-reaching implications for environmental management and sustainable development. In traditional African societies, shifting cultivation, including the “slash and burn agriculture”, thrived because population size was small relative to the available land, ie, societies were underpopulated. As population increased and land sizes diminished, it became necessary for agriculturalists to adopt intensification in agriculturally fertile land and extensification by agriculturalists extending agriculture to formerly non-agricultural lands, for instance, marginal and deforested areas (Bilsborrow and Okoth-Ogendo, 1992). In drylands, which represent a substantial part of SSA, nomadic pastoralists have been moving with

their livestock, in some cases overgrazing and causing environmental degradation. Where agriculturalists have adopted extensification, they have generally invaded the pastures, thereby engaging in serious conflicts and violence with nomadic population; examples abound in East Africa's rangelands (Talbot).

In certain circumstances, agriculturalists have *out-migrated from densely settled areas*, where there is acute pressure on the land, to neighbouring areas for purposes of agricultural land colonisation. This explains in-migration into Rift Valley Province (the former "White Highlands" which were exclusively for white settlement) from the more densely settled Central and Western Provinces of Kenya during the period of land settlement (approximately 1962-1975) and why "land clashes" had to occur in 1991-93 when the indigenous population disputed invasion of their hereditary land (Oucho, 1984, 1996). This example is not limited to Kenya; rather, it has been replicated in virtually all SSA countries where agriculturalists, envisioning land shortages at some stage, colonise agricultural, or even marginal, lands in their neighbourhood to augment and resources, generally at the expense of the indigenous population.

Demographic Indicators

Population Size and Growth

At the close of the twentieth Century, demographic indicators of SSA countries depict an irksome situation. Of Africa's total population of 738.730 million as of mid-1996, Sub-Saharan Africa accounts for a staggering 577.358 million or 78.2 percent of the continental total. For Sub-Saharan Africa alone, the sub-regional percentage distributions are: Eastern Africa (39.4%), Western Africa (37.3%), Middle Africa (14.8%) and Southern Africa (8.4%); at mid-next century when SSA will have a population of 1.7 billion, the projected percentages are expected to be 40.4%, 36.9%, 16.5% and 6.2% respectively. Both Eastern and Middle Africa will improve their proportions as both Western and Southern Africa record declining proportions for SSA's population. In a descending order, the top five largest populations in SSA are, and will continue to be, Nigeria, the Democratic Republic of Congo (formerly Zaire), Ethiopia, United Republic of Tanzania and Kenya.

Population growth rate explains why sub-regional differences in population size exist and will persist in future. Middle Africa leads the peak with a growth rate of well over 3 per cent per annum, due largely to improving fertility where in the past infertility and sub-fertility reigned. Western Africa comes second with a growth rate of nearly 3 per cent per annum; the sub-region consists of some of the slowly growing populations, such as those of St. Helena and Cape Verde Islands and the Sahelian countries (Mauritania, Senegal and Burkina Faso), with

Liberia experiencing a negative growth rate due to massive refugee outflow since 1992. Except for Malawi, Somalia and the Indian Ocean islands with exceptionally slow growth rates and Rwanda with a negative growth rate due to the outflow of refugees, all Eastern African countries record high population growth rates. The slowest population growth rate is in Southern Africa where all the countries register virtually uniform population growth rate. It is important to stress, however, that there is a declining trend in the SSA population growth rate which lurked above 3 per cent for much of the previous decades. This declining population growth is attributed to fertility decline which has been taking place since the 1980s in virtually all SSA countries as mortality continues to decline.

Crude and Refined Fertility and Mortality Measures

Two fertility measures warrant consideration, namely: Fertility Indices and Mortality Indices.

Fertility Indices

Crude birth rate (CBR) measures births per 1000 population; it is a crude measure because it presupposes that both males and females and those within and outside child-bearing ages do give birth. The CBR is highest in Middle Africa, followed by Western Africa and Eastern Africa which tie, and Southern Africa as a distant fourth. It is in the Sahelian countries of Niger and Mali and in the Western, Eastern and Southern African countries of Guinea, Uganda and Malawi where CBR is highest.

A more refined measure is the *total fertility rate* (TFR), representing the average number of births to women of child-bearing age (15-39 years). Eastern, Middle and Western Africa tie in leading with a TFR of 6.4 children, followed by Southern Africa. But the TFR levels correlate closely with CBR levels as it is highest in Niger (7.4) and is noticeably high in Malawi (7.2) Angola (7.2), Mali (7.1), Burkina Faso (7.1) and Uganda (7.1). These are TFR levels comparable to Kenya's TFR in the 1970s: it should be remembered that high fertility and fast declining mortality were responsible for Kenya's highest population growth rate (about 4.1 per cent per annum) in Africa in the late 1970s and early 1980s.

Mortality Indices

Likewise there are crude and refined mortality measures, namely *crude death rate* (CDR) and *infant mortality rate* (IMR) which reflect the quality of health and life expectancy at birth. **Crude death rate** measures the rate of all deaths per 1,000 population, including infants, children, women adults of all ages and old-age population whose mortality varies considerably. **Infant mortality rate**,

on the other hand, measures the rate at which infants die before reaching their first birthday (i.e., those aged 0-11 months); it is often higher than the general under-five mortality, before children become more adaptable and resilient healthwise. **Life expectancy at birth** is the average number of years newly born are expected to stay alive before dying; generally it increases as socio-economic development increases, though devastating pandemics or epidemics such as AIDS would tend to reduce it.

Crude death rate is highest in Eastern Africa where Rwanda, Malawi, Uganda and Burundi register exceptionally high CDRs; Western Africa comes second with Sierra Leone, Liberia, Guinea-Bissau and Guinea recording equally high rates; Middle Africa, where countries of the sub-region register nearly uniform CDRs, has medium rates; and Southern African countries have more than halved their CDRs from those in the first two sub-regions. *It would appear that countries which have been experiencing civil war and economic difficulties still lurk in a different mortality enclave from that of other SSA countries.*

Infant mortality rates in Africa remain the highest in the world. Again, the general rate is similar to that of the crude death rates. Countries with IMR rates above 120 per 1,000 live births include Liberia, Sierra Leone, Mali, Guinea-Bissau, Guinea, Gambia and Niger in Western Africa; Malawi, Rwanda and Burundi in Eastern Africa; and Angola and Congo (Brazzaville) in Middle Africa. Clearly Southern Africa is in a class of its own, experiencing much lower IMRs.

Life expectancy, which has declined in the era of AIDS pandemics, it is still exceptionally low in SSA countries. It is highest in Southern Africa where all the countries have life expectancy of 50 or more years; followed by Middle Africa where, however, the national figures are more or less uniform; then comes Eastern Africa where the figures range from a mere 23 years for Rwanda to over 70 years in the Indian Ocean islands of Reunion and Mauritius; and at the tail end is Western Africa where variations among the countries is, however, negligible.

Internal and International Migration

Spatial dynamics of population - spatial and urban population distribution, and both internal and international migration determine the total population within a country or part of a country. Highlights of these are given to underscore considerable variations in the continent.

Population Density

Africa is generally a sparsely populated continent. The large chunks of arid and semi-arid lands (ASAL) including the Sahara and the Kalahari deserts in

inhospitable tropical forests are largely responsible for spatial population distribution. But within any particular country, there are pockets of very densely settled areas in which population pressure on the land is already being experienced. Of the sub-regions, Eastern Africa is the most densely settled (within the Indian Ocean islands, Burundi and Rwanda having very high population densities), followed by Western Africa, Southern and Middle Africa in a descending order.

Urban-rural distinguishes the total population between urban and rural areas. It should be cautioned that the term “urban” is fluid in SSA countries, as whereas some countries have adopted the threshold settlement size of 2,000 people to denote an urban centre, others apply the proportion of non-agricultural activities, a settlement’s administrative role and so on. This invalidates attempts to compare urbanisation among SSA countries or between Africa’s and that of other developing countries.

In SSA, the proportion of urban population has increased steadily in the three-odd decades 1960-1993 and projections are expected to be dominant by the year 2000. In Mauritius, it ranges from a small percentage in 1960 to a projected figure of 42% in the year 2000; in South Africa from 47% to 53%, respectively; in Congo (Brazzaville) from 32% to 63%, respectively; in Nigeria from a mere 14% to a staggering 43%, respectively; and in Kenya from 7% to 32%, respectively. These statistics symbolise the rapid rate of urbanisation that has been taking place in the region. Yet in many SSA there is the “urban primary” whereby one principal city, often the national capital, dominates the national scene; incidentally except for Lagos in Nigeria and Kinshasa in the Democratic Republic of Congo, these cities have much smaller populations than do Asian and Latin American cities.

Migration is simply defined as spatial or geographical mobility of population involving a change in the usual residence (IUSSP, 1982: 92-93). Distinction is made between internal migration which denotes movement within the national boundaries and international migration in which movements cross defined territorial boundaries.

Internal migration consists of four types: (a) rural-rural which accounts for the bulk of internal migration in many SSA countries (comprising nomadic pastoralism, movements to agricultural land colonisation); (b) rural-urban migration which was important in the first two decades of independence in SSA countries but whose rate has so far dwindled; (c) urban-urban (inter-urban) which is still limited in many SSA countries, but which promises to gain prominence in future as urbanisation increases; and (d) urban-rural, including return migration of retired workers, the deceased and their relations, unemployed person, and those who have lost employment.

Important features of internal migration include the following:

- ❑ It is both a cause and an effect of a country's development pattern.
- ❑ It is easily studied from census data (e.g. by cross classifying place of birth with place of renumeration statistics) as well as survey data and case studies.
- ❑ While return migration is a characteristic of first-generation migrants, it does not apply for second and subsequent generations of migrants who often break socio-cultural links with their origins.
- ❑ Migrants are selected by ethnicity, sex, age and economic activity.
- ❑ The peak age of migration is often 20-29 years and that of return migration begins at 45 years in most SSA countries.
- ❑ Determinants of migration include external factors, community level variables, household characteristics and decisions, environmental and resource factors and so on.
- ❑ Consequences of migration are positive and negative in both origins and destinations.

International migration also consists of four board types: (a) permanent immigration (e.g., Europeans in South Africa and Asiatic in many SSA countries) and emigration (e.g., slave traffic to Asia and the New World); (b) labour migration which comprises cheap labour (e.g., mine workers from Southern Africa states to South Africa) and skilled persons (e.g., highly educated and professionals in the South-North “brain drain” and from the rest of Africa to Southern Africa, especially the buoyant economies of Botswana, Namibia and South Africa - as “skilled relocation”); (c) refugees, including asylum seekers, which is by far the most dominant type of international migration in SSA, especially in Eastern Africa; and (d) illegal/clandestine/undocumented migration along the generally arbitrarily drawn, porous, unpoliceable borders dividing one ethnic group into two or more nationalities.

International migration has the following features:

- ❑ *Permanent migration* sustains diaspora which is useful in political, economic and social networks and linkages.
- ❑ *Documented migration* depends on rules of entry into the immigration country and rules of exit from an emigration country.
- ❑ While *South-North migration* (especially from West and Middle Africa to the developed nations) constitutes “brain drain”, intra-Africa one is “skill relocation”.

- ❑ *Refugee flow* is by far the most dominant type of migration, with SSA accounting for more than one-half of the world's refugees. It is the result of *coup d'états*, civil wars, floods and environmental problems such as drought and famine. Together with internally displaced populations, refugees disrupt development efforts in any sending or receiving country.
- ❑ *Illegal/ clandestine/ undocumented migration* is rampant along all borders of SSA countries depending on political, economic and social circumstances.
- ❑ All SSA institutions of regional economic integration - e.g., ECOWAS, COMESA and SADC - have protocols on free movement of persons, right of residence and establishment, which have not been fully implemented. When implemented, SSA will be a region of countries without boundaries, and one where better "skill relocation" would be effected for the benefit of all the countries which make up the region.
- ❑ *International migration* (different types of it) is caused by wide-ranging factors: demographic, economic, political, socio-cultural and environmental.

Poverty

Definitions

Literature on poverty suggests that while the term is commonplace, it is by no means clear to most people. The simplest definition of poverty (UNCOS, 1996:108) is that:

Poverty implies deprivation of human needs that are not met. It is generally understood to arise from a lack of income or assets... Definitions that set a "poverty line" to divide the population into the "poor" and the "non-poor" are often most inaccurate because they simply standardise what is highly complex and varied.

To this end three concepts may help define poverty, namely:

- ❑ **Poverty** in terms of *lack of physical necessities, assets and income*;
- ❑ **Deprivation** which encompasses the above and includes other dimensions such as *isolation, vulnerability and powerlessness*; and
- ❑ **Unreliability** which denotes *defencelessness, and exposure to risk, shocks*

and stress. It is, therefore, important to be absolutely clear about the aspects of poverty being discussed at any particular time. Most SSA government seem to favour the simplistic “income level” definition as they fail to provide the population with the physical necessities or to give them opportunities to acquire dependable assets. This is presumably because the Bretton Woods Institutions (The World Bank and the International Monetary Fund) express national incomes and assets in terms of gross/national product (GNP) per capita or gross domestic product (GDP), national averages that mask intra-country variations and that depict misleading pictures about individual countries, especially when compared internationally.

The literature on poverty is also replete with concepts such as “*absolute*” and “*relative*” poverty, *reduction, alleviation and eradication of poverty*, which do not convey intended meanings unless the kind of poverty referred to is clearly defined, well defined measures are employed as well conceived intervention measures are designed.

A Geographer echoing British students’ view in 1988 that “to think of Africa is to think of poverty” (O’Connor, 1991-1) clearly simplifies his definition of poverty for a continent sitting on wealth which is yet to be properly utilised by African Countries and the African people. He points from the onset that his book, *Poverty in Africa: A Geographical Approach*, is concerned with “material poverty”, that is, low level of income and low levels of consumption of goods and services, which is reflected in diet (reflected by internutrition and malnutrition) and ill-health linked to low levels of education. The study notes that the poorest groups are found in rural areas, that female-headed households are poorer than male-headed ones, that women are generally poorer than men and both teenage school-leavers and the elderly are the poorest in SSA countries (O’Connor, 1991:23-30).

Nature and Extent of Poverty in Sub-Saharan Africa

On the basis of income alone, 45-50 per cent of the population in SSA live below the poverty line. In 1993, an estimated 40 per cent lived on less than US\$1 per person a day, with at least half of them in East Africa and Nigeria. The general trend for the selected 14 SSA countries in the five years 1985-1990 was an increase in the percentage of population with less than US\$1 a day, with substantial increases in Rwanda and Ethiopia (then war-torn countries) as well as Cote d’Ivoire. The rest of the precipitous countries enough to warrant lack of government action.

Causes of Poverty

In a recent study, *Taking Action for Poverty Reduction in Sub-Saharan Africa*, the World Bank (1996) identifies eight main causes of poverty as (i) inadequate access to employment opportunities; (ii) inadequate physical assets (e.g. land and capital) and minimal access by the poor to credit, or even on a small scale; (iii) inadequate access to the means of supplying rural development in poor regions, (iv) inadequate access to markets where the poor can sell goods and services; (v) low endowment of human capital; (vi) destruction of natural resources, leading to environmental degradation and reduced productivity; (vii) inadequate assistance for those living at the margin and those victimised by transitory poverty and (viii) lack of participation, including failure to draw the poor into the design of development programmes.

Indices of Poverty

Human Development Report 1996 (UNDP, 1996: 109-112) applies the Capability Poverty Measure (CPM) to estimate the extent and depth of poverty in 101 developing countries. Explaining that human development is defined by the expansion of capabilities which, unlike income, are ends and are reflected in human outcomes (e.g. the quality of people's lives), the HDR 1996 refers to deprivation as a lack of basic capabilities, when people are unable to reach a certain level of essential human achievement or functioning (UNDP, 1996 109), i.e., the people are poor. The CPM is a simple index composed of three indicators that reflect the percentage of the population with capabilities shortfalls in three basic dimensions of human development, namely (UNDP, 1996 109).

Dimensions of Human Development

Corresponding Indicators

- ☐ Living a healthy, well-nourished life: Percentage of children under age 5 who are underweight.
- ☐ Having a capability of safe healthy reproduction: Percentage of births unattended by trained health personnel.
- ☐ Being literate and knowledgeable: Percentage of women 15 years and above who are illiterate.

In the CPM, the problem of aggregation across the three variables is solved by choosing variables expressed in terms of the percentage of the relevant population that is poor.

The threshold for defining poverty is based on the standard definitions for underweight, for trained personnel and for literacy which are already in use. Other plausible variables in the CPM include the percentage of low-birth weight babies or the percentage of one-year-olds immunised. Adding together percentages for the CPM three variables, the average Capacity Poverty Measure in a country is derived.

The SSA countries record very high CPMs, ranging from an average value of 20s-30s in Mauritius, Zimbabwe, Swaziland, Kenya, Botswana, and South Africa; to the 40s in Malawi, the Democratic Republic of Congo (formerly Zaire), Togo, Uganda and Central African Republic; the 50s in Senegal, Rwanda, Nigeria, Benin, Guinea, Guinea-Bissau, Mali and Burkina Faso; the 60s in Mauritania, Chad and Sierra Leone and the formerly war-torn countries of Somalia, Angola, Burundi and Mozambique; and 70s and above in Ethiopia (then including Eritrea) and Niger (UNDP, 1996: 111-112). These figures are closely correlated with the Human Development Index (HDI) values for SSA countries. A closer look at the three CPM variables and the real GDP per capita reveal a similar pattern.

Environment

Definitions and Issues

The environment is what envelopes human beings - flora and fauna that interplay in both production and consumption processes. In some instances, distinction is made between the *natural environment* (consisting of physical and biological phenomena) and the *human environment*, made of activities such as agriculture, industrialisation, fishing, deforestation and afforestation/reforestation, mining and urbanisation. This distinction makes little sense because both components of environment are interlinked through intricate processes.

Generally, *environmental issues relate to resources* - natural (physical and biological) and human - *some of which are renewable*, while *others are non-renewable*. A cursory consideration of resources of the atmosphere, lithosphere, hydrosphere, and biosphere will show that the *African environment has undergone degradation due to over-exploitation of resources, poor conservation measures, human greed in the context of international trade and profit-making in the sale of resources exploited and poor government policies and resource-sensitive planning strategies.*

The recent concern has been on *population, environment, and development interrelationships (PED)*, in which three basic scenarios emerge:

- Population influences the environmental which in turn affects development;

- ❑ Environment affect population, thereby influencing the development process; and
- ❑ Development affect environment which in turn influences demographic behaviour.

But more scenarios may be conceived depending on issues that are identified in a particular region, country or part of a country.

Regional environmental trends essentially cover *land* (degradation), *forest* (loss, degradation), *biodiversity* (loss, habitat fragmentation), *fresh water* (scarcity), *pollution*, *marine and coastal zones* (degradation), atmosphere (pollution) and *urban and industrial* (contamination, waste). The last four are increasing fast in Africa (UNEP, 1997:7).

Environmental Hot Spots

The World Bank (1996), using work by the Food and Agriculture Organisation (FAO), divides Sub-Saharan Africa into six sub-regionally based ecological zones: (I) Sudano-Sahelian Belt, (ii) Humid West Africa, (iii) the Congo Basin. (iv) East Africa, (v) Southern Africa, and (vi) The islands of the Indian Ocean. The main highlights of the natural capital (natural resources) of each are provided.

The Sudano-Sahelian Belt

This zone is the most fragile and is the least favourable for development in the whole of SSA region. Its liabilities include poor soils and low unreliable rainfall, resulting in extremely short cropping period and incessant drought. Except for the large basins of the Niger River and Lake Chad as well as the Nile River Basin in Sudan, the Sudano-Sahelian Belt countries have exceptionally low potential, especially the land-locked countries such as Burkina Faso, Chad, Mali and Niger. There is also the problem of soil degradation which has aggravated the risk of drought due to loss of organic matter and nutrients (e.g. phosphorus), deterioration of soil structure and surface crusting (World Bank, 1996:24). Population pressure, therefore, mounts in the major wetlands such as the inner Niger Delta in Mali, Lake Chad and along the Nile River. The ecological zone constitutes a suitable laboratory for studying the process and effects of agricultural intensification and their implications for populations and natural resource as well as environmental management.

Humid West Africa

This ecological zone has favourable natural capital due to favourable climatic conditions (high and regular rainfall and hot, humid temperatures) and soils of reasonable quality, though lacking phosphorus. But the region has experienced large-scale immigration from the Sahelian countries, thereby exerting pressure on the resources and environment. Also, in-migration into the coastal areas has caused environmental stress, which has been reinforced by rapid urbanisation and the resultant environmental pollution in the fast growing cities. The population factor has also caused deforestation, as has extensification as deforestation paves the way for agricultural activity, which, however, is less vibrant than in the rest of SSA.

East Africa

The natural capital of this sub-region is renowned for its unique scenery and the diversity of its parks and reserves, which have favoured the tourist industry (e.g. in Kenya). It has also good soils in the highlands, which coupled with quasi-temperature conditions, have sustained commercial agricultural production. The situation applies to the East African Plateau, the Great Lakes Region, Ethiopian Highlands and agriculturally endowed areas of Tanzania and Zimbabwe. But the attractiveness of this ecological zone has stimulated rapid population growth which has resulted in population pressure on the land, leading to agricultural extensification into deforested areas and even marginal lands. Land degradation has taken place not only in these densely settled areas but also in the Lake Victoria Basin.

Southern Africa

The natural capital of Southern Africa is rich in terms of biodiversity and production potential in a region which has large chunks of arid and semi-arid lands experiencing a moderate-to-high risk of drought. The South African past policies have had a negative impact on the environment by encouraging agricultural development through subsidies on farm inputs and irrigation development without stimulating enough soil and water conservation (World Bank, 1996: 31). The country is experiencing pollution problems because of its energy and industrial development based on mineral coal (e.g. in the Johannesburg area). The region is well cultivated as it has reasonably good soil, though highly variable climatic conditions cause recurrent droughts. Unfortunately, soil degradation is occurring in grazing land between Luanda and Huambo in Angola, in the Lesotho highlands and in North-Eastern Botswana (p.33).

The Indian Ocean Islands

The islands of the Indian Ocean share more or less similar environmental features which determine their future in terms of their biodiversity capital which is of global significance, particularly in Madagascar; the management of marine resources in the development of tourism; the mountainous topography which requires special attention in terms of soil conservation and watershed management; tourism which has considerable potential and is essential to the economic development of the islands (World Bank, 1996: 33). Although Madagascar is dominant in its size and exceptional diversity of its landscapes as well as the uniqueness of its flora and fauna, it, like the Comoros, remains less developed than Mauritius and Seychelles.

More than half of the total area of these islands is cultivable because of relatively good soils and favourable climatic conditions. The main problems are a high risk of erosion due to broken terrain and rampant deforestation (especially in Madagascar). The hot spots of the sub-region in Madagascar are the central Highlands and the mountainous eastern zone where land degradation has been taking place.

Some Environmental Management Problems

A number of environmental problems in the developing world. These are **deforestation** - its annual rate and efforts made in reforestation: production of fuel wood and charcoal which is closely linked with deforestation; and internal renewable water resources (for human, animal and industrial consumption), particularly their annual withdrawals. Deforestation is particularly significant in Western and Middle Africa sub-regions - in Nigeria, Cote d'Ivoire and the Democratic Republic of Congo (formerly Zaire) and Cameroon in the latter. However, the annual rate of deforestation is rather low in SSA countries although, rates above 3 per cent are reported in the Mauritius, the Comoros, Cote d'Ivoire and Malawi; in majority of countries, rates below 1 per cent are typical (UNDP, 1966: 180-1).

Production of fuel wood and charcoal is a major environmental problem in Sub-Sahara Africa. The general trend has been an increase of the phenomenon in all SSA countries except Mauritius where it decreased between 1979-81 and 1993. As the only affordable source of energy for the bulk of rural and poor urban population, fuel wood and charcoal production threatens any afforestation and reforestation efforts which are being made with little success in many SSA countries.

Annual fresh water withdrawals as percentage of water resources in 1980-89 are, like deforestation, also insignificant, except in the Atlantic Ocean islands of

Cape Verde and in Madagascar and Mauritius in the Indian Ocean. As the sources of freshwater dry up as a result of deforestation and desiccation of watersheds, the problem of fresh water will be exacerbated by diverse demands.

In Africa the driving forces of sustainable development which exert environmental impacts include the *production systems* (agriculture, livestock production, fishing and hunting), *population growth*, *industrialisation*, *urbanisation*, *fuelwood and energy management*, *poverty and affluence* and a number of miscellaneous activities and phenomena (Okogbo, 1966:145-147). The general constraints on sustainable development are (a) political colonial legacy, political instability, corruption and deficiencies in governance, deficiencies in planning, deficiencies in legal and legislative support of development programme and lack of effective regional integration and collaboration in development; (b) socio-economic deficiencies in education and training, lack of effective campaign of public entitlement and orientation, poverty, unfavourable economic conditions and limitations in financial support and; (c) technological constraints centering on the application of science and appropriate technologies to the conservation, management, processing and rational utilisation of natural resources. Besides, there are specific or sectoral constraints; (i) on agriculture (ii) on industrial development, such as environmental and natural resource constraints, technological and technical constraints and socio-economic constraints and (iii) mine industry development - environmental and natural resource constraints; technical and technological constraints implies that a careful assessment of variables of the various constraints is necessary to prescribe suitable solutions for eliminating them.

Conclusion

This Chapter has demonstrated the complexity and diversity of population, poverty and environment in Sub-Saharan Africa. The region's demographic, socio-economic welfare and environmental profiles differ by sub-regions, individual countries in respective sub-regions and part of any particular country. In order to enable SSA governments formulate and/or reformulate meaningful policies on these issues and work closely with NGOs, the private sector and international donor agencies, they will of necessity facilitate co-operation among researchers, planners and policy makers focusing on both individual fields and multidisciplinary ventures.

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CHAPTER 7

INFORMATION DISSEMINATION AND MANAGEMENT

V T C Matsoga

Project Officer

Training and Public Education

GTZ/NCSA Waste Management Project

Gaborone, Botswana

Information Dissemination and Management

Introduction

Information Dissemination and Management is a very important tool in any developmental project or programme. It is a topic that has been taken for granted by the educated, bureaucrats, technocrats and planners. The key concepts related to information dissemination and management are defined below:

Information: Knowledge or facts acquired or derived, from study instruction or observation.

Dissemination: The spreading of news, information and beliefs as wide as possible.

Management: An act or practice of directing, guiding, controlling and influencing something or someone.

Communication: The transfer of information as facts, wishes or emotions from a source to a receiver. This can be an act or a process.

Public: A colony comprising groups of people sharing unconventional ideals bound together by such aspects as religious dogma, racial undertones, and economical similarities.

Participation: A scheme or system of partnership and common destiny enriched by thorough and joint consultations within and without the project groups.

The Process of Information Dissemination in Society

In today's society, information dissemination and management, is very vital and occupies a high priority in the planning sequence. There are *various reasons and circumstances that favour or facilitate the process of information dissemination*, among which are:

- a) To keep the people informed of the affairs around them in order to secure their participation;
- b) To legitimise a project or programme in order to ensure its success;

- c) To effect some changes in attitudes and methodology of operations in a given situation; and
- d) To impart skills and knowledge in order to empower a community or an individual.

Information dissemination as a process can be influenced by the following factors:

- a) Knowledge of/about the community;
- b) Composition of the community;
- c) Characteristics of the community;
 - (i) *Sanguines* – ever ready but not dependable people
 - (ii) *Cholerics* – workaholics and optimistic people
 - (iii) *Melancholics* – pessimistic and critical people
 - (iv) *Phlegmatics* – dependable and organised people
- d) Totality of the message or information from project conception, through implementation to completion; and
- e) Time factor and occupation of the community.

The grim reality must be noted that due to lack of knowledge of the communities, many officers such as thinkers, planners, advisors, administrators and politicians, have fallen victim to errors relating to the propensity to import *modern technologies and the techniques of modernisation*. They have not obtained the legitimisation of imported technologies by the accepted traditional leadership. They have usually either tried to impose these important ideas and techniques on the citizenry, without paying much attention to existing local traditions or mentality; or they have appealed to local innovators who, though indigenous, often times tend to be equally foreign in outlook.

One other phenomenon in information dissemination is the notion that ‘things or development’ should always start in the urban areas and then slowly filter to the masses in the rural areas. This is seldom the desired approach. Such approaches have significantly disaggregated developments peoples of the towns and peoples of the villages within one country, and by so doing pushing the developmental scales of balance towards the cities and towns. There are many examples of this situation namely, the rural urban dichotomy, such as in the medical field, road construction industry and technology transfer, waste management, and sports facilities. This should change if our information dissemination should continue to be a success.

In Botswana, through the Primary Health Care concept, the approach has been changed for the better. The country has capitalised on this concept to reach out to all the communities irrespective of where they are. It has been realised that there is no community which is identical to another. Approaches to these communities should depend on what that community attributes and functionality are. This is somewhat obscure to many people, especially public officers. They normally engage in what may be termed the “come-to-me-syndrome”. This is counter productive in the world of today.

Information can be communicated through many avenues and fora. In Botswana, the following are used:

a) **The Kgotla Meetings**

These are excellent avenues to relay information to the general public. The meetings are normally presided upon by the traditional chiefs. The chief can easily legitimise a programme.

b) **Training and Public Education**

These are normally organised, formal and/or informal training sessions where information can be imparted. Seminars and workshops are also included. Training sessions are meant to produce a more informed person in any given undertaking.

c) **Non-Governmental Organisations (NGOs)**

These provide an important avenue for information dissemination. They include churches, political parties, clubs, societies and youth and women organisations.

d) **Law Enforcement**

This can be one of the most effective means of sending messages, particularly within the context of a legal framework. A number of pieces of legislation need to be implemented to enforce compliance on certain issues of local or national importance.

e) **Education through Media**

This is generally a very important tool. It encompasses television, newspapers and radio. Information management on the other hand, serves to gauge the success or failures of an organisation. It serves as a mirror of an organisation and it serves as a dependable springboard into the future. There are many ways to ensure that the information received is well managed, and these are: statistics, reports, archives, libraries and computers.

Information management is primarily implemented for the following purposes:

- ☐ As reference material;
- ☐ For comparison, where one can compare their statistics with another; and
- ☐ To be used as a measuring tool for progress or retro-gression.

Conclusion

For information to be meaningful and useful, it must be periodically *updated and checked against other sources*. It must be properly managed. Information management is important for the household, club, organisation, department, ministry, country and for governance of any form. The world is becoming a global village due to the information which is communicated around. It must therefore be adequately managed.

CHAPTER 8

INDICATORS OF ENVIRONMENTAL POLLUTION FROM A SCIENTIFIC PERSPECTIVE: THE ROLE OF REMOTELY SENSED DATA IN ENVIRONMENTAL MANAGEMENT

Susan Ringrose

**Department of Environmental Science
University of Botswana
Gaborone, Botswana**

**Phone: 355 2540 Fax: 355 2784
E-mail: ringroses@noka.ub.bw**

Indicators of Environmental Pollution

from a Scientific Perspective:

The Role of Remotely Sensed Data in Environmental Management

Introduction

This chapter considers first, an overview of available remotely sensed imagery and further looks into some uses/limitations from the perspective of *pollution detection and monitoring*. This is followed by an overview of projects involving environmental change with emphasis on environmental change in Botswana. Finally, some of the causes of environmental change are considered in the context of global warming.

Available Imagery

A number of different imagery types are available to date. The most frequently used medium resolution satellite derived data are referred to as *Multispectral Scanner (MSS) imagery*, *Thematic Mapper (TM) imagery* and the *French SPOT imagery*, the so-called optical sensors. These cover a range of wavebands in the electromagnetic spectrum but are mainly focused on the visible, near-infra-red and mid-infra-red. This is because most soil and vegetative features are readily identifiable in these parts of the spectrum. These data sources tend to have pixel sizes which vary from 10 x 10m to commonly 30 x 30m. This means that thematic maps can be made from these images at scales varying from about 1:50 000 to 1:25 000. Although certain extensive atmospheric pollution sources may be visible especially towards the 1:25 000 scale, generally these kinds of scales tend to limit the usefulness of satellite based remotely sensed data in terms of identifying (single) non-extensive point sources of pollution. However *their repeat cycles* (as they pass overhead roughly once per two weeks) *mean that satellite based data can be used to monitor extensive pollution sources (like factory emissions from a large industrial area) or for broad scale environmental monitoring*. An additional advantage of the TM sensor is its ability to obtain data in the thermal part of the spectrum, which means it can be used for monitoring heat sources as long as these are relatively large. Mostly thermal pollution info, for instance, the Great Lakes of North America is monitored using airborne thermal sensors.

Radar data sources in which active sensors use long wave parts of the electromagnetic spectrum have been used to detect such pollutants as oil spills in the ocean. The oil causes a dampening effect on the ocean waves which tends to

decrease intensity of the return signal recognisable as darker patches on the imagery. However, again better data is available from airborne radar sources (like AIRSAR) than from conventional satellite based radar (like ERS-1 or Radarsat) because of the greater detail and precision needed in mapping and tracking pollutants.

Since the end of the Cold War episode, greater emphasis has been placed on the availability of very high resolution imagery with pixel sizes of less than 1m or a few centimetres as a number of applications require the use of more detailed data sources. These data tend to be obtainable from, for instance, manned space craft such as the joint Russian/American MIR spacecraft which are in semi-permanent orbit at relatively low altitudes above the earth's surface.

Information supplied from the NUR spacecraft has included multispectral photography over some of the major cities of the earth. Imagery taken over for instance, Istanbul, has provided information on point source pollution emanating from some of the coal fired thermal electricity generating plants in the city (Figure 2 pp.7). What can not be seen using these shorter waveband images is the amount of pollution being discharged by Istanbul into the Sea of Marmara and the Bosphorus. These waterbodies and the adjacent Black Sea are known to be heavily polluted because of the industrial plants which are focused along the shores, particularly in the former Soviet Union.

Some of the pollutants could be seen if specialised multispectral data were obtained and processed.

Usually this requires a fair amount of ground truth as the processed spectral data need to be calibrated against the pollution media. Another aspect of the potential use of remotely sensed data stems from the application of meteorological sources. These satellites provide low resolution imagery (pixel sizes 1km or greater) but have the advantage of having rapid orbital (repeat) cycles returning data to earth once or twice daily. Data from one such satellite called NOAA-14 have been used to map the extent of smoke/haze in the atmosphere whether this is derived from so-called natural sources or from industrial sources. An advantage of NOAA imagery is that the thermal detectors on board can pick up heat emitted from the earth's surface and so can be used to monitor hot-spots irrespective of their source. Such thermal imagery is usually best retrieved from night time data when the contrast in thermal emittance with the surrounding air/land surface is at its maximum. This is possible as the NOAA series of satellites are not only in continuous orbit but also transmit continuously through the day and night.

Environmental Change in Botswana

The following project outline is an example of how TM imagery has been used to monitor environmental change in Botswana. This project which was commissioned by the UK Overseas Development Administration (ODA) was undertaken mainly to assist Botswana fulfil its obligations under the United Nations Convention to Combat Drought and Desertification (Ringrose et al., 1997). Range degradation has long been regarded as a problem in Botswana and was recognised as such before Independence in 1966 (e.g. Parsons and Crowder, 1988). Degradation and desertification are defined by United Nations agencies (e.g. United Nations, 1992) as:

“areas undergoing reduced biological productivity as a result of human induced or climatic factors”.

Areas of reduced productivity and by implication, areas of soil erosion are regarded by a number of authorities as being degraded and therefore undergoing environmental change. However the status of lack of productivity, and in many cases, eroded soils cannot be identified accurately on satellite imagery so a *surrogate degradation indicator* is required. In this work, the indicator of potential degradation was the *existence of extensive areas of highly reflective bare soil*. These were particularly visible for instance where degradation occurred around cattle posts and settlements. This work had an integral element of change over time, so the bare soil degraded areas which remained degraded through time were given most emphasis.

This project was undertaken in two stages. **Stage 1** entailed a visual comparison between potential range degradation features throughout Botswana in the drought years (1984/5) with similar feature during an essentially post (major) drought episode (1994/5). **Stage 2** involved supervised classification of the 1994/5 imagery from the post drought episode.

Stage 1

Mapping of 1984/5 wet season imagery took place using a *visual interpretation* of 1:1 000 000 MSS7 (near infra-red). Percentage bare soil areas were plotted using ARC/INFO into 234 50 x 50 km grid squares and resulted in 146 788 km² of potentially degraded (bare soil) areas being identified over 25% of Botswana. These bare soil degraded areas are widely distributed over the country and mainly result from the effects of drought but also include aspects of human induced pressure on the natural vegetation cover. Mapping of 1994 data took place using a 1:1 000 000 false colour composite comprising TM3, TM4 and TM5 data resulted in 37 872 km of potentially degraded (bare soil) areas being mapped over 6.5% of Botswana. This mainly depicted the extent to

which vegetation recovery took place since the 1980s major drought period. A change map was produced to indicate which areas had improved or deteriorated since the last major drought over the 234 grid squares. Areas which appeared to have responded positively to rains include much of the north-west, centre (including the Central Kalahari Game Reserve and the Moremi Chobe Park systems), the south-east of Botswana and the Boteti area. Since the vegetation cover is mainly natural, this recovery is considered to represent no significant change - just natural post drought recovery. Some relatively large areas appeared not to have recovered since the drought. These included extensive soil eroded areas peripheral to the ephemeral rivers in the north-centre and large scale burn scars in the South West of Botswana. It appears that both heavy grazing close to rivers which are prone to flood and repeated burning serve to prevent natural vegetation cover regrowth over time and thereby induce environmental change.

Stage 2

Stage 2 of the project involved the *production of a digital image map* (based on three band Thematic Mapper imagery) *using image processing techniques to depict more closely specific areas of degradation*. Image processing was undertaken to transform the original three band image into a thematically mapped product. Such processing techniques enable the user to manipulate pixel values in the individual bands so that specific aspects of the imagery can be enhanced (e.g. Jensen, 1989). In this case image processing included haze correction, to try and minimise variation in illumination (or brightness) of the pixels across the mosaiced images and supervised classification. Steps in the supervised classification process ensured that specific training areas (with known pixel values and field based attributes) were used to identify similar pixel areas across an image.

This is a process whereby individual band data are computer manipulated using known training sites to produce maps on a specific theme. For this a mosaiced digital image comprising forty full and sub-scenes were acquired. This produced a 800 Mb image file.

Although the definitions of bare soil degraded areas were the same as for the visual analysis (Stage 1) in the case of the digital classification, three “degraded” area classes were generated because of the greater degree of detail inherent in the digital products. In the digital imagery, bare soil areas which were believed to be potentially degraded were more readily identified as were naturally occurring bare soil areas, for instance, the Makgadikgadi Pans.

Between these two were areas which may or may not be naturally occurring or which may or may not respond favourably following rains. These were

ascribed to a partial potentially degraded category on the classified image. A further aspect of degradation which was more visible on the enlarged digital product was the occurrence of possible bush encroached areas. These three categories of potential environmental change were mapped and their extents quantified for the entire country over the 1994/5 wet season, giving totals of:

1. Bare soil-potentially degraded areas 28 592km² (4.9% of Botswana)
2. Partial potentially degraded areas 35 159km² (6.1% of Botswana)
3. Possible bush encroached areas 37 141km² (6.4% of Botswana)

These results were substantially in agreement with those found during the visual interpretation exercise for 1994/5 but have the advantage of being more specific with respect to locations which have changed indegraded and of including areas which are apparently bush encroached. Disadvantages include a *lack of adjustment in illumination over successive orbits in the whole country mosaic which vary in their timing of acquisition by several weeks*. Areas which apparently had undergone negative environmental change included the eroded areas adjacent to the ephemeral eastern rivers, mentioned above and also specific areas in the Kalahari which appear to be either heavily grazed, burned or cleared under various government food security programmes.

As indicated major aspects of environmental change include changes which have led to the increase in bare soil areas but additional changes are known to have led to the development of woody weeds or bush encroachment. In an attempt to determine more about the causes of such changes more detailed work was conducted in the vicinity of boreholes (cattle posts) and settlements in the southern Kalahari area (Ringrose et al, 1996). This work indicated that a large proportion of the bare soil areas were found within a 4 km radius of the major villages (Figure 3) and most of the woody weed areas were found close to cattle posts. In another study in northern Botswana it was determined that the development of fences also leads to the development of bare soil degraded areas, especially where these cut off the migration routes of wildlife (Ringrose et al., 1997, in press). Most of these changes may be described as human induced either directly as a result of clearing or tree felling activities for firewood/construction or indirectly as a result of livestock/smallstock grazing and the erection of fences.

Conclusion

Although more detailed imagery is now available often satellite imagery can only be used to identify point sources of, say, atmospheric pollution.

Problems arise when pollutants are absorbed into the oceans or soil cover as these tend to be less visible when optical sensors are used. However if the pollutants change the colour of lakes or rivers then optical sensors are more effective. Also there are cases recorded where toxic substances in soils significantly alter the growth patterns of the vegetation cover and so their presence can be detected through the vegetation. The commonly used optical imagery (e.g. Thematic Mapper imagery) can be used for monitoring vegetation change because of the repeat cycles of the Landsat series of satellites.

An example given from Botswana has shown how TM imagery has been used to map the increase in bare soil area (range degradation) in an attempt to locate problem areas and thereby assist in Botswana's efforts to combat drought and desertification.

Acknowledgments

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CHAPTER 9

MAKING THE TRANSITION TO A MANAGED DISTRIBUTED INFORMATION NETWORK ARCHITECTURE: A WASTE MANAGEMENT NETWORK

Rogers W'O Okot-Uma
Commonwealth Secretariat
Marlborough House
Pall Mall, London SW1Y 5HX
Tel:+44 171 747 6339 Fax:+44 171 747 6335
Email:r.okot-uma@commonwealth.int

Making the Transition to a Distributed Waste Management Information Network: *A Systems Development Framework*

Introduction

Information is an essential commodity in any attempt that seeks contain contextual environmental problems and find new ways of managing limited resources. Diverse interests and perspectives often interpret the same data in radically different ways. For a potential user-base comprising a network of countries, the necessity arises, therefore, to present information in a data mode that is un-ambiguous, consistent and in a consensual common format. The potential contribution which a rapid transition to an information-based society can make to sustainable development cannot be over-emphasised. Making the transition to a distributed waste management network provides a systems development framework within which countries near or far and wide apart can share waste management information and best practices between and within themselves. The contribution which information and communication technologies (ICTs) can make with regard to the enhancement of waste management is deployed within the context a managed network topology based on the use of the Internet and its medium the world wide web (WWW). The article is amenable to re-use for design of similar information networks based on the managed network architecture principle.

Common environmental issues are the result of direct and indirect physical, chemical and biological pressures exerted on the environment by activities of anthropogenic origin, for the purpose of economic development. Environmental policy development is the identification of environmental concerns and agreement of solutions within various contexts and stakeholders. Sustainable development policies seek to strike a balance between economic, social and environmental goals or “securities”. Key challenges in any attempt to develop an information system to support decision-making and management pertain to an understanding of a number of questions. With regard to waste management, answers to such questions may be perceived to form the essence of the basis for a systems development framework for a Distributed Waste Management Information Network (Waste_Net). This is depicted in Figure 9.1 (see pp 120).

FIGURE 1:

1 Establishing Requirements

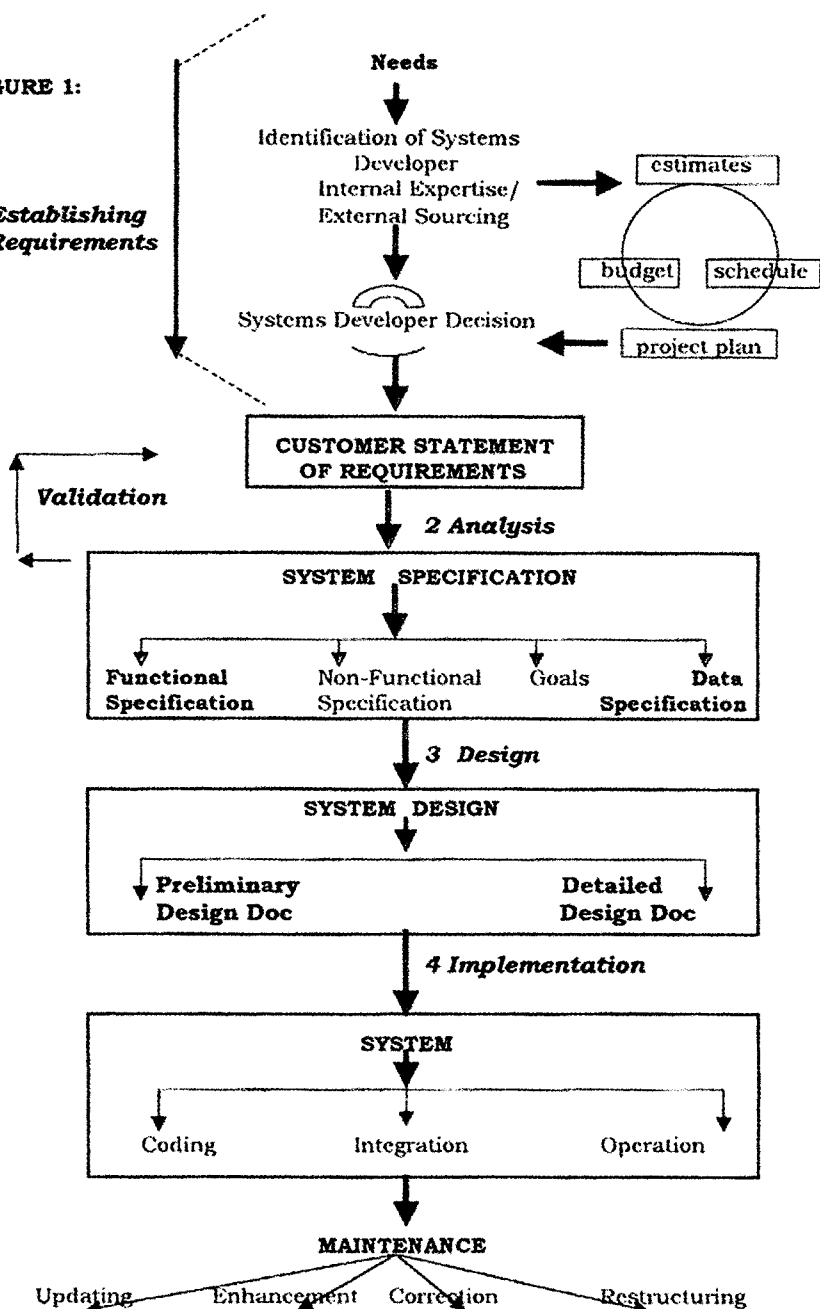


Fig. 9.1 A SYSTEMS DEVELOPMENT LIFE CYCLE

Information Needs Analysis

Information Needs Analysis with regard to Waste Management will comprise that process whereby the *needs of stakeholders* - expressed in a variety of ways, namely, narrow, broad, technical or bureaucratic, are guided into a consistent, mutually agreed, set of information objectives on waste management. It focuses on a series of basic questions concerning waste management information usage, hence defining the context for the intended waste management information network:

Information needs analysis is an important early state in the systems development life-cycle, during which methods of collaboration between *providers and users* are established. It is proposed that such analysis is conducted in a consultative, inclusive manner, if benefits of various kinds are to accrue, which are of practical value, such as the following:

- ☐ Cost-effectiveness;
- ☐ Efficiency; and
- ☐ Strategic alliance and partnership.

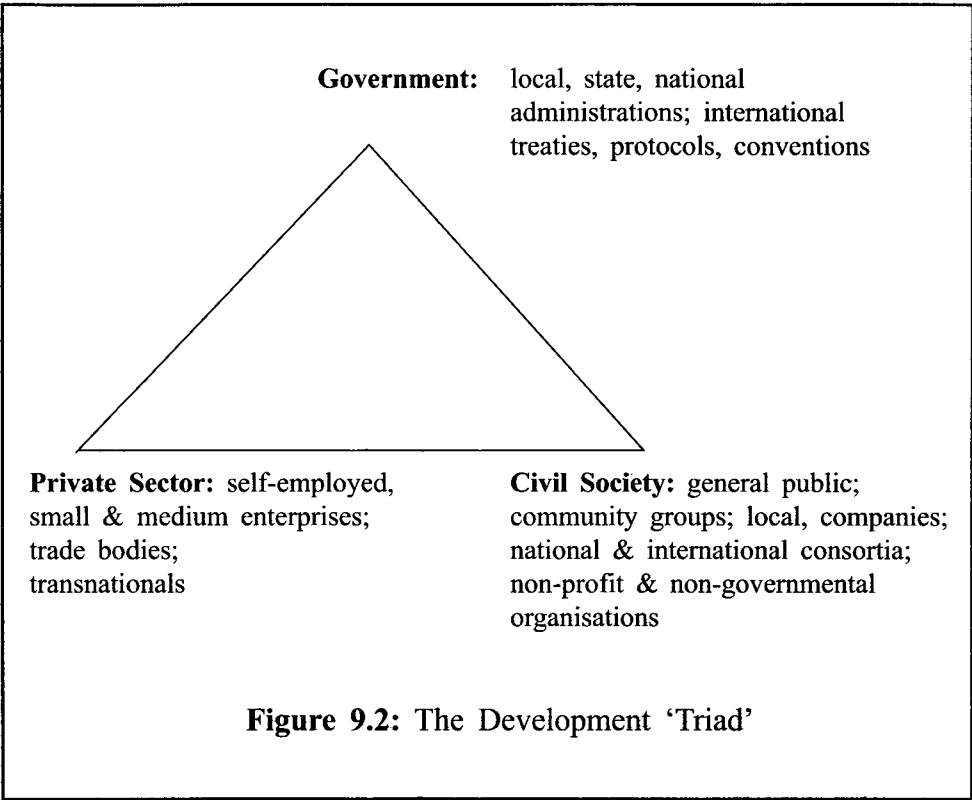
An indication of the importance of information needs analysis may take up to 80% of the start-up phase (Richardson, 1994).

(a) Policy Analysis Questions

- ☐ What are the main goals with respect to the need for a waste management information network?
- ☐ Who are the stakeholders or intended users for the proposed system?
- ☐ How do the stakeholders currently make use of waste management information?
- ☐ What are the broad constraints that may affect the use of the proposed waste management system?
- ☐ What plans, legislation and regulations might affect the development and use of a waste management information network?
- ☐ Over what time-scale is the information content of the network needed?
- ☐ How often will the information network be used?

It is conceivable to note that for the case of the proposed system, the

stakeholders will be a *subset* of the categories formed by government, private sector and civic society which, together, may be referred to as the Development ‘Triad’ (Sandbrook, 1994). This depicted in Figure 9.2.



(b) Policy Support Mechanisms

The next step towards addressing the issue under consideration is for stakeholders to *integrate their various needs and perspectives into a common vision*. This may not suit all stakeholders perfectly, but the aim is to find a solution to the issue which combines as many social, economic and ecological demands as is feasible, given the diversity of perspectives. A key element of this process is *consultation and consensus-building*, which can be structured using a number **tools** and **methods** and facilitated by objective concerns. Structured approaches include Questionnaires and Interviews. Group Approaches include Stakeholder Analysis, Visioning Exercises, Brainstorming, Problem tree Analysis, Working Groups and Workshops.

The aim of a **Stakeholder Analysis** is to determine which groups are most relevant to an issue, policy or project. Inviting too many stakeholders to participate in the process of consensus-building can lead to high overall costs, prolonged consultation periods, introduction of extraneous issues and the

possibility of conflicts arising. Inviting too few stakeholders could imply that some groups have been overlooked or excluded, leading to resentment and increased likelihood of non co-operation. Whatever choice is made, it is important that the project is perceived to be owned by the stakeholders. **Problem Tree Analysis** is a useful method for enhancing problem definition so that strategies can be formulated to address their underlying causes. A fragment of problem tree analysis is depicted in Figure 9.3 below for waste management.

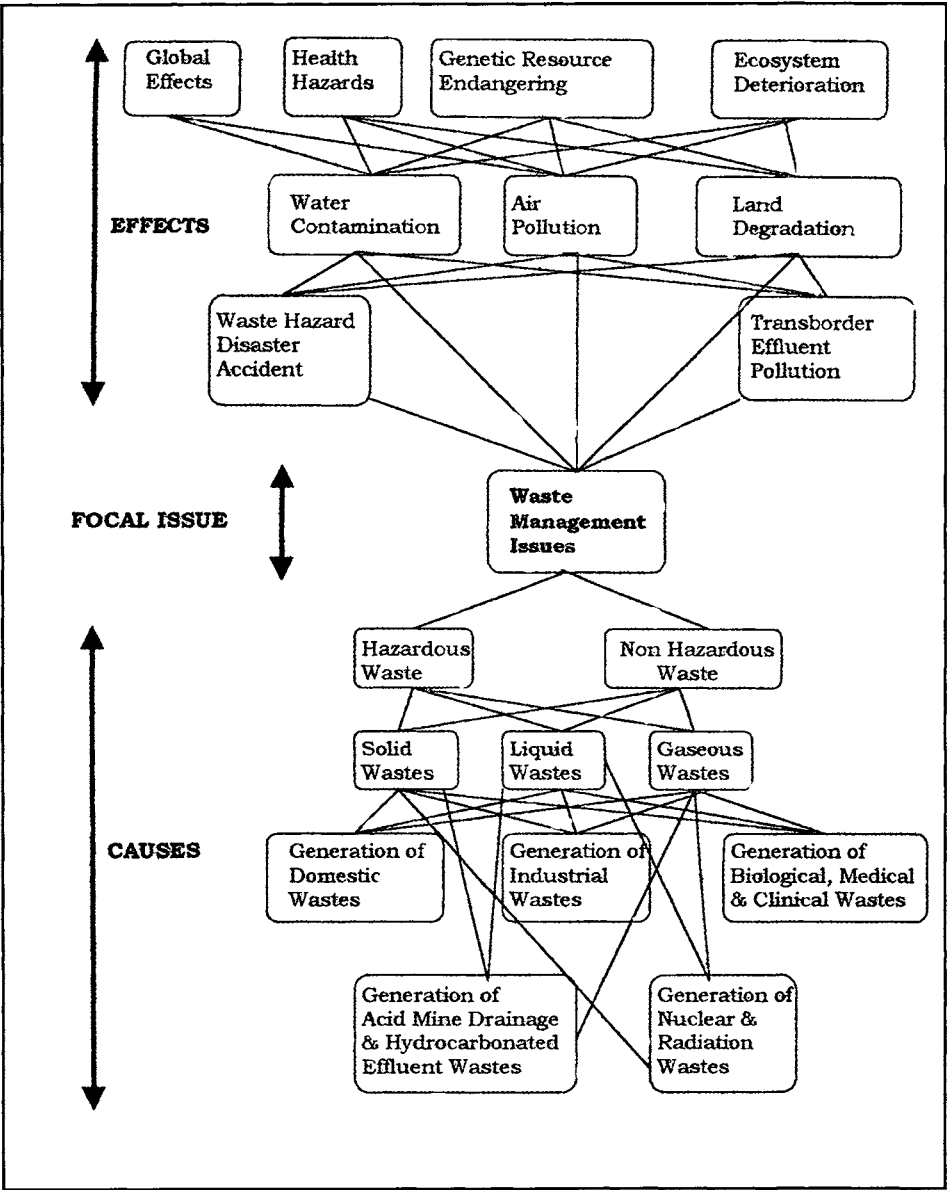


Figure 9.3: Problem Tree Analysis for Waste Management

Customer Statement of Requirements

The **Customer Statement of Requirements Phase** pertains to what specific information under the broad area of waste management is *required* by whom and in what form to enable stakeholders to confirm their consensual disposition with regard to the proposed Waste Management Information Network. Customer Statements of Requirements will *provide an informal description of the properties of the proposed information network, written in natural language and expressed in terms of application terms rather than computing terms*. Essentially, the content of the Customer Statement of Requirements will detail an identification of the required purpose of the system as perceived by *the customer*.

A fragment of the Customer Statement of Requirements might state as follows:

- ☐ The system should enable *country profile data* on WorkGroup members to be inputted, stored, searched and outputted;
- ☐ The system should enable *specific information on members of the WorkGroup* to be searched on a country by country basis;
- ☐ The system should enable *country profile data* on WorkGroup members to be accessed in either a *centralised database* at one specific physical location or a *distributed database* at geographically disparate locations;

System Specification

Systems Specification represents a *description of the characteristics of the proposed system as perceived by the systems developer*. The only way to check that requirements analysis has been carried out correctly is by asking the customer to check the systems specification against the customer's statement of requirements.

System specification should be partitioned to include both Horizontal and Vertical Partitionality:

(a) **Horizontal Partitionality** refers to the the separation of system specification into the following component:

- ☐ Functional Specifications.
- ☐ Non-Functional Requirements.
- ☐ Data Requirements.

Goals

Functional Specifications pertain to WHAT the system is expected to do and not HOW the system should carry out a function. As an illustrative fragment of a functional specification, it is conceivable that the proposed system should be able to do the following:

☐ **Define a Country Profile Format for Waste Management:**

- ☐ Eco-Development Data Summary.
- ☐ Environmental Organisational Framework.
- ☐ Environmental National Strategy.
- ☐ National Accession to Environmental Conventions and Protocols.
- ☐ Waste Profile Classification by Sector
- ☐ Legal Instruments for Waste Management.
- ☐ National Quality Standards for Air and Drinking Water.
- ☐ Summary of Documented Impact Studies.
- ☐ Summary of Documented Good Practices in Waste Mitigation and Disposal.
- ☐ Summary of Documented Good Practices in Specific Areas of Waste Management.
- ☐ Examples of Successful Government-Private Sector Partnership Projects in Waste Management.
- ☐ Examples of documented Disaster Preparedness Guidelines in the Event of Specific Hazard Waste Accidents.

☐ **Search and Display by Country:**

- ☐ Summary of waste management policy, policy principles and national strategy, whether explicit, implicit or non-existent;
- ☐ Listing of organisational and institutional frameworks with functional responsibilities for waste management;
- ☐ Summary of *waste management legal instruments*;
- ☐ Summary of *waste classification listing* by the following categories:
 - (a) solid, liquid, and gaseous wastes;
 - (b) hazardous solid, hazardous liquid, hazardous gaseous wastes;
 - (c) industrial, biomedical/clinical, nuclear/radiation wastes;
 - (d) mining wastes.

- ❑ Summary of *national quality standards* with regard to the following;
 - (a) Air;
 - (b) Drinking water;
 - (c) Agricultural water

- ❑ Summary of *waste impact studies* on:
 - (a) air, soil and water quality;
 - (b) flora, fauna, habitats and ecosystems;
 - (c) agricultural and forestry resource.

- ❑ Summary of proven good practices in waste mitigation and disposal technologies deployed in specific wastes in the following categories:
 - (a) waste avoidance;
 - (b) waste reduction;
 - (c) waste recycling/reuse;
 - (d) waste treatment; and
 - (e) waste disposal.

- ❑ Summary of proven good practices in waste treatment and disposal wastes in the following categories:
 - (a) solid waste;
 - (b) liquid waste;
 - (c) biomedical/clinical waste; and
 - (d) hazardous waste.

- ❑ Summary of Case Studies and Best Practices in various areas of waste management, including the following:
 - (a) EIA for sanitary fills;
 - (b) Health EIA for personnel exposed to named occupational hazardous wastes;
 - (c) Landfill practices;
 - (d) Biomedical waste disposal;
 - (e) Nuclear waste treatment, containment and disposal; and
 - (f) Scavenging.

- ❑ Summary of Waste-related Conventions and Protocols to which a country is signatory.

- ❑ Examples of Government-Private Sector partnership in waste management.

- ❑ Examples of Good Codes of Practices in the event of a hazardous waste accident *in-situ* or in transit.

Non-Functional Requirements

As well as statements of function, a customer statement of requirements will contain Non-Functional Requirements.

- ❑ In the fragment of customer statement of requirements above there is the **design and/or implementation directive** that the future system should conform one of the following network topology options:
 - (i) **Centralised Network architecture**, in which the information systems located in one, central location, with nodes (partners) supporting this as necessary. Here the central node may be perceived as controlling access to data and information products, thus providing difficulties to establish a 'co-operative' spirit.
 - (ii) **Fully-Distributed Network architecture**, in which nodes (partners) operate in an unrestricted environment, communication is encouraged between all parties, and no attempt is made to co-ordinate or control the partnerships. Here the information is spread across all network nodes, namely, the network is the system, nodes are not co-ordinated or provided with direction, resulting in possible duplication of effort, lack of agreed standards and generally impeded progress towards common information objectives.
 - (iii) **Managed Network architecture**, in which nodes (partners) communicate free between themselves but co-ordination and other network services is provided through a 'hub' which serves the collective interests of all network partners rather than the specific interest of a single node.

A managed network architecture topology may be selected for ease of co-ordination and collective integration.

- ❑ The necessity to realise a distributed architecture in which partners of the network are located in different countries, points to the need to develop a system that conforms to a designated method of delivery, namely, one which is Internet-based and which makes use of the expedience and the potential of the World Wide Web (WWW).
- ❑ The choice to develop WASTE_Net on the Internet and the World Wide Web in itself leads to **Hardware and Software constraints** in relation to the pertinent information and communication technologies (ICTs). To be able to participate in the project, access to the Internet and the World Wide Web will be desirable with certain minimal requirements:

PC Requirements

At least a 486 DX66 IBM-compatible PC, equipped with 16 MB RAM to get either Internet Explorer or Netscape to function under Windows 95/98/3.x, and 24-32 MB to run other programs at the same time.

Windows NT versions demand at least 32 MB of RAM: depending on which optional components are desired for installation. Netscape 4.x requires between 18 and 30 MB of hard disk space, and Internet Explorer 4.x and 5.x, between 40 and 80 MB.

Windows 2000, which incorporates Internet Explorer 5, demands at least Pentium 133, with 64 MB of RAM.

Mac Requirements

A **PowerPC processor** is desirable for running Internet Explorer 4.5, Netscape Communicator 4.7x, and later versions of both. Internet Explorer 4.5 and 5.x will run on **MacOS 7.5.3 or later**, and 12 MB of RAM. Netscape 4.7x requires 16 MB of RAM if running **MacOS 7.6.1**, and 24 MB of RAM, for MacOS 8.0 or greater.

Other PCs

For older machines running Windows 3.1, a best choice for the browser is **Internet Explorer 3.03**. It can function on a 4 MB of RAM and as little as 7 MB of disk space for a browser-only installation, plus it also includes the TCP/IP dialling software that Windows 3.1 omits.

The Mac equivalent also requires somewhat less RAM and disk space than its successor. If that's still heavy, **Netscape 2.0x** is better than no browser at all.

Alternatively, one may investigate the less known but distinctly impressive **Opera** (<http://www.opera.com>). This packs a browser, mail sender, and newsreader into couple of MB.

You will find every browser ever released across all platforms for free download at: <http://browsers.evolt.org>.

For the implementation of WASTE_Net, **no timing, schedule or budget** constraints have been stated. In practice, statements about these parameters would form part and parcel of the non-functional requirements. A statement that the proposed system will contain a specific content also forms part of the non-functional requirements whilst content stated in a functional form would form part of the functional specification.

Goals

Goals relate to statements which guide the systems developer or systems designer where *choice or degree of freedom* exists. For WASTE_Net, it may be assumed that there are no restrictions with regard to the following:

- ☐ Choice of programming language, standard or protocol;
- ☐ Deadline, timing or schedule for delivery of system; and
- ☐ Budget for the implementation of the system.

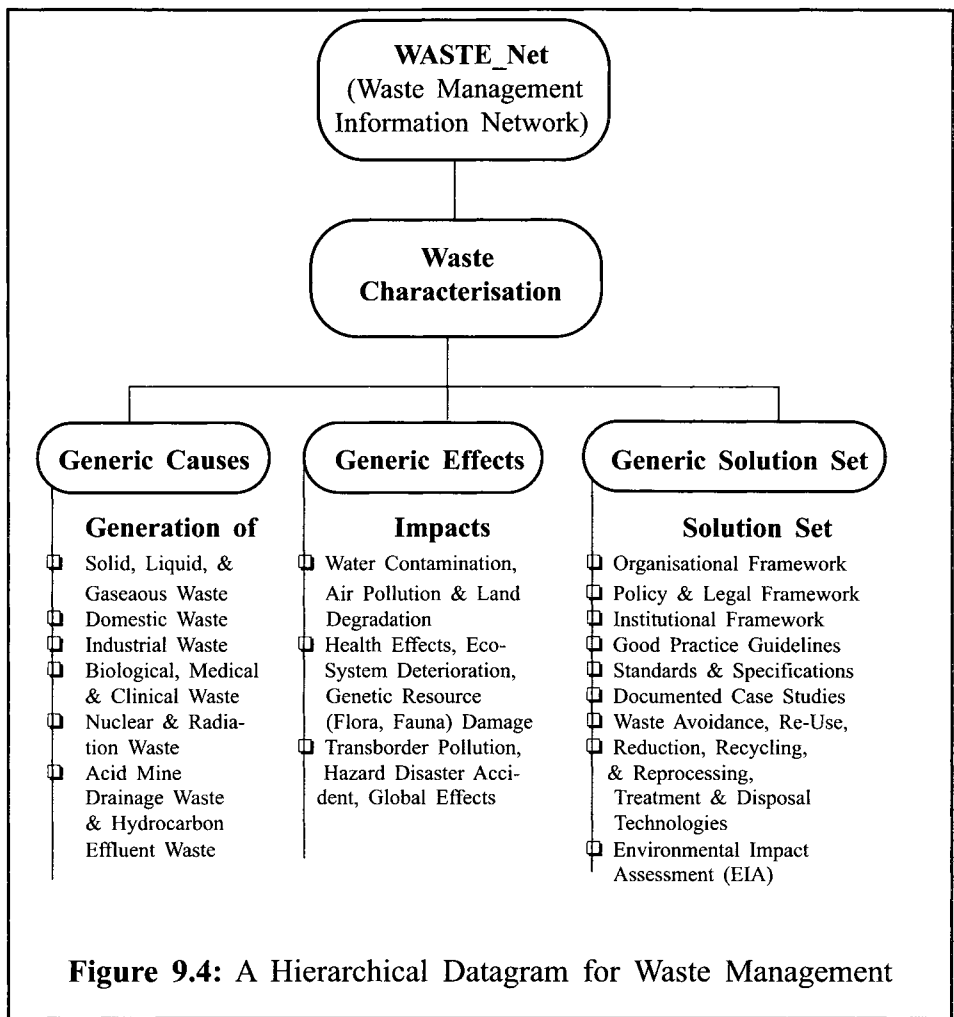
Data Requirements

A statement of requirements may contain references to data used by the proposed system., such as the following:

- ☐ Statement on data structure of pertinent database sub-systems; and
- ☐ Statement on format of report forms.

For WASTE_Net, the data structure will comprise a combination of standard dataset formats inherent in Web documents: textual, tabular, graphical and photographic.

(b) **Vertical Partitionality** represents the system specification into a series of levels of abstraction. Each level corresponds to a level of abstraction in the statement of requirements. This enables the specification to be examined by various interests at different levels of the development team.



Implementation

Vertical partitionality with regard to datasets for WASTE_Net may be represented in the hierarchical datagram above (FIGURE 9.4).

(a) System Design

WASTE_Net will comprise a distributed database on the World Wide Web, with a managed network topology. HyperText Mark-Up Language (HTML), with its complement of hyperlink facilities and multimedia capability, will be used as the “programming” language.

As a response to the fragment of functional specification provided above, a corresponding fragment of HTML code can be evolved, which sets up a Home page for WASTE_Net, with sample information for a Hypothetical Sample Country Profile on Waste Management, and with hypertext linkages to Country Members of WASTE_Net.

(b) *Integration*

For a managed network, integration would comprise hyperlink pointers to corresponding Website addresses of the WASTE_Net membership in the different countries. For the purpose of this article, hyperlink pointers will be limited to country profiles within a single hypertext document.

(c) *Operation*

Operation of WASTE_Net will be demonstrated on the basis of the fragment of functional specifications given above. Such a prototype should be able to provide a systems developer with good potential for expansion to include multimedia components of diverse kinds including diagrams, pictures, sounds and even animation.

(d) *Maintenance*

Maintenance involves enhancement, adaptation and updating of various attributes of a system. WASTE_Net, like any other hypertext database on the Internet and the World Wide Web, will need to be maintained at periodic intervals in order for the currency of the information therein to remain truly timely. The imperative for timely maintenance makes the choice of a managed network architecture for WASTE_Net the more significant.

Conclusion

WASTE_Net as presented in this article is exemplary of the principles of systems development in the implementation of an information network for intra- or inter-collaboration among countries on an area of common interest such as waste management. It can be used by both the professional and the neophyte alike in initially building a pilot information network of their choice.

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CHAPTER 10

THE IMPACT OF POLLUTANTS ON SOILS AND AIR QUALITY

Otlogetswe Totolo

Department of Environmental Science

University of Botswana

Private bag 00704

Gaborone, Botswana.

Phone: 267-3552524 Fax: 267-356591

E-mail: totoloo@noka.ub.bw

The Impact of Pollutants on Soils and Air Quality

Introduction

Developing countries rely mostly on their soil resources to sustain livelihoods of their populations. *Because of their ever-increasing populations, enormous pressure is exerted on soils and other resources, which result with their use beyond sustainable levels. Waste products are also generated and in most cases are not properly disposed and they end up reducing the quality of both soil and air resources.*

Soil and air pollution studies have received a lot of attention more especially in developing countries where pollutants have been produced over a long period of time. Pollutants were produced as by-products of processes that sustained the activities of the human race. Hazardous waste, which was produced from industries as well as agricultural enterprises, found its way to either soil, air or water resources. This behaviour continued unabated for quite some time until human health and productivity of the soil resources was seriously impaired. Soil and air quality issues have now spread to developing countries where some still use technologies that are old-fashioned and not so environmentally friendly.

This chapter *examines different soil and air pollutants and how they affect the quality of such resources. The sources of this hazardous waste are identified and possible redemption measures are also suggested.* Examples from Botswana as well as other countries on soil and air pollution are used in the chapter.

Impacts of Pollutants on Soils and Air Quality

Hazardous waste is *solid waste that causes harm because of its quantity, concentration, or physical, chemical or infectious characteristics.* Hazardous substances can be present as contaminants in soil and fill materials; as components of buildings or structures; as wastes deposited in the ground, in tanks or pipes; as substances used or produced during the reclamation works; or as contaminants in surface or groundwater.

Physical and chemical soil properties determine soil quality. **Physical properties** such as bulk density and texture influence aeration, permeability, infiltrability, and other attributes such as water-holding capacity or constructive properties can be quantified and related to quality. **Chemical properties** are

the concentrations of organic and inorganic constituents that determine characteristics such as soil fertility, biological activity, degree of pollution, salinity, corrosiveness, or shrink-swell potential and are also quantifiable and related to soil quality.

The ability of a soil to produce quality food, fibre, or feed refers to the contribution the soil makes to the capacity of a site to have profitable production of crops that are free of harmful substances. The site quality would then include a desirable combination of soil characteristics (including low concentrations of pollutants), climate and available water. Where pollutants are disposed to the ground without necessary precautions as, for example, indiscriminate dumping of waste, such activities will tend to lead to soil as well as surface and groundwater pollution. This, for example, requires that authorities have to pay special attention to the construction of sanitary landfills as opposed to ordinary dumping which result in contamination of both soils and water resources.

Types of Pollutants

There are a number of pollutants that have been identified, which affect soils, water and air quality. Some of these are discussed below.

Nutrients

This category primarily reflects the negative impacts of Nitrogen and Phosphorous when present at relatively high concentrations. *The presence of Phosphorous in surface water and nitrates in surface- and ground- water are the main indicators of environmental contamination of soil.* Agricultural production practices are responsible for a fair share of the problems associated with excessive nutrients. Significant contributions are also made from private home and horticultural uses of fertilisers, naturally-occurring sources, sewage treatment facilities, septic tanks, food processing plants, and livestock.

Pesticides

Pesticides represent a wide range of mostly organically based chemicals used to control pests such as weeds, insects, rodents, or plant pathogens. Once again agricultural production practices account for the majority of pesticide use, with private home and horticultural uses also being significant. Pesticides are normally released intentionally into the environment at low levels, although accidental spills involving large quantities or high concentrations do occur.

Hazardous Substances

Hazardous substances comprise the broadest category of all. It is a catch-all term that basically *includes materials that are acutely or chronically toxic to*

humans and other organisms when improperly administered, used, or disposed of. Many of the hazardous substances are organic compounds with properties analogous to pesticides. However, hazardous substances are generally not intentionally released into the environment; and soil contamination problems usually involve improper use, disposal, or accidental spills over small areas with high concentrations of the chemical in question.

Acidification

This category of pollutants, comprising **acidification**, includes several unrelated processes. **Acid precipitation** *is mainly the end result of conversion of the oxides of N and S into their respective acids in the atmosphere.* The concern is with the precipitation having a lower than normal pH and its impact on the environment. **Acid mine drainage** represents another source of acidification where water has been acidified by the weathering and oxidation of sulphide materials, primarily pyrite (FeS₂). Such water can have pH as low as 2.0 and can have significant impacts on soil or surface water systems.

Salinity and Sodicty

Salinity and sodicty are primarily characterised by *reductions in plant productivity due to water stress caused by the increased osmotic potential and changes in physical properties (dispersion with a resultant reduction in permeability) when salt or sodium concentrations in soils become too high.* Irrigation with water containing high salt concentrations or a high level of sodium relative to Calcium and Magnesium are the chief causes of these problems. Runoff from roads de-iced with sodium chloride onto roadside soils is another lesser source of salinity and sodicty.

Trace Elements

Trace elements *are elements that are normally present in relatively low concentrations in soils or plants.* They may be essential for growth and development of humans or other organisms, although many are not. Trace elements of concern as pollutants are those that cause acute or chronic health problems in humans, animals, plants, or aquatic organisms when present in above-critical threshold concentrations.

Sediments

Sediments *represent soil particles that have been eroded from the landscape and have been carried to surface waters.* Areas most susceptible to sediment-generating erosion include construction sites, recently tilled farmland, or overgrazed pastures. Sediments can physically block light transmission through water which can, in turn: (i) alter the ecology of the body of water; and/or (ii)

can be enriched in Phosphorous, which can accelerate eutrophication, and can act as sources or sinks for a variety of water pollutants. Sediments can also accumulate in surface waters, thus inhibiting navigation and recreation activities and reducing the longevity of darn structures.

Particulate, Greenhouse Gases and Smog-forming Compounds

Particulate matter *is relatively inert particles generally consisting of carbon, soil, volcanic ash etc. suspended in the atmosphere.* **Greenhouse gases** are the gases responsible for the greenhouse effect. *The greenhouse effect refers to an apparent increase in the concentration of various gases in the atmosphere - primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons - that make it more difficult for radiated heat to escape the atmosphere, hence resulting in an increase in the mean global temperature above that existing without the influence of man.* Some greenhouse gases are manmade and others are naturally occurring, although their concentrations are increasing in the atmosphere due to human activities

Air Quality

Introduction

Air is a mixture of gases in defined proportions that can be changed as a result of pollution. **Atmospheric pollution** *involves the addition (or, theoretically, subtraction) of particles, gases or energy forms such as heat, radiation or noise so that the altered atmosphere is less useful to mankind or poses some harm because of its impact on weather, climate, human health, animals, vegetation and materials* (Godish, 1991). The concept of pollution entails a sense of degradation, a loss of quality, and adverse environmental effects whether it is applied to the air, water, or land.

Historically, air pollution concerns have been associated with ambient air and with the freely moving air of the outdoor environment. As a consequence, control programmes focus on ambient air pollution. However, air pollution is not just limited to the outdoor environment. Significant pollution can occur in occupational environments, in the built environment of our homes and offices and in personal habits such as smoking.

Air Pollution

Air that is polluted is defined as *air that contains one or more chemicals in high enough concentration to harm human beings, other animals, vegetation or materials* (Miller, 1996).

There are two generic types of air pollutants, namely, primary air pollutants and secondary air pollutants. **Primary air pollutants** are *chemicals that are added directly to the atmosphere in above normal concentrations*. Examples include the emission of carbon dioxide by industrial manufacturing processes, leading to a rise above normal concentrations in the atmosphere. Another example is the emission of lead from car exhausts resulting from petrol combustion. **Secondary air pollutants** are harmful chemical substances formed in the atmosphere through chemical reactions amongst air components.

Air pollution is undesirable in the environment because it has some negative impacts like corrosion of paint; buildings, statues and it could also damage trees and crops.

Air As a Finite Resource

Clean air is essential to the existence of all living things including human beings. On average, each human being requires about 14kg of air per day to satisfy basic physiological (including respiratory) requirements. The atmosphere is made up of different layers and about 95% of the air is in the troposphere. Most air pollutants are added to the troposphere where they are mixed vertically and horizontally by air currents. The composition of air varies according to the location. In general, percentages of carbon dioxide and water vapour vary but the other percentages remain relatively constant.

Effects of Air Pollution on Living Organisms and Materials

Damage to Human Health

The human respiratory system has a number of mechanisms to protect individuals from air pollution. Mucus and cilia are the main structures responsible for the protection of organisms from pollution.

Many years of exposure to smoking and air pollutants can destroy these defence mechanisms leading to lung cancer, chronic bronchitis and emphysema. Elderly people, infants, pregnant women, and people with heart disease, asthma, or other respiratory diseases are especially vulnerable to air pollution (Miller, 1996).

Damage to Plants

Air pollutants have negative impacts on the growth and productivity of plants. **Secondary air pollutants** in particular, when they fall down with rain, are capable of removing chlorophyll from vegetation, thus leaving vegetation

yellowish in colour. Vegetation without chlorophyll will not be able to photosynthesise and this has a tendency to affect vegetation growth and productivity. Air pollutants are also responsible for removing wax, which reduces evapotranspiration from vegetation leaves. With removal of wax from their leaves, vegetation loses a lot of water that affects the normal functioning of trees.

Major Classes of Air Pollutants

Carbon oxides	Carbon monoxide, Carbon dioxide.
Sulphur oxide	Sulphur dioxide, Sulphur trioxide.
Nitrogen oxides	Nitric oxide, Nitrogen dioxide, Nitrous oxide.
Volatile organic compounds	Methane, Propane, Benzene, Chlorofluorocarbons (CFCs).
Suspended particles	Solid particles (dust, soot, asbestos, lead, nitrate and sulphate salts), liquid droplets (sulphuric acid, PCBs, dioxins, pesticides).
Photochemical oxidants	Ozone, Peroxyacyl nitrates (PANs), Hydrogen peroxide (H ₂ O ₂), Aldehydes.
Radioactive substances	Radon-222, Iodine-131, Strontium-90, Plutonium-239, emissions from fossil fuel and nuclear power plants.
Other inorganic compounds	Asbestos, hydrogen fluoride (HF), hydrogen sulphide, Ammonia, Sulphuric acid, Nitric acid.
Other organic compounds	Pesticides, Herbicides, Various alcohols and acids.

Table 10.1: Major Classes of Air Pollutants (*Source:* Miller, 1996)

Plants could also be damaged when air pollutants directly block the pores of leaves. The impact of this damage is generally noticed after a long period of time. By then, the process cannot be reversed and so much damage has been done. This problem is not so severe in developing countries as compared with the situation prevailing in the more developed countries with a long history of industrialisation. Severe damage to vegetation as a result of air pollutants has

been reported in both Europe and North America. According to Miller (1996), in 1991, the seven European countries with the highest percentages of coniferous forest damage were Great Britain (57%), Poland (45%), Czechoslovakia (41%), Denmark (30%), Portugal (30%), Russia (26%), and Germany (25%).

Damage to Aquatic Life

When it rains, a lot of air pollutants are brought back to the ground. Running water to ponds, lakes and other water bodies will tend to transport these air pollutants. The receiving water bodies will, more often than not, suddenly become inundated with a milieu of chemical waste that changes their natural set-up. The result of all this is negative impact on aquatic life. Most lakes in Europe and North America are dead as a result of pollution.

Damage to Materials

Air pollutants are responsible for damage for a number of structures. The fallout of soot on buildings, cars and clothing requires costly cleaning. Air pollutants break down exterior paint on cars and houses, and they deteriorate roofing materials. Irreplaceable marble statues, historic buildings, and stained-glass windows around the world have been pitted, gouged, and discoloured by air pollutants.

Possible Solutions to Preventing and Reducing Air and Soil Pollution

Soil and air quality can be improved if in the first instance fewer pollutants are released into the environment. This can be achieved by setting standards that have to be adhered by individuals, companies and industries. Most of the waste products could be recycled and reused in order to reduce the volume of waste material which will eventually find its way to soil, water and air resources causing pollution.

Governments should have clear guidelines on how to dispose different types of waste. The type of waste industries are likely to produce have to be known well in advance before securing a licence of operation. Once the waste products likely to be generated are known then, a monitoring system has to be put in place in order to ensure that set standards are adhered to. All this will require countries to set ministries or departments for the environment.

Before setting up landfills thorough investigations have to be undertaken to

ensure that the structure will not pose any risk to both soil and water resources. Vehicles should constantly be monitored for the type and amount of gases they produce and this must be done on a regular basis.

Information on air and soil quality in developing countries is very scarce and therefore this is a challenge to developing countries scientists to generate information on this subject in order to advance the noble goals of sustainable development which embrace sensible use of our resources.

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CHAPTER 11

AIR POLLUTION CONTROL

C J Matale

**Department Of Mines
Private Bag 0049
Gaborone, Botswana**

Phone: 352641 Fax: 352141

Air Pollution Control

Introduction

Most of anthropogenic activities generate contaminants that pollute the air with potential adverse effects on human health and the environment. To overcome this problem appropriate air pollution control measures have to be developed and implemented. This Chapter gives a general overview of air pollution control from industrial sources.

The setting of standards as provided by appropriate legislation and the administrative processes achieving those targets are briefly discussed. Selected desulphurisation methods are given as examples of sulphur dioxide reduction from coal-fired power station. The reduction of nitrogen oxides also discussed.

General Overview

The economy of most nations around the globe is dependent on the use of fossil fuels and/or the exploitation of mineral resources. These activities create air pollution problems that have potential adverse effects on humans and the environment.

Studies have shown that people living in polluted air are likely to contract certain diseases as compared to those living in clean air conditions. Air Pollution has been linked to lung cancer and other respiratory diseases. Asthmatics are known to have their problems aggravated by exposure to low levels of certain air pollutants.

The *weathering* of stone wall and *corrosion* of metals by acid deposition is another example of how air pollution can damage property. Adverse effects of *acid rain on forest and aquatic life* has been documented in North America and Europe. The *major precursor of acid rain is sulphur dioxide emissions* from the combustion of fossil fuels. It is therefore *important to control air pollution for the protection of human health and the environment.*

This Chapter gives *an overview of controlling air pollution from industrial sources.* It briefly describes the regulatory and technological aspects of air pollution control. It should be pointed out that air pollution control technology is quite expensive and is often economic to install on big plants. A precaution should also be taken that an air pollution is not transformed into another problem that might even be more detrimental to the environment.

Controlling Air Pollution

Strategies

Efforts to control air pollution can only be meaningful under the provisions of an appropriate legislation and policies. Legislation forms a basis for the establishment of an air pollution regulatory agency. This agency would then be responsible for development and implementation of air pollution control programmes which will include among other things, the following key issues:

- i) Standard Setting;
- ii) Compliance Enforcement and Monitoring; and
- iii) Environmental Evaluation Process.

Standards

The regulated community needs to know exactly what is required of them by the regulatory agency. This need is best met by *setting air pollution standards*. The standards may be *generalised to apply to categories of similar facilities* or it may be *in the form of guidelines* that will be used by the regulatory agency how to develop and apply the standards to individual industry on case-by-case basis. This is usually achieved through a permitting process.

Botswana uses this approach. Standards may be classified as ambient, emission or discharge, and design standards. Environmental Law Institute explains these standards as shown below.

Design Standards: The design standards prescribe technologies to be used in particular industrial operations. These standards have advantages and disadvantages of their own.

Advantages

- ☐ Set clear requirements that apply to the regulated entity;
- ☐ The results are predictable; and
- ☐ Relatively easy to enforce.

Disadvantages

- ☐ Not flexible as to how the air pollution goal should be met;
- ☐ Do not allow for innovation which might be essential for pollution prevention;

- ❑ If the prescribed technology is not of the desired level of capability, environmental quality may not be achieved; and
- ❑ Embody a lack of incentive for voluntary compliance.

Ambient Standards: The *ambient standards or air quality standards express the desired level of the quality of the ambient air which the particular pollutant or pollutants should not exceed.* These standards usually refer to the concentration of the pollutant in the air as it is taken up by the receptor. For this reason it is necessary to determine what emission quantities from a source will ensure that these standards are complied with. This is achieved through the use of air pollution dispersion models. The models simulate the physical processes in the atmosphere and calculate ground level concentrations. The input data into the model comprise of height of discharge point above ground, temperature of the waste gases, exit velocity and meteorological parameters such as wind speed and atmospheric stability.

Advantage

- ❑ They are related directly to the environment to be protected.

Disadvantages

- ❑ Difficult to determine what industrial process resulted in the violation of the standard;
- ❑ It is often difficult to determine what level of discharge is required to meet the standard; and
- ❑ Because of the above disadvantages ambient standards are difficult to enforce on their own.

For these and other reasons, ambient standards are always used in combination with more specific design or emission standards. They are often used in determining design and emission standards. In addition, if design or emission standards are not sufficient to keep an individual emission – or group of emissions – from violating the ambient standard, stricter limits will be imposed that will ensure that the ambient standard is not violated. This combination of standards help to ensure both that the ambient environment is not excessively polluted and that a predictable and enforceable standard can apply to each regulated entity.

Emission Standards: Standards may be expressed in terms of what pollutants may be released into the environment by a particular source. These standards measure the amount of pollution permissible at the “end of the pipe” – ie, at the point when the pollutants are discharged by the source into the

atmosphere. The advantages and disadvantages of emission standards are listed below.

Advantages

- ☐ The make compliance and enforcement is quite straightforward;
- ☐ Indicate a clear point where the level of pollution can be measured; and
- ☐ Dictate exact performance expectations for the regulated entity.

Disadvantages

- ☐ Determination of appropriate emission standards is not straightforward; and
- ☐ The standards are linked to the receiving environment by extrapolation.

Practice

Once the standards have been set, air pollution can be controlled in three ways to meet those standards:

- ☐ Preventing pollutant from forming at source;
- ☐ Dispersing the pollutants in the atmosphere in such a way that ground level concentrations are within acceptable levels; and
- ☐ Removing the pollutant from the waste gases before discharging them into the atmosphere.

(a) Air Pollution Prevention: This may be achieved in several ways:

- Changing the raw materials.
- Changing the production process.
- Changing the equipment.
- Improving operation and maintenance practices.

(b) Dispersing the Pollutants: The aim of this approach is to dilute pollutant concentrations to acceptable levels before they reach the exposure unit. This may be achieved by:

- increasing the chimney height; and
- moving the plant.

(c) Pollutant Removal: The pollutant is removed or collected from the waste gases.

It is often necessary to use more than one method in order to meet the

standards.

Controlling Gaseous Emissions

Industrial emissions are predominantly sulphur dioxide (SO₂) and nitrogen oxides (NO_x) from the combustion of fossil fuels. The SO₂ arises from the oxidation of sulphur contained in the fuel. There is no other source of SO₂ from the combustion of sulphur containing fuel other than the oxidation of the sulphur itself. With NO_x the situation is somewhat different. There is the oxidation of the fuel nitrogen to nitric oxide (NO) of course, but there is also the oxidation of the combustion air leading to the formation of nitrogen oxide (NO_x). This depends on temperature and the amount of excess air used.

Several control measures for SO₂ and NO_x exist. These may be *preventive* (addressing the problem at the source) or *end-of-pipe techniques*. The following is a brief description of selected methods.

Preventive methods for SO₂: These may entail the removal of sulphur from the fuel. Perhaps the simplest one is coal beneficiation. The sulphur in the coal is in two forms:

- ❑ Pyritic sulphur, which is associated with the mineral impurities (usually iron pyrite in the coal); and
- ❑ Organic sulphur, which is the one chemically combined with the carbon in the coal.

The sulphur associated with mineral impurities is removed by cleaning the coal. The coal is crushed into fine particles and passed through a heavy media separator. Because of differences in specific gravity the coal floats on top of the separating medium and the mineral impurities sink to the bottom. How much sulphur containing mineral impurities can be removed this way depends on the amount and form of sulphur present. This varies widely with the origin or location of the coal deposit.

The organic sulphur can be removed only by changing the chemical structure of the fuel.

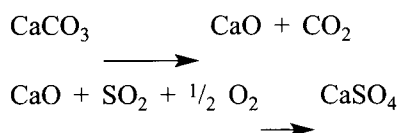
Desulphurisation During Combustion: The reduction of SO₂ emission may be achieved by the addition of limestone into the boiler together with coal. The alternative stages of limestone introduction (CaCO₃) into the system is shown in Figure 11.1. The addition of CaCO₃ into the boiler represent desulphurisation during combustion and the addition at the scrubbing representing flue gas desulphurisation (FGD).

Desulphurisation: After Combustion the flue gases may be treated to reduce

their SO₂ content to acceptable levels in an FGD plant. The main requirement of the plant is that the flue gases be brought into intimate contact with the absorber material which is usually in the form of a liquid or slurry. This is usually achieved by a counter-current flow system where the flue gases are introduced through the bottom of the absorption tower and the absorbing material at the top. These FGD scrubber plants are designed such that they meet specific SO₂ removal requirements which are influenced to some extent by plant size.

In its simplest form an SO₂ absorption unit will have a tower which may be packed with a suitable material. However, in industrial application the plant may be more complex than this, since there are interfering components that have to be removed before the SO₂ removal process could begin. Sometimes a unit operation for the regeneration of the absorbing material for recycling may be required adding further complexity to the FGD plant. The regeneration unit produces concentrated SO₂ gas for the manufacture of sulphuric acid or elemental sulphur. The plant configuration, however, may be dictated by operating conditions.

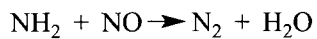
There are several FGD systems in the world but the limestone/gypsum process seems to be the most favoured for a large combustion plant. A slurry of limestone in water is used as an absorber and the SO₂ in the flue gas reacts with the limestone to form calcium sulphate or gypsum which is a marketable product. Sulphur removal efficiencies of 90% and over are normally achieved (2). The gypsum is used for the manufacture of plaster boards and other building materials.



NO_x Control: The control of nitrogen oxides can be achieved by changing the combustion conditions and burner design as well as by flue gas denitrification. Staged combustion can reduce NO_x in flue gas. In this process the fuel is initially burned with less air than stoichiometrically required. Secondary combustion air is introduced at a later stage to complete the combustion. Low NO_x Burners used in utility boilers employ this technique. There are several ways of NO_x removal from the flue gases.

Ammoniate Infection: Nitric Oxide (NO) is converted to molecular nitrogen as shown by the following simply reaction.

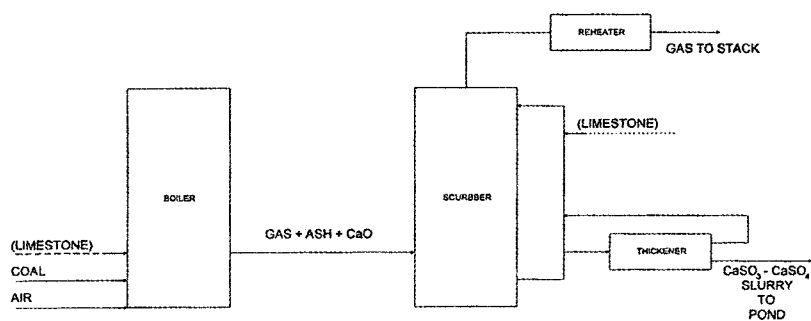




This process is temperature sensitive and will operate between 900 - 1100°C.

FIGURE 11.1

REMOVAL OF SO_2 FROM FLUE GASES BY LIMESTONE SCRUBBING



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CHAPTER 12

FORESTRY DEBATES IN SOUTHERN AFRICA

Otlogetswe Totolo

**Department of Environmental Science
University of Botswana
Private Bag 0022
Gaborone, Botswana**

**Phone: 267-3552524 Fax: 267-356591
E-mail: totoloo@noka.ub.bw**

Forestry Debates in Southern Africa

Introduction

Woodlands and forests are an integral part of the environment and are a prime factor in the livelihood of mankind in a number of ways, including the provision of fuelwood, creation of sculptures, regulation of climate, and provision of sinks for carbon dioxide. The main consideration with respect to the use of trees is to use them in a more sustainable manner and to conserve them for future generations such that their productive capacity is not seriously affected. Sustainability of the use of woodlands and forests can only be realised and maintained if grassroots decision making and participation is encouraged at local, national and regional levels. This means that there is a need to use the existing indigenous resource management as the building blocks for sustainable development. The other question to be explored is the need to conserve *biological diversity* which entails a variety of genetic resources which are essential in the interlinkages between living organisms and their environment. Indigenous forests and woodlands, because of their diverse nature and their adaptability to the natural environment of the region throughout time will ensure that biodiversity is maintained. Therefore, those rare animal and plant species which are unique to this region will be preserved for the future.

According to Clarke (1994), traditionally, people in the SADC region have lived in harmony with trees but this delicate balance is changing because of more demand on woodland resources (like deforestation) as a result of population growth. Despite the fact that trees are slowly diminishing, the people of the region still have deep respect for trees and a detailed knowledge of their names and uses. Furthermore, a wide range of traditional woodland management practices have evolved and continue to evolve in response to forest disturbance like deforestation.

In the past, traditional woodland management have been ignored in favour of management strategies which were developed outside the region which did very little to halt the deterioration of woodland resources. Until and unless there is a recognition to promote traditional woodland and forest management strategies, sustainability will never be realised.

Most traditional SADC rural communities still have deep respect for indigenous forests and woodlands which are expressed in their mythology, traditional religions and ceremonies. Traditional doctors continue to procure some of the medicines from forest resources.

Extent and Variation in Indigenous Forests

In the SADC region there are large tracts of land which are still covered by indigenous forests and woodlands. However, the extent and variation of these forests vary with climate and the geological influence of the region. Namibia, Botswana, Southern Zambia and Zimbabwe are mainly dominated by the Kalahari sands and therefore the vegetation which is mostly thorn scrub savannah, tree and scrub savannah in the that kind of environment is very similar in the aforementioned regions. As one progresses from Southern Zambia northwards, the vegetation changes from dry forest, to seasonal forest and into the rainforest. Mozambique, Zambia, Angola and Tanzania are mainly dominated by the dry forest, Zimbabwe by tree and scrub savannah, Botswana by thorn scrub savannah and tree and scrub savannah. South western part of Botswana is mainly covered by desert vegetation (arid shrub savannah). Namibia is dominated by the desert vegetation and the north of the country is vegetated by tree and scrub savannah. South Africa has more complicated vegetation types, which is a reflection of the complex microclimates within that country. The Northern Province, Gauteng, Free State, and North West Province are mostly dominated by the tree and scrub savannah. The Cape and the Northern Cape Provinces are mostly dominated by desert and thorn scrub savannah which extends into Botswana and Namibia. The Eastern Cape, Mpumalanga, and KwaZulu/Natal have mostly grasslands and the eastern coast has areas covered with the rainforests because of the rain throughout the year.

Table 12.1
Woodland and forest resources in southern Africa
(Land areas in km²)

(Source: State of the ENVIRONMENT in Southern Africa 1994).

Country	Land Area (km ²)	Natural Forest & Woodland	Existing Percentage Plantations	Annual Reforestation (Deforestation)
Angola	1 246 700	1 170 651 (94%)	1800 (0.14%)	0.002% (0.2%)
Botswana	566 730 525 600 7	(93%)	- (0.0012%)	(0.1%)
Lesotho	30 355	160 (0.0053%)	70 (0.23%)	0.03% (-)
Malawi	94 080	45 510 (49%)	1440 (1.5%)	0.043% (3.5%)
Mozambique	784 090 581 350 400	(74%)	0.005% (0.05%)	(0.8%)
Namibia	823 290 560 650 2	(68.1%)	(-) 0.0002%)	(-)
South Africa	1 221 037	45 150 (3.7%)	16 400 (1.3%)	0.05% (-)
Swaziland	17 200	5 996 (34.9%)	1 040 (6.0%)	0.29% (-)
Tanzania	886 040 599 400 980	(67.6%)	0.01% (0.1%)	(0.3%)
Zambia	743 390 676 067 629	(90.9%)	0.003% (0.08%)	(0.2%)
Zimbabwe	390 580 233 900 1 500	(59.9%)	0.01% (0.38%)	(0.4%)
TOTALS	6 803 492	4 445 434 (65.3%)	22 959 (0.34%)	0.014% (-)

From the Table 12.1 above, Angola has the highest percentage area (94%), followed by Botswana with 93% of the land still covered with natural forests and woodlands. This implies that the two countries have not been disturbed by anthropogenic activities significantly. In Botswana's case, the population is still very low (1.3 million people) and is concentrated on the eastern part of the country. Angola has been ravaged by long trials and tribulations of war and subsequently most of the inhabitants of Angola have not found it easy to go into forested areas because of the danger of land mines or have been in fear of being attacked. Although land mines are a menace to the Angolans, the environment has benefited because large tracts of land lie undisturbed by human activities.

South Africa has the lowest percentage of natural forests and woodlands because most of the country has been disturbed by human activities. To redress the deforestation of natural woodlands and forests, South Africa is one of the countries which has embarked on the creation of plantations throughout the country with the aim of conserving the land on steep slopes which are a common occurrence.

Swaziland has the highest percentage of existing plantations (6%) and this could be explained by the fact the country is mostly mountainous and therefore it is essential to protect the soil from water erosion.

Lesotho has the lowest percentage of natural forests and woodlands because historically Basotho were pushed away from the lower fertile valleys by the settlers to the mountains, where they settled. This crowding of Basotho in limited land lead to the overutilisation of the forest resources and therefore this explains why Lesotho has the lowest percentage coverage of natural forests and woodlands.

In general, SADC region has a reasonable percentage (65.3%) of natural forests and woodlands which ensures that most of genetic diversity of the region can be conserved. Plantations of exotic species play a meaningful role in the conservation of the land and in providing alternative wood resources for the local people. Conservation of natural forests and woodlands can only succeed if it has the blessing of the local communities.

Goods and Services from the Natural Forests

For most people in the SADC countries, *indigenous forests and woodlands have for centuries provided building material, fuelwood, food, medicines, cosmetics, regulated local climate and shelter. In addition to this, many trees have been of great cultural importance*, as for instance, leadwood (*Combretum imberbe*) or, in the very old Namibian legends, the *Omumborombonga* tree has been respected as an ancestral tree. According to the stories told from generation to generation, human beings, cattle, sheep and various animals originated from that tree (Asare, 1990).

Indigenous forests and woodlands play a very crucial role in the livelihoods of the people of Southern Africa. There are quite a number of uses which have been derived from timber from the woodlands. *The most common usage is the firewood from forest and woodlands.* Most traditional communities depend on firewood as an energy source and therefore felling of trees around settlements is very common. It has been confirmed by Kgathi (1989) that the distance to collect firewood has increased with time. This has exerted a lot of pressure on most families because they spend most of the time travelling to collect firewood

and neglecting other aspects of their livelihood. Fuelwood is used also for heating homes, lighting and cooking. Therefore it could be discerned that fuelwood is of paramount importance in the lives of most inhabitants of the SADC region. According to Cogill and Kiugu (1990), in Namibia in the Owambo, 95% of the households had no electricity and 85% used wood for cooking. Erkkila and Siiskonen (1992) reveal that the most marked long-term change in the energy supply scheme had been the increase in the hauling distance of fuelwood. At the beginning of the last century fuelwood was fetched mainly from the adjacent forested areas lying between population clusters or communities, but today in most areas these forested areas have almost totally disappeared from densely populated centres.

*In all rural areas of SADC countries, woodlands are very popular in the construction of houses, kraals and also in the carving of sculptures for selling mainly to tourists. In Zimbabwe, Botswana, Namibia and Zambia the most important tree species used for carving is the wild teak (*Pterocarpus angolensis*). Trees are also an important source of veld products like the wild berries, nuts and some fibres and this is mostly important in the rural areas. It is also worth noting that most of the villages in Northern Botswana, Namibia, parts of Zambia and Zimbabwe still use poles for the construction of their houses and homesteads and the most popular tree used is the *Colophospermum mopane* (Mopane). The mopane poles are highly resistant to the action of termites and this is why they are very popular in the construction of houses. Mopane is also very popular as a source of fuelwood because it does not smoke too much.*

In Namibia and Northern Botswana, the most important fruit trees are: **Marula** (*Sclerocarya birrea subsp. caffra*), **Omuye** or bird plum (*Berchemia discolor*), **Omwandi** or African ebony (*Diospyros mespiliformis*) and **Omulunga** or fan palm (*Hyphaene petersiana*). Wine and brandy are made from wild fruits and the most popular wine is made of marula.

*Baskets of various types are also made from forest resources and these include cereal containers, fishing baskets and tunnel nets. The most common material used in the making of baskets is the young leaves of fan palm, which are first dried and then split into narrow strips. Various wooden containers, cups and buckets are made from the fairly soft woods of *Albizia anthelminitica*, *Berchemia discolor*, *Commiphora africana*, *C. angolensis*, *Peltophorum africanum*, and *Ricinodendron rautanenii*.*

In Botswana, Zambia, Namibia, Zimbabwe, Angola and Malawi, wooden mortars and pestles are used to grind millet and sorghum and sometimes also to pulverise leaves of several species for body powders used to reduce body odours and provide a pleasant scent. The mortar or base is usually made from the heartwood of *Burkea africana* and sometimes from *Combretum imberbe* or

Pterocarpus angolensis. The pestle is obtained from the heartwood of *Colophospermum mopane* (Rodin, 1985).

Drums, the universal traditional instrument throughout Southern Africa, are usually of hardwoods such as *Pterocarpus angolensis* or *Sclerocarya birrea subsp. caffra*. Dug-out canoes are used commonly along the rivers and flooded areas in the Okavango Delta, Victoria Falls and Lake Kariba. Most of these canoes are made from the following tree species: *Baikiaea plurijuga*, *Guibourtia coleosperma* and *Pterocarpus angolensis*.

Traditionally most of the people in the SADC region have cultural activities like initiation ceremonies which are normally carried out in secluded forest areas. These are very *important cultural as well as religious rites which commands the use of certain indigenous forests. Forests also provide a natural environment for citizens to come closer to nature.* This view applies more especially to the city dwellers who once in a while go out into the forests to experience the wilderness. In addition, forests have an aesthetic beauty which can attract tourists which might bring revenue to the country. Most tourists are interested in the environment in its pristine condition.

Forests and woodlands are absolutely crucial in watershed management. A well vegetated watershed is protected from water erosion and therefore generation of sediments which could be carried to the streams and lakes thus reducing their volume is markedly reduced. If indigenous forests are conserved in watersheds, this has an added advantage because they are well adapted to their natural environmental conditions and therefore will be more effective in reducing production of sediments by erosional processes.

A variety of genetic resources can be obtained from diverse tree species and therefore *indigenous forests and woodlands which are diverse by their very nature provide an opportunity for having a wide spectrum of genetic material.* Therefore plantations which are mostly single species impact negatively on the idea of biodiversity. In natural ecosystems biodiversity is very important because organisms are dependent on each other through food chains and food webs. This complex interrelationship of organisms can be seriously disturbed if some of them are removed by anthropogenic activities like deforestation. The ultimate result might be the disappearance of some very important plant genetic material and other organisms probably very important in the medical field.

The idea of genetic resources in woodlands and forests has to do with scientific, social and economic value arising from genetic diversity between and among species. One of the most important factors about genetic variation is that it provides a natural barrier against alterations in the natural environment. The natural balance includes protection against those changes brought about by diseases, pests climate etc. Genetic variation make it possible for different

plants and animals to adapt and multiply in an environment in which they would not otherwise function. These natural adaptive mechanisms can only be possible if trees have not been reduced to a few or single species.

The concept of an ecosystem in most countries of the world has been reduced to something that could be read in books. It is of utmost importance that samples of ecosystems should be preserved in the SADC region. Governments through their game parks and nature reserves have gone a long way in preserving natural ecosystems. Such natural ecosystems will be rare in the future because of the competing demands on land resources for different uses. It is therefore advocated that our environmental conservation policies be strengthened.

As the population increases within the SADC region, more and more land will be needed to produce food. The demand for more arable land imply clearing more trees for ploughing. This is tantamount to reduction of biodiversity of the region. There are certain government policies which encourage clearing of the land for arable agricultural purposes like Accelerated Land Development Programme (ALDEP) of Botswana which was meant to assist the resource-poor farmers with destumping of their fields. The result of the programme was that large tracts of land was cleared with the sponsorship of the government and only a small percentage of the land was placed under productive arable agriculture. This was very unfortunate because Botswana is an arid country and clearing of vegetation can only lead to more environmental problems including the loss of genetic resources.

Zonation of Forest Lands

In most SADC countries, there are forest reserves, game reserves and parks which are mostly controlled by the state. There are however, a few of the above mentioned land uses that are run privately more especially in South Africa.

In all SADC countries, there are departments of wildlife and national parks with the aim of conserving wildlife resources. It has been realised that such resources belong to the whole nation and therefore must be controlled in such a way that they benefit the majority of people. The returns which are gained from a good wildlife management programme are in the form of foreign currency from tourists. In Botswana, the government has adopted low volume strategy for visitors into the game parks. This has an advantage of attracting a few people to our tourist areas but who spend a significant amount of money. This has an added advantage because the environment could be kept in its almost original form, thus maintaining biodiversity of the land. The main disadvantage of this approach is that not many local people have money to spend on very expensive tourist ventures and as a result it is only foreign visitors who are likely to benefit from such an arrangement. A counter

argument might be that the whole nation will benefit from foreign currency brought into the country by tourists. The other argument might be that employment opportunities are created when the local people are employed by the tourist industries as guides and even in hotels.

The general world mood is towards privatisation including that of forest reserves. The main advantage with having private land is that the owners are always striving to maximise productivity and in doing that creating employment for most people. Management is thought to be more efficient and thus contributing to the general productivity of the area. The disadvantages with private land is that all the resources within the private land are to the exclusive use of the owner and therefore all those other resources that he does not need are not accessible to the general public.

Public or communal land in most cases does not have strong management mechanisms and as a result the land is normally placed under very serious pressure because of the competing demands on it. Resources under public control including woodlands and forests are sometimes over-harvested which could lead to reduced biodiversity and soil cover. Reduction of vegetation cover make the soil prone to soil erosion. Communities must be encouraged to engage in sustainable utilisation of forests and woodlands. This approach will ensure that both *non-consumptive uses* (for example trees to protect the soil, aesthetic beauty of the land, cultural as well as religious sites) and *consumptive use of certain tree species* for sculptures and curios for tourists are conserved by all people using them thus promoting sustainability and conservation of biodiversity in any particular locality.

The Justification for Indigenous Forest Management

Most of Southern Africa has been troubled by *deforestation as a result of over-harvesting of the regions forest resources*. To counteract this problem, SADC countries have engaged in rigorous *afforestation programmes in the form of plantations of eucalyptus and pine trees*. Examples of plantations in the region are: Usutu pine plantation in Swaziland and Mufundi plantation in Tanzania. These exotic forest plantations are composed of only one species and therefore they seriously affect the biodiversity of the region. Exotic plants which have been found to be very competitive in this environment and therefore they have been found in some instances to push out the indigenous forests thus contributing to reduction in biodiversity. According to Chenje and Johnson (1994) Blue swallows disappeared from Zimbabwe's Eastern Highlands in the 1970s, because of the loss of habitat due to exotic tree planting. In South Africa, about 30% of the transvaal's rare and endangered plants are in areas targeted for tree plantations. In Tanzania, pine plantations occupy land previously covered with indigenous woodland and most of Malawi's tree plantations replace afromontane forest.

Exotic trees have been found, in *addition to out competing indigenous trees, to use a lot of water for their fast growth and the consequences are the drying of streams*. This concern has been mostly registered in South Africa which has the highest number of plantations in the region. It was recorded that on Cathedral Peak in South Africa, streamflows were reduced by almost half within two decades of widespread planting of pines in grasslands. Overall in South Africa, tree plantations have reduced river runoff by 2.4 %, or 1 284 cubic metres.

It is abundantly clear that SADC countries have to engage on a rigorous research programme to utilise indigenous trees in plantations because they have evolved in this environment for many years and therefore are well adapted to the soil, climate and the diseases within this region. This approach will ensure the biodiversity of SADC is maintained.

Multiple Use Management Strategies

Forests and Woodlands Management

The only way forward in the use of indigenous forests and woodlands in Southern Africa is by gaining the support of all interested parties involved. This will involve striking a balance between forestry management by communities, private groups, individuals and governments.

Forests and woodlands could be managed in such a way that they can provide firewood for rural population, timber for industries, traditional curios normally bought by tourists and indeed as cover to protect the soil from erosion. This multiple approach to utilising forests will ensure that benefits derived from them will go to a cross section of the nation.

Need for Efficient Charcoal Manufacture

Traditionally, most of the people in the SADC region use fuelwood for cooking and this is normally done in open air which tends to waste heat energy and therefore demanding the use of more wood resources. *One management strategy that could be engaged is by developing stoves which can use energy more efficiently for cooking. More efficient charcoal manufacture strategies by local communities could also be encouraged in order to reduce more harvesting of wood resources.*

Conservation of Woodland and Forest Resources

Poles for the construction of houses and fences could also be treated such that they last longer in the environment and the net result is the reduction of harvesting of trees for the same purpose. The pricing and marketing of woodland resources must be geared towards *conservation of woodland and*

forest resources. More money could be paid to collectors from woodlots and regulated areas and less to those collecting firewood from natural forests. Legislation could also help by forbidding cutting of natural woodlands and forests. It has to be emphasised that the realisation of these strategies can only succeed with the support of the local communities and this requires more *public education* on the importance of conserving our natural resources. The target group should be mostly school children who should be encouraged to grow up with this natural resources conservation spirit. The general public should also be made aware of conservation issues and demonstration should also be made of how to control things like soil erosion in order to achieve sustainable production of the land.

Agroforestry Practices

Farm forestry by local communities should also be encouraged and this will take the form of village woodlots where harvesting of trees for various functions could be permitted. Agroforestry could also be tried which will involve planting trees along side crops. The tree species grown will depend on the needs of a particular community. For example, communities in need of *fuelwood* will plant trees which can give them firewood. Those who are aiming at *improving the fertility status of the soil* will concentrate on species which fix nutrients into the soil. *Windbreaks and shelterbelts* could also be planted to slow down high velocity winds which might cause a lot of damage to the land in the form of wind erosion.

Community Support

For any forestry management strategy to succeed it must have the full support of all the people involved. Politicians as the policy makers, should be made aware of the importance of conservation of woodland and forest resources. Grassroots participation in both planning and implementation approaches should be encouraged in order to ensure that the process moves from the bottom to the top. This strategy will ensure that any proposed project has the full support of the local communities. It has to be emphasised that natural resources conservation (including forests and woodlands) requires the participation of all citizens, all government departments/ministries and non-governmental organisations which must be guided by a strong government policy and control in recognition that this is a colossal task which has demographic, social, technological, economic and political dimensions.

Genetic Banks for Woodland and Forest Resources

In order to ensure that the regions genetic resources are not lost by whatever means, there is a need to create genetic banks for woodland and forest for SADC. With the modern biotechnology techniques those species which are in

danger can be propagated and be redistributed throughout the region. The creation of gene banks requires a lot of financial resources and may be that is where the contribution by international financial organisations will be mostly valuable.

Industrial Wood Production

Industrial wood production must be tackled with utmost care and this will entail doing a lot of research on the sustainable harvesting methods and how much to harvest. Once enough research has been done, harvesting at appropriate levels could be recommended in order to supply wood industrially. Industrial plantations and processing plants create jobs for the rural communities.

Institutional Support

National forestry institutions like Forestry Association Botswana (FAB) must be given a lot of support to build their institutional strength so that they *engage in high profile research on indigenous woodlands* and forests with the results that can benefit the whole nation. This can only be achieved if international organisations can provide *massive support for the education and training of professional and technical researchers*. With strong institutional capacity, research results can flow between countries within the region thus ensuring research questions of interest to the whole SADC are carried out systematically thus facilitating the exchange of information between researchers to be more easy. The research results should be appropriate, meaning that they must be geared towards the user. It is pointless to generate information that cannot benefit the majority of the people in the region in the long run. In order to ensure that results are immediately applicable to the user, the user must be involved during the research process in order to solve the problem that he is facing. Extension service can also be tried to use the research results to the benefit of the user (Clarke, 1994).

Major Conditions for Sustainable Management

Governing-Community Collaboration

For woodlands and forests to be managed sustainably, governments and communities must work hand in hand to ensure that the resources are not used beyond levels of possible regeneration. It has to be emphasised that for any government policy to succeed it must have the support of the majority of the people and the same principle will apply to forestry management.

The above suggestion does not wish to preclude individuals to venture into forestry industry. *A balance has to be struck between the management of forest resources by individuals and governments alike*. This arrangement will ensure

that national projects could benefit from the revenue accrued from forestry and woodlands managed by the state as well as by individuals. For example in Botswana *Mukwa* (bloodwood) and *Mukusi* (Zimbabwean Teak) are being exploited commercially by a private company but how much to exploit these trees is controlled by the government. As a result there is no danger of overexploiting the vegetation because there are guidelines like cutting mature trees of a minimum diameter of 30 cm per acre. At this rate there is no danger of exhausting forest resources.

Institutional Strengthening

Sustainable management of woodland and forest resources can only be realised if forestry institutions are provided with the necessary capacity and strength in terms of trained professional and technical personnel. This will ensure that reliable forestry databases throughout SADC are created and the exchange of information is facilitated. Those plant species which are under threat of extinction can be conserved throughout the region thus ensuring plant genetic diversity of the region is maintained.

Conservation: Multinational Approach

Conservation of natural resources demands multidimensional approach and therefore research on the most suitable plant species to conserve soil requires the input of plant scientists as well as those of soil scientists. The multidisciplinary approach to resource conservation must be reflected in research teams which are investigating questions with the view of making recommendations to the users.

Investment on Conservation of Forests and Woodlands

The complexity of diverse wildlife resources could only be maintained if forest and woodland resources are conserved. *Plantations of exotic plant species should be approached with caution because we might run into the danger of losing some of our rare wildlife species.* Therefore it is being suggested in this discourse that governments should come up with deliberate policies to encourage individuals and groups of individuals to invest in forestry industry of both indigenous woodlands and exotic plantations. *Where the land is badly affected, it is most appropriate to plant fast growing plant species* which could protect the land from further damage. The other reason to *invest in the conservation of woodlands and forests is their ability to provide timber and fuelwood to both the industry and fuelwood for local consumption.* This has an added advantage because communities could be directed to specific areas where they can collect firewood for their needs thus reducing pressure on natural forests and woodlands.

Forests and woodlands must be conserved in order to preserve the genetic diversity of the plant species of the region. It has already been pointed out that organisms within the environment are interrelated to each other and therefore if there are some missing in these interlinkages, this will inevitably lead to the disappearance of certain species. Therefore, it is recommended that money has to be sourced from international and national governments to embark on a programme to create gene banks of rare species. If such species disappear from the environment, they can be re-introduced.

Summary and Conclusions

Forests and woodlands are part of the linkages which exist in ecosystems and therefore are very important in ensuring that the diversity of life is perpetuated on earth. The reduction of biodiversity is brought about by single species plantations which in the long run adversely affect the genetic resources of a particular area. Plantations of exotic plants have been found to cause a lot of problems like the use of too much water leading to the drying of streams and they also outcompete indigenous trees again contributing to the reduction in biodiversity.

Firewood, sinks of carbon dioxide, climatic regulation and construction of households are some of the uses which are provided by forests and woodlands. Land degradation could be arrested by the use of indigenous trees which are well adapted to the environmental conditions of the region.

Conservation of forest resources can only be successful if it includes participation of local people at all levels of decision making. It has to be emphasised that commercial logging has the potential to bring revenue to respective countries but it must be regulated in order to control the amount of harvesting of tree species. The control of harvesting will ensure that biodiversity is maintained and the question of sustainability is also addressed to spare some of the trees for future generations.

Indigenous trees add aesthetic beauty to the landscape and in addition there are certain forests which have been used for traditional ceremonies and other cultural matters and therefore must be conserved as part of history and heritage.

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PART 3

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CHAPTER 13

POLLUTION AND REMEDIATION OF POLLUTED GROUNDWATER

Robin Hazell and Deborah McLaren

**Water Surveys of Botswana
PMB 1398
Gaborone, Botswana**

**Fax: 267-561285
E-mail: wsb@global.co.za**

Pollution and Remediation of Polluted Groundwater

Introduction

In this chapter, the environment and dynamics of groundwater are discussed in relation to polluting substances. The principal pollutants are identified, and an outline is given of the historical development of pollution, in scale and variety. The controls over the vulnerability of ground and groundwater to pollution are evaluated, and the concept of aquifer protection outlined. *The commonest pollutants are postulated to be hydrocarbons and their derivatives.* Detection of pollution is followed by remediation, and the commoner clean up processes are described. Case histories are introduced. The differences in the nature and scale of pollution in temperate as against semi-arid countries, and in densely populated as against sparsely populated terrain are discussed.

Overview

Groundwater contamination is perceived to be *the introduction of any substance that does not naturally occur in it. Pollution is the introduction of a substantial quantity of any such substance in concentrations over a level defined by a directive following national legislation. That level or maximum admissible concentration is variable between the receiving environment and between governing bodies.*

Water enters the ground to finish up in subsurface storage and is then *groundwater*. If the host rock is permeable, it is an *aquifer*. Water moves through the ground as a fluid. It follows that other fluids, provided they are not too viscous, can follow the same paths. So groundwater, whether in aquifers or not, can be contaminated. Only in aquifers does it pose an immediate problem, but contaminants which enter an almost impermeable rock can gradually migrate into an aquifer. The quality of groundwater is affected by many influences other than human. The youngest groundwater has a composition approximating that of rainwater. The longer they are in contact with their host, the more solutes they will acquire, until they are saturated and at chemical equilibrium.

Historically, massive impacts on water quality have resulted from invasion by hydrocarbons that have leaked from natural storage in older lithological structures. Radioactive pollution of groundwater emanates from deposits of radioactive minerals. Unstable or soluble substances such as volcanic dust can be widely dispersed by winds. Bedded evaporites leach into groundwater.

Long before the human race got to work, the products of decay and excretion by animals and plants affected groundwater. Generally speaking, poor quality groundwater resulting from natural influences are tolerable in that populations have either avoided affected groundwater or have used surface resources.

The dividing line between polluted groundwater and that of naturally poor quality is not precise. Forest and wild fauna can cause poor quality groundwater but do not, by definition, introduce pollutants. On an adjoining farm vegetation and livestock create pollutants.

A prograding coastline in Africa is a combination of beach ridges and lagoons. The lagoons fill up with vegetation, silts and clays, and ultimately a lot of iron oxides. The resulting coastal plain is underlain by elongated sand aquifers bounded by iron-laden clays. If the groundwater moves naturally and slowly, poor quality water in significant quantities is not drawn in from the adjoining lagoon deposits. If a well-field is put in, pumping soon brings in iron in an acid environment, and the emerging water, on exposure to air, precipitates iron and clogs the system between water abstraction and public supply.

Evaporites in contact with groundwater, e g in the Middle East, are not a great nuisance until a strong vertical groundwater gradient is induced by pumping from a relatively distant, unpolluted aquifer, when dissolved sulphates migrate into the well-field area. There are many groundwater pollution risks in Botswana, exacerbated by these sandy soils, but in terms of per unit area of groundwater, these are less significant than in a densely populated terrain like the United Kingdom.

Aquifer Vulnerability

The degree to which groundwater is vulnerable to pollution is controlled by the ease or difficulty with which pollutants can reach the aquifers in which the groundwater is stored. Discussion now centres on pollutants derived from human activity. Generally though not always, pollutants come from the surface. They pass either in solution or in non-aqueous fluid flow downward through the unsaturated sub-soil through the partially saturated zone, into the groundwater.

The soil is a complex catalyst in which bacteria, air and humic acids play a part in attacking and breaking down or altering most organic and some inorganic substances. A thick well-developed soil is naturally more effective in halting further progress of pollutants than a thin soil.

The unsaturated sub-soil carries some bacteria and a lot of air. Fluids percolating through this zone are subject to further attack. The more impermeable, the more the progress of fluids is retarded, or even halted; and the thicker this zone, the longer is the fluid under attack.

In both the soil and sub-soil, degradation of contaminants is a natural chemical process which proceeds regardless of bacterial action. Within the aquifer, bacteria exist, and air sometimes exists. So groundwater, especially if it is moving, can further be purified by the action of both aerobic and anaerobic bacteria.

Aquifer vulnerability is strongly influenced by the various thicknesses of soil and types of substrate - thin soils often provide little protection against bacterial invasion.

Well-head Vulnerability

The vulnerability of groundwater in a well-field can be controlled by defined constraints to invasion by pollutants at the well-head. The essential difference between aquifer vulnerability and well-head vulnerability is that the first is almost constant and the second varies with the controls imposed, the size and disposition of the well-field, and the pollutants present.

Well-head Protection Areas (WHPAs) are defined fairly uniformly world wide, and are based on the time taken for groundwater to migrate from potential pollutants, and the distance travelled. WHPAs comprise the following:

- ☐ A small, fenced operational courtyard, wherein only essential activities are permitted;
- ☐ An inner source protection zone, to protect against pathogens. In Europe this is a 50 day zone; in Botswana where soils are thin and temperatures high, a 100 day zone or a minimum distance of 100m radius from the borehole is preferred;
- ☐ An intermediate fracture flow protection zone applied in Botswana to dominating fracture porous aquifers, and the control is 1 km radius; and
- ☐ An outer source protection zone, corresponding to an arbitrary 100 year catchment.

Exclusion, Detection and Remediation of the Principal Pollutants

For the purpose of the discussions in this chapter, pollutants may be grouped as follows:

- ☐ Relatively insoluble non-aqueous phase liquids;

- ❑ Polluting solutes in water; and
- ❑ Pathogens.

Two types of pollutant origin are distinguished:

- ❑ **Point source** eg: a septic tank or chemical factory leak; and
- ❑ **Diffuse source** eg: fertiliser spreading and pesticide spraying.

Point source pollution contaminates aquifers in pulses, especially if the host rock is a mixture of permeable and impermeable material behind which pollutants get trapped. It will be readily appreciated that the punch of a point source is more invasive than a more gentle, widespread attack.

Non-Aqueous Phase Liquids.

Most non-aqueous phase liquids are hydrocarbons and hydrocarbon derivatives. They are classified as lighter than water (**Light Non Aqueous Phase Liquids** or LNAPLs) or denser than water (**Dense Non Aqueous Phase Liquids** or DNAPLs). Mercifully most non-aqueous phase liquids are of the light variety and hence sit on the groundwater surface.

Dense liquids that lie under the water on the aquifer floor are often difficult to locate. If the floor is irregular the liquid accumulates in pools, which must be defined before the liquid can be removed. Of all fluids, apart from water, petroleum and spills thereof are the commonest, simply because in the current consumer society lifestyle, hydrocarbons are at present the cheapest source of energy. With a bit of luck, the future will see hydrocarbons displaced but meanwhile the movement of petroleum products from source to point of use will inevitably generate spills.

Spills of petroleum are accidental and infrequent, but they occur at points rather than diffusely, and in considerable volume (as tanker spillages or long lasting leaks) so they penetrate the soil, the first and major line of defence. Leakage from underground storage tanks, though relatively small in volume, is one of the most common causes of hydrocarbon pollution. Usually the pollutant has reached the aquifer before it is detected, typically by taste, in borehole water supplies. Prevention of such spillage is simply achieved, by providing protection where the risk of spillage is high.

A hydrocarbon spillage forms a pancake on the water table, its *disposition* related to the polluting source and the hydraulic gradient, its *thickness* related to its viscosity, and its *extent* related to the hydraulic gradient and to the duration of the spillage. The pancake is underlain by a zone of polluted groundwater, where the water has absorbed as much pollutant as it can. This is not much, but is the indicator that pollution exists. A 'smear' zone of

residual hydrocarbons is left above the pancake as the rest of the water level fluctuates.

Like most organic compounds, petroleum is vulnerable to oxidation and in time and with access to air the lighter hydrocarbons will decompose to carbon dioxide and will evaporate. Viscous hydrocarbons will slowly separate into lighter components and heavy tars which are as resistant to decomposition as tarmac on a road. But their relatively high viscosity inhibits the downward movement of heavy hydrocarbons into an aquifer. Given that leaving nature to run its course belongs to a spacious age long past, the measures now employed to clean up a hydrocarbon spill are any or all of the following:

(a) Bulk Removal of the Host Material in the Vadose (unsaturated) Zone

The more viscous fraction of the spillage lags behind the migrating mass in the zone of downward percolation, and can often be dug out. The host is removed to be ‘farmed’ as in ground pollution.

(b) Removal by Pumping from a Borehole

A scavenger pump placed in a borehole opposite the pancake removes a mixture of hydrocarbon and water to a chambered tank at the surface, whence the oil is skimmed off and the water ducted to a lagoon for final oxidation. To make the hydrocarbon to flow towards the scavenger, a deep pump removes a limited amount of groundwater, creating a gradient. This has the added benefit of stopping further lateral migration of the pollutant. Water can also be passed through activated carbon filters and re-injected, though this is more commonly undertaken in remediating a chlorinated hydrocarbon spill

(c) Decomposition of the Hydrocarbon to Carbon Dioxide by Injecting Air

This is mainly effective in removing tainted water. Air is constantly pumped into the polluted groundwater; the soil gas immediately above the water table is analysed for carbon dioxide and the regression plotted. As time goes by, the carbon dioxide decreases more and more until the permissible concentration of pollutant is achieved. Air injection not only oxidises the hydrocarbon but also provides the oxygen required for aerobic bacteria to degrade the hydrocarbons.

(d) Decomposition of the Hydrocarbons by Injecting Bacteria and/or Nutrients

Bacteria are routinely present in hydrocarbons and will ordinarily attack pollutants present in the hydrocarbons. Whether introducing more bacteria significantly speeds up the process is a debated question, as the bacteria - which naturally degrade the pollutant - rapidly multiply when the correct 'food' and environment exist. Introducing nutrients is also practised, and is also a debated question.

Major spillages do not appear to have occurred in Botswana. A spillage at Artesia (North of Gaborone on the Francistown Road) occurred in November 1996. There was some concern that a well-field less than 20 km away near Mmamabula would be affected, but though no remedial measures appear to have been taken, there have been no reports of groundwater pollution. Beneath the thin cover of Kalahari sands the Karoo sandstones aquifers do not appear to have been invaded. Though the soils are thin it may be that the Kalahari sands have exerted an attenuating influence.

(e) Halogenated Hydrocarbons

Modified hydrocarbons are used in industry, mainly as solvents. It is difficult in practice to prevent the used material from leaking into the ground, and until quite recently the accumulations of generations of heedless leakage were unnoticed. Most are LNAPLs and are dealt with in a way similar to that applied to petroleum.

(f) Polluting Solutes in Water

This group comprises the following:

- ☐ Faecal and vegetative material;
- ☐ Industrial chemicals;
- ☐ Heavy metals in storm water from quarries, mines, settlement lagoons, highways etc;
- ☐ Salt; and
- ☐ Soluble agricultural chemicals.

Faecal and Vegetative Material

In Botswana, rotting vegetation is an almost negligible source of pollution. The widespread use of pit latrines, however, is a strong potential threat. Excrement

bypasses the soil profile and the only protection against bacterial invasion of groundwater is attenuation in the unsaturated zone. Nitrates can also build up in groundwater to an undesirable level. The remedy is to encourage the use of sealed and improved latrines.

Industrial Chemicals

Risks relating to industrial chemicals are restricted to industrial zones, which in Botswana are few. The principal sources are solvents, and acid and alkaline wastes. For example, breweries use much caustic soda and resulting effluents can destroy the soil structure before wreaking havoc in the groundwater. The remedy is to treat the effluent on site.

Salt is widely used in northern latitudes where it is spread on roads to inhibit icing; it reaches storm drains and is difficult to exclude from the groundwater. Needless to say, there is no problem in Botswana in this respect.

Soluble Agricultural Chemicals

Fertilisers tend to be widely and excessively used in non-organic farming situations. The object is to provide nutrients to the root zone of growing crops. Nitrate is derived from fertilisers as well as from animal and vegetation remnants and national directives on water quality imposes a limit, in the range 30 to 50 mg/l. In Botswana the limit is rather higher. The risk is not from ingestion of nitrate itself but in the gut it tends to reduce to nitrite, which is a carcinogenic. Where the unsaturated zone is thick nitrate is mostly degraded to nitrogen, but more generally the remedy is to educate the users of fertiliser into using minimal quantities despite the blandishments of the manufacturers.

Finally, a startling thought. Water can pollute groundwater. If hot water from a factory, or power plant, is discharged into the ground, it changes the bacterial types and quantities, it can enable some dormant pathogens to energise and multiply and can change the dissolved solid concentration. If the water is continuously recirculated, the effect can be serious. This has happened in the Cheshire plain of United Kingdom. Even water at an ambient temperature can contaminate not groundwater but the host - the aquifer. A strong rise in water level following artificial recharge can lead to the groundwater coming into contact with pollutants previously out of reach

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CHAPTER 14

WATER QUALITY GUIDELINES AND STANDARDS

Yvonne Gotlop Bogatsu

**Department of Environmental Science
University of Botswana
Private Bag 0022
Gaborone, Botswana**

**Phone: 267-3552524 Fax: 267-356591
E-mail: gotlopyk@noka.ub.bw**

Water Quality

Guidelines and Standards

Introduction

Water quality may be assessed in aspects of potable water and wastewater. Guidelines for water quality differ from standards in that they are more flexible. Guidelines may actually be altered to develop standards. The guidelines for water quality as stipulated by World Health Organisation (WHO, 1993) may be modified to suit each country's requirements for managing water and wastewater. Water quality guidelines are set primarily to control pollution of water with the objective to protect health and damage to the environment. Standards for water quality need not be unrealistically stringent but must be such that water resources are protected from pollution and also such that standards do not inhibit provision of water where needed.

This chapter is intended to distinguish between guidelines and standards for water quality. Guidelines are generally not meant to be synonymous to standards. For instance WHO guidelines are meant to assist countries of the world to operate within a certain range of levels for particular constituents in water. The chapter will further discuss the purpose for water quality guidelines and standards. Furthermore, factors to be considered for setting national water quality standards will be suggested.

Guidelines unlike standards are not as obligatory but are flexible and may be used to set up more specific standards. On the other hand, standards are only necessary where exceeding them may be drastic to health or may cause damage to the environment. Standards are usually developed at national level utilising international guidelines, they are set with consideration to health and the environment.

Ideally water standards and guidelines are set to assist in quantifying the levels of constituents which are used to determine whether water is of good quality or not. The quality of water to be used either for potable or other purposes must be at acceptable levels. The permissible levels of chemical, biological, or physical substances in water are determined by either effects on health, aesthetic factors, or by impacts on the environment. Guidelines and standards used for potable water vary greatly from those for wastewater. Developing countries like many other countries of the world modify the World Health Organisation (WHO) guidelines for water quality to suit conditions in their countries. These countries may require more stringent limitations than those for WHO, or may require flexible guidelines. If water quality is beyond international requirements for instance, then national standards may be set to

exceed international guidelines but not to levels which may be detrimental to health or the environment.

The internationally set guidelines by WHO are meant to be used to assist governments to know approximate levels at which health may be affected or pollution may occur in water. Governments in different countries may then set national standards or guidelines using WHO guidelines as reference points or values. An illustration of this practice may be seen when comparing drinking water quality guidelines for Tanzania with those for Botswana (Table 14.1).

Table 14.1: Comparison of Potable Water Quality Guidelines

(Sources: Snowy Mountains Engineering et al – 1991, Water Utilities Corporation, 1995)

Parameter	WHO	Botswana (Urban)	Botswana Tanzania (Rural)	
Total Coliform (per 100 ml)	0	10	100	No data
Faecal Coliform (per 100 ml)	0	0	10	No data
Faecal streptococci (per 100 ml)	0	0	10	No data
Alkalinity (mg/l)	no value	no value	no value	No value
Chloride (mg/l)	250	600	600	800
Colour (TCU)	15	20	50	50
Iron (mg/l)	0.3	0.7	1.0	1.0
Manganese (mg/l)	0.1	0.5	0.5	0.5
pH	6-9	6.5-8.5	6.5-9.2	-
Sodium (mg/l)	200	200	-	-
Total Dissolved Solids, TDS (mg/l)	500	1000	1500	2000
Sulphate (mg/l)	250	400	600	600
Turbidity (NTU)	5	1	25	30
Fluoride (mg/l)	0.7-1.5	1.5	3.0	-
Nitrate (mg/l)	45	45	100	-

Purposes for Guidelines and Standards

Guidelines and standards for water quality are useful for purposes of controlling pollution of water resources and for protecting the environment. Public health factors being the primary reasons why WHO establishes drinking water quality guidelines, may also be monitored using quality of water. In order for this quality to be attained, water and wastewater may be treated to permissible levels, the water management processes may be monitored, this may involve such aspects as testing the quality of water.

It is quite typical in developing countries to put more emphasis on supplying water to the people and paying less attention to the environmental implications of the wastewater produced from this supply. There may be a number of factors causing this, such conditions as water scarcity, insufficient human and capital resources, and other related factors lead to situations whereby water supply is given precedence over treatment and handling of wastewater.

Potable Water Quality Guidelines and Standards

When establishing national standards for water quality, the main factor to consider using is the risk benefit method of approach. In this approach the existing quality and quantity of water should be used to assist in setting up national standards. *The criteria for developing drinking water quality standards should take into consideration national priorities as well as socio-economic issues* (WHO, 1993a). The water quality guidelines suggested by WHO have one main intention, that is, to cover the most important aspects of drinking water quality. WHO *emphasises that priority be given to microbiological quality of potable water, and physical and chemical parameters to become secondary.* WHO (1993c) suggests that when using their drinking water quality guidelines to develop national standards, that industrial, socio-economic, and geographical conditions should be taken into account. Such factors may result in national standards which differ to a large extent from the guidelines values.

The guidelines by WHO *recommend that developing countries should put emphasis on standards for biological quality.*

Water Quality Testing

The foremost goal for any country should be to protect water supply from contamination. *The best way of protecting water resources from contamination is at source.* There have been instances in Botswana where contaminated water supplies undergo continual treatment such as chlorination whereas if contamination was eliminated at source there would be no need to disinfect the water.

The detection of microbiological pollution is usually carried out using coliform group of bacteria to indicate pollution. Since primary emphasis is placed on microbiological quality of water, especially in developing countries, such quality is tested using coliform organisms as indicators of pathogenic bacterial pollution. Treating bacteriological pollution involves disinfection using chlorine, other developed or more industrialised countries may use ozone for disinfection.

Protection Zone Guidelines

The protection zone study was carried out by Water Surveys Botswana through the government of Botswana. The purpose of the guidelines was to protect water resources from pollution, especially major well-fields and dams. These guidelines were developed for specific well-fields but can be applied in areas with similar conditions using the flowpath model.

Wastewater Quality Guidelines & Standards

The guidelines and standards developed by WHO for wastewater quality are seldom altered by developing countries. This may be traced back to priority given to supplying water than handling effluents. Other reasons for this may be inadequate resources and skills required in wastewater management. Considering the semi arid conditions in most developing countries, the quality of wastewater from industries, households, and institutions may contain high concentrations of pollutants than in areas with wet climates. This may be attributed to the lack of runoff or natural flow in arid areas which would otherwise dilute the wastewater. Although wastewater guidelines incorporate ephemeral stream quality, one wonders to what extent the recommended quality considers seasonal streams in semi-arid environments.

Botswana has adopted the WHO guidelines for effluent quality as indicated in the page opposite (Table 14.2). Not all parameters have been tabulated but only those of primary concern. These guidelines differ from the potable water quality standards in that they are more stringent with some parameters required to be of better quality than in drinking water quality. Although effluent quality should be strict enough to protect quality of receiving waters they should be fair to all disposers, and should be used with consideration of the characteristics of the effluent at discharge point (Tchobalocous).

Apart from these guidelines there are also effluent quality restrictions which only apply when recommendations are made for domestic effluent which is intended to be reused for irrigation. Such restrictions provide guideline values for BOD and coliform bacteria in reused wastewater.

Table 14.2: Recommended Limits for Wastewater Quality used in Botswana

Parameter (mg/l)	Potential Streams	Ephemeral Streams
pH	6.5 - 9.5	5.5 - 9.0
Dissolved Oxygen	75	75
BOD	20	30
COD	30	75
Ammonia (as N)	1.0	10
Nitrate	2.0	-
Total Phosphorus	1.5	-
Sodium	400	600
Total Dissolved Solids	1000	2000
Total Coliform/100ml	5000	20000
Faecal Copliform/100ml	100	500

Apart from these permissible levels a proposed effluent quality guideline for industrial effluents entering public sewers follows on Table 14.3 (DLGSM, 1994). Although flexibility in standard setting is required, especially in developing countries where compliance seems unattainable, there are parameters which should always be included in setting wastewater quality standards, such substances as scum and grease, dissolved and suspended solids, dissolved oxygen, BOD, COD and coliform bacteria. Although these are not exhaustive, their presence indicates the level of contamination of the water.

Table 14.3: Guidelines for Industrial Effluents Entering Public Sewers (*Source:* DLGSM, 1994)

Parameter	Limitation
pH	6.0 - 9.5
Ammonia, mg/l	< = 100
TDS, mg/l	<=3000
Temperature, degC	<= 43
BOD, mg/l	As stated on trade effluent agreement
TSS	<i>no limit</i>

Effluent Quality Assessment

Trade Effluent

The Trade Effluent Agreement between wastewater treatment authorities and industries is used to assess the quality of water from these industries entering sewers.

Quality Monitoring

The quality of effluent from treatment processes undergoes physical and biochemical monitoring. Physical inspections may be carried out to assess treatment efficiency of the systems. Further assessment involves monitoring the quality of effluent from wastewater treatment plants, and making recommendations regarding their treatment efficiency.

Effluent Discharge Permits

The government of Botswana through the Water Appointment Board issues water rights and effluent discharge permits to deserving applicants. This system makes it easier to trace sources of water pollution and to deny polluters such permits until they mitigate any pollution they have caused.

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CHAPTER 15

AN OVERVIEW OF WASTEWATER TREATMENT IN DEVELOPING COUNTRIES

J S N Khupe

**Faculty of Engineering and Technology
University of Botswana
Private Bag 0022
Gaborone, Botswana**

**Phone: 267-3552524 Fax: 267-356591
E-mail: khupej@noka.ub.bw**

An Overview of Wastewater Treatment in Developing Countries

Introduction

Basic requirements for lasting health improvements are *wholesome water supply*; appropriate *wastewater collection, treatment and disposal systems*; appropriate *excreta disposal systems*; and general understanding of public health programmes.

Every community produces both liquid and solid wastes. The liquid portion is essentially the water supply that has been fouled by a variety of uses. Wastewater may be of domestic and institutional or commercial and industry origin. In addition surface and storm water sources are included in the design of sewers and sewage treatment plants.

Water used in processes (industrial, domestic, etc) generates wastewater which has to be disposed of safely. If wastewater is not treated its accumulations will lead to *decomposition of organic matter* resulting in the release of offensive odours, will contain numerous *pathogens* which cause diseases, will contain nutrients which stimulate growth of aquatic plants, and may contain *toxic compounds*.

The above necessitates the immediate removal of wastewater from its sources of generation followed by treatment and disposal. The ultimate goal of wastewater management is the protection of the environment in a manner commensurate with public health, economic, social and political concerns.

Wastewater Quality

Suspended Solids (SS)

Suspended Solids (SS) give rise to the turbidity of a sewage and indicate the presence of various chemical and microbiological pollutants. SS are determined by filtering a measured volume of the wastewater and retaining the solids on a filter paper which is then oven dried and weighed.

Oxygen Demand (OD)

Oxygen Demand (OD) is the amount of oxygen required to oxidise the various organics within the sewage. OD is thus a gross and indirect measure of the

total organic load contained in the sewage. OD is usually expressed as chemical oxygen demand (COD) or biochemical oxygen demand (BOD). COD provide a measure for all organics while BOD provide a measure for only the amount of biodegradable organic matter contained in the sewage.

Pathogenic Micro-organisms

Sewage will contain all types of **pathogens** being excreted by the contributing population. These constitute a health hazard and any consideration about the treatment and disposal of sewage must take this hazard into account. The need to remove pathogens should therefore be borne in mind when selecting a type of treatment works to be built.

Toxic Chemicals

Sewage with industrial component may contain *metals, phenols, and other substances toxic to human and animal and plant life*. Decisions about treatment and disposal of such wastewater must be based on careful consideration of these toxic effects.

Effluent Quality and Disposal

Sewage treatment works are designed to *reduce the concentration of suspended solids and oxygen demand, pathogens and toxic chemicals to produce an effluent of a given quality*. The desired quality of an effluent required will depend on the ratio of effluent flow to the receiving water flow (on the dilution available), on the quality of the receiving water, and on the use to which the receiving water is put.

Several common features of tropical rivers seriously affect their use as receiving waters for effluent discharges.

- ❑ *There is often a large difference between minimum and maximum flows.* At some times of the year heavy rains in the catchment will cause high flows whereas at other times flows will be low or non existent. At periods of low flow, the dilution provided by the river may be minimal and the flow may be nearly or completely undiluted effluent. In such cases high effluent quality is required.
- ❑ *At warmer temperatures water will contain less oxygen and in addition the rate at which bacteria use up available oxygen will be increased.* These factors reduce the oxygen available to meet the Oxygen Demand of the effluent.

- ❑ *Tropical rivers are often turbid, having high silt load, and slow flowing. Both these features will further reduce the availability of oxygen. Turbid waters will inhibit photosynthesis and thus reduce the production of oxygen by algae. Sluggish flow will hinder the surface diffusion of oxygen into the water and the dispersal of the effluent.*

In many cases in developing countries the microbiological quality of the effluent is more important where the inhabitants of downstream villages drink untreated river water.

Industrial Waste

Factories in developing countries are often located in areas such as the peripheries of large cities where the surrounding population uses untreated surface water for domestic purposes. Effluent discharge in the surface water then poses a health risk to local communities. Industrial wastes may also endanger public health by contaminating irrigated food crops, by contaminating or killing fish which are a source of protein, or by affecting bathing places.

The flow of effluent might be seasonal, particularly from the many industries which process agricultural products, and pollution problems will be increased if the peak discharge coincides with the season of low flows in the streams and rivers. Fish could be killed and populations depending on the river for water supply will lose their source of water supply.

Many different industries produce harmful wastes. Food and drink industries tend to discharge heavy organic pollution, rendering heavy Oxygen Demand in urban streams used as water sources by low income groups. Problems are caused by dyes from textile factories, plating wastes from metal-finishing works, toxic effluents from chemical factories, heavy metal such as mercury and lead in waste from mines and factories.

Control

Most developing countries do not have adequate environmental control legislation, neither a body with clear responsibility, nor the means and authority to enforce it adequately. The cost of pollution control measures required for some industrial processes in the developed world may amount to 40% of the capital investment and 15% of operating costs. Clearly, because of this, there are savings, besides the reduction in its wage bill, which a corporation may make by moving a factory to a developing country, even if that means importing all the raw material and exporting the finished products. Politicians and administrators in developing countries are unwilling to deter the

foreign investment they seek for their countries industrial development. Besides, large foreign companies have the resources and the expertise to evade the pollution control authority.

It is impossible to lay down standards in advance for all possible pollutants. The system should be in terms of guidelines rather than standards. The responsibility for treatment of polluting wastes must rest with the polluter, and it would normally be preferable to apply special treatment required as the waste leaves the factory, rather than combine it with other wastes.

Where toxic or hazardous substances are concerned, the legislation should be in such a form that the pollution control agency can define which substances are to be included, that prior consent can be conditional and can be revoked. Control can be assisted if a register is kept of all hazardous substances imported or manufactured, including what quantities and involved, and where.

Wastewater Management

Handling of Human Excreta

Collection and disposal of excreta is very important for control of infectious diseases. There is a direct relationship between water supply, wastewater, excreta disposal and health.

There are two ways of disposing of human excreta:

- ❑ **On site disposal** - waste material is disposed of into a latrine or septic tank within the residential plot. On-site disposal facilities include the conventional pit latrines, Ventilated Improved Pit latrine (VIP), septic tanks, aqua-prives, composting latrines, pour flush latrines etc.
- ❑ **Off site disposal** - involves immediate removal of waste material through a network of sewers to the treatment works.

Rural Sanitation

This is not primarily a technical problem. There is a variety of on site disposal systems which are appropriate and cheap. Examples of these are pit, latrines, composting latrines, reed odourless latrine, multrum, etc.

The main problem with rural sanitation is to encourage the population to use and maintain the facilities. There are several reasons contributing to non use of latrines and among them are the following: strong cultural preferences; people require a reason or motivation for using a latrine (e.g. privacy); any kind of

latrine requires maintenance and will become fouled and offensive if not maintained.

Urban Sanitation

Around all major towns in developing countries the major problems are excreta and refuse disposal systems in low-income, high-density communities. The high density communities without adequate sanitation range from unplanned slums to planned high density housing areas where adequate sanitation has not been provided largely due to financial constraints. The most appropriate and convenient sanitation system under the circumstances is the conventional water borne sewage system but developing countries find the system inappropriate for several reasons, including the following:

Cost: High capital construction costs - laying sewers. Possible sources to finance the project if no donor; funds include borrowed money and repaid later, implying that the community must cover the repayment costs by sewerage charges or additional taxes, or the city must subsidise the sector at an opportunity cost to other sectors of public spending.

Water Use: Water borne systems use large amounts of drinking water (expensively treated) to merely transport wastes along pipes. In developing countries water is scarce and very expensive resource, frequently overloaded limited distribution systems, therefore water cannot be used extravagantly.

Water borne sewerage can be installed only in communities with individual house water connections; the majority of low income urban dwellers do not have this facility. Many of those with connections may have only intermittent supplies of water. Sewers can rapidly become blocked during the periods when the water is shut off.

Construction: Water borne sewerage is a complex system requiring careful and skilled construction if it is to operate smoothly. Such skills are generally in short supply in a developing country, forcing employment of expatriate companies, with subsequent loss of foreign exchange.

Sewer Laying: By and large, sewers must be laid in straight lines. To dig large trenches in straight lines through squatter settlements will necessitate the demolition of a substantial number of houses, which will often be socially and politically unacceptable.

Blockages: Conventional water borne systems are prone to blockages if large objects are fed into them. Materials used traditionally in certain areas for anal cleansing, such as sticks, stone, corn cobs, may also obstruct sewers.

Wastewater Treatment

On site Water borne Sewerage Systems

Septic Tank

A septic tank is an on site water borne sewage system suitable for areas with in-house water connections but without a network of sewers and a sewage treatment plant. All wastewater from the establishment is flushed into this system. The effluent overflows into a soak away or drain field while the solids settle at the bottom of the tank. It provides a high standard of hygiene and comfort; it needs little maintenance other than desludging at regular intervals.

The septic tank can be upgraded by connecting to a sewerage system using small bore sewers.

Aqua Privy

The system is based on the septic tank principle. In-house water connection is not a necessary criterion for its provision. It requires only sufficient water to clean the squatting plate and maintain a water seal to prevent fly breeding and odours. The system, like septic tank, can be upgraded by connecting to a sewerage system.

Sewerage Systems

Provision of water borne off site disposal system in a community is warranted when:

- ☐ there is sufficient water available and in-house connected;
- ☐ the population density is such that there is no room for on site disposal systems;
- ☐ the inhabitants can afford to install the required fixtures in the buildings; and
- ☐ existing water resources and the environment need protection against pollution.

Sewerage system if properly maintained, is the safest method of wastewater disposal as the waste is taken out of the premises to the treatment plant through a network of sewers. A sewerage system consists basically of a network of pipelines (called sewers) and manholes.

The sizes of sewer pipes depend on the amount of wastewater which is to flow through them. At the beginning of the sewer the flow may be minimal and this may result in deposition of particles in the sewer. These sewers therefore need periodic flushing to remove the accumulated particles.

Sewerage systems end at a treatment plant where wastewater is subjected to both physical and biological treatment. Some kind of industrial wastewater is sometimes subjected to chemical treatment. The end product of treatment is effluent which can be disposed of in different ways depending on its quality. A by-product of wastewater treatment is sludge. Sludge requires to be stabilised for safe handling and disposal.

Biological Wastewater Treatment Processing

There are three basic types of aerobic units:

- ☐ Percolating filter or bacteria bed;
- ☐ Activated sludge; and
- ☐ Stabilisation pond.

The *biological filter* and *activated sludge* rely on similar principles. The *stabilisation pond* which is only suited to warm climates operates somewhat differently utilising bacteria and algae.

Percolating Filter

The **percolating filter** consists basically of a bed of stones, circular or rectangular in plan with intermittent or continuous addition of settled sewage to the surface. On a conventional filter the medium is 50 - 100 mm preferably hard angular stone grading dosed by a rotating distributor mechanism, the normal depth of the bed being 1.8 m.

Liquid trickles through the interstices in the medium where micro-organisms grow in the protected areas forming a slime or film, the liquid flowing over the film rather than through it. The film consists primarily of bacteria, protozoa, and fungi that feed on waste organics.

The organisms attached to the media in the upper layer of bed grow rapidly, feeding on the abundant food supply. As the wastewater trickles downward, the organic content decreases to the point where micro-organisms in the lower zone are in a state of starvation. Thus the larger proportion of BOD is extracted in upper 0.6 to 0.9m of a 1.8 m filter. Excess microbial growth sloughing off the media is removed from the filter effluent by a final clarifier.

Operational problems include the following:

- ❑ **Effluent quality and odours** both associated with organic loading, industrial wastes, and cold weather;
- ❑ **Filter flies**, which breed in sheltered zones of the media; and
- ❑ **Ponding**

Activated Sludge (Biological Aeration)

Activated sludge process depends on the use of high concentration of micro-organisms present as a floc kept suspended by agitation with either compressed air or mechanical agitation. In either case high rates of oxygen transfer are possible.

Raw wastewater flowing into the aeration basin contains organic matter (BOD) as food supply. Bacteria metabolise the waste solids, producing new growth while taking dissolved oxygen and releasing carbon dioxide. Protozoa graze on bacteria for energy to reproduce. Some of the microbial growths die, releasing cell contents to solution for synthesis. After addition of a large population of micro-organisms, aerating raw wastewater for a few hours removes organic matter from solution by synthesis into microbial cells. Mixed liquor is continuously transferred to a clarifier for gravity separation of the biological floc and discharge of the clarified effluent. Settled floc is returned continuously to the aeration basin for mixing with entering raw wastewater.

The activated sludge process though found in several developing countries has the following disadvantages:

- ❑ It is a highly technical system requiring highly trained technical staff which is relatively in short supply in a lot of developing countries;
- ❑ Complex design;
- ❑ High construction and maintenance costs;
- ❑ Complex electro-mechanical equipment for energy input; and
- ❑ Final effluent needs tertiary treatment in order to be safely re-used.

Stabilisation Ponds

Waste stabilisation ponds are large shallow man made lakes, usually

rectangular in plan and between 1 - 5 m deep, in which raw wastewater is treated through natural biological and physical processes. They require no mechanical equipment.

There are three types of ponds - *anaerobic*, *facultative* and *maturation*. Each type has a specific function. Anaerobic ponds are included when treating strong wastes. Facultative ponds used for treating normal domestic wastes. Maturation ponds are used for the reduction of faecal bacteria.

Anaerobic Ponds

Anaerobic ponds receive raw wastewater, with solids which settle down to undergo anaerobic digestion. By using anaerobic ponds total land requirement for the system could be reduced:

Depth:	3 - 5 m
Detention time :	5 days
BOD reduction:	60 - 70%
Desludging period:	Every 5 years

Facultative Ponds

Facultative ponds are commonly employed for stabilising municipal wastewater. The bacterial reactions include both anaerobic and aerobic decomposition of organic matter, and hence, the term facultative pond.

Waste organics in suspension are broken down by bacteria releasing nitrogen and phosphorus nutrients and carbon dioxide. Algae use these inorganic compounds for growth along with energy from sunlight, releasing oxygen to solution. Dissolved oxygen is in turn taken up by the bacteria, thus closing the symbiotic cycle. Oxygen is also introduced by re-aeration through wind action. Settleable solids decomposed under anaerobic conditions on the bottom yield inorganic nutrients and odourous compounds. The latter are generally oxidised in the aerobic surface water, thus preventing their emission to the atmosphere.

Depth:	1.5 - 2 m
Detention time :	20-40 days
BOD reduction:	60 - 99%
Desludging period:	Every 5 years

It follows that anaerobic pond desludging is not necessary.

Maturation Ponds

Maturation ponds follow the facultative pond principles. Wholly aerobic. May also serve as tertiary treatment for the effluent from a conventional treatment plant with primary and secondary treatment.

Depth:	1 m
Detention time:	7 days (usually the result of two ponds)
Pathogen removal:	99.999%

Appropriate Technology

Stabilisation ponds system is mostly effective in warmer climates. Most of the developing countries fall within this category. The following reasons make stabilisation ponds the most appropriate wastewater treatment system for developing countries.

- ☐ Does not require highly trained technical staff for its management;
- ☐ Low cost, simple operation, and easy maintenance;
- ☐ High pathogen removal, effluent can be re-used for unrestricted irrigation;
- ☐ Useful also for treating variety of industrial wastes; and
- ☐ Long detention time facilitates acceptance of shock loads.

The two main problems are as follows but are far outweighed by the advantages:

- ☐ Large land required; and
- ☐ Problems of smell and mosquitoes.

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CHAPTER 16

MICROBIOLOGICAL ASSESSMENT AND MONITORING OF ENVIRONMENTAL POLLUTANTS

Sesai Mpuchane

**Department of Biological Sciences
University of Botswana
Gaborone, Botswana**

**Phone: 267 3552601 Fax: 267 3552784
E-mail: mpuchanes@noka.ub.bw**

Microbiological Assessment and Monitoring of Environmental Pollutants

Introduction

Individuals and governments have shown a great concern about the quality of the environment. Many governmental and non-governmental organisations are committed to activities that will reduce the effects of pollution of air, soil and water. Pollution does not only affect man, but also has grave effects on domestic livestock, wildlife, climate, forests and crops. Pollution management therefore needs to be prioritised by all governments.

In order to have a successful pollution management programme, some basic information about the pollutants is essential. The type(s) of pollutants present, their source, distribution and effects on the environment must be known. The cost of any remedial action must also be considered. It must be appreciated that the list of pollutants is extensive. For instance over 1,500 pollutants have been listed in the “black list” and the “grey list” depending on the levels of toxicity. (Mason 1991). It is also common to find more than one pollutant in specific environments and therefore effects on the environment could be complex.

Table 16.1: Categories of Pollutants found in Fresh Water
(*Source:* Mason 1991)

Acids and Alkalis
Anions (eg sulphide, sulphite, cyanide)
Detergents
Domestic Sewage and Farm manures
Food Processing Wastes (including processes taking place on the farm)
Gases (eg chlorine, ammonia)
Heavy metals (eg cadmium, zinc, lead)
Nutrients (especially phosphates and nitrates)
Oil and Oil Dispersants
Organic Toxic Wastes (eg formaldehydes, phenols)
Pathogens
Pesticides
Polychlorinated Biphenyls (PCBs)
Radionuclides

Table 16.1 shows the various categories of pollutants found in fresh water. These may either be *organic or inorganic* and can be *viable (in the case of microbes)* or *non-viable* and are caused by various factors.

General: Some Commonly Discussed Causes of Pollution

Some commonly discussed causes of pollution are heat, radionuclides, oil, heavy metals and organochlorines. Their effects on the environment and on living things are widespread.

Heat Pollution

A number of power utility industrial plants (e.g. electricity generating) generate heat which require large volumes of cooling water. This water is taken from the environment and later returned at a much higher temperature. This increase in temperature called thermal pollution changes the density and oxygen concentration of water. This will inevitably alter the biological species. For instance, Blue-green algae will dominate as they are tolerant of these elevated temperatures. Bacterial populations will also change with varying temperatures.

Radionuclide Sources of Pollution

There are various natural sources of radioactivity in nature. In nuclear power stations, water from the environment is used for cooling. This cooling water may acquire some radioactivity which is discharged into water bodies. Disposal of nuclear wastes in the environment also poses risks because disposal sites eventually leak and contaminate surface and ground water. The same may occur as a result of nuclear industry accidents. The occurrence of such radio nuclides may cause acute toxicity or chronic effects to man, fish, aquatic birds and shellfish.

Oil Pollution

The pollution of water bodies by oil affects fish, birds and plants. A number of micro-organisms are stimulated in the presence of oil. The ecology of water ecosystem changes in response to the generally deleterious effects of pollution.

Heavy Metals

Heavy metals are termed conservative pollutants since they are either not broken down or they are, over a long period of time. Examples are mercury, cadmium and lead, which are known to affect human life. Sources of heavy metal pollution are: weathering of rocks, bearing them, volcanic eruptions, fossils fuel, burning, paints, instruments, horticultural sprays. Fish take in heavy metals in their diet or through their gills. Mercury, for instance, accumulates in fish and while there is no apparent disadvantage to the fish, vertebrates (eg birds) that

feed on the fish are at risk. Cadmium poisoning is associated with kidney damage in human and lead poisoning affects fish, water fowl and human.

Other Pollutants

Other important pollutants are **organochlorides** such as insecticides and polychlorinated biphenyls (PCBs) that are found in air and water. Toxicity to fish, various invertebrates and mammals has been demonstrated.

Effective Management of Pollution

For *effective management of pollution*, one needs to know the following:

- ☐ The substances entering the environment and their quantities, sources, distribution.
- ☐ Effects of these substances within the environment.
- ☐ Trends in concentrations and effects, and causes of these changes.
- ☐ How far these inputs, concentrations, effects and trends can be modified and by what means, at what costs.

A decision one has to make in monitoring the levels of pollution is whether to use biological or non-biological strategies. Biological species respond to intermittent pollution. In most environments, the activity of axenic cultures results in many different intermediates of pollutants. Biological samplers can easily pick these different substances. Chemical sampling programmes could miss these pollutants since they are programmed only for specific pollutants. It would be very costly to programme for all the pollutants available, let alone their intermediate breakdown products.

Normally, effluents contain a variety of pollutants and not single ones. Pollutants occurring together may act completely independently on the target, in that case one may find a dominant pollutant whose effects is most felt by the target; others may have an additive antagonistic or synergistic effects.

Biological Strategies

Once the decision to use Biological strategies to monitor pollution has been made, one has to find an organism that is suitable for bioassays. Such an organism must have the following characteristics:

- ❑ The organism must be *sensitive to the material or environmental factors* under consideration;
- ❑ It must be *widely distributed and readily available* in good numbers throughout the year;
- ❑ It should have *economic, recreational or ecological importance* both locally and nationally;
- ❑ it should be *easily cultured* in the laboratory;
- ❑ it should be *in good condition, free from parasites or disease*;
- ❑ it should be *suitable for bioassay testing*.

Small organisms with short generation times are preferred for bioassays. Fish are also used as they are important, in demonstrating long term effects of exposure to pollutants.

There are two types of bioassays: *biostimulation* and *toxicity tests*:

Biostimulation tests are used, for instance, to evaluate the nutrient status of a water body (eg. with algae), to distinguish between total and available nutrients to organisms and to determine effects of changing water quality on growth.

Toxicity tests on the other hand are used for screening of chemicals to determine the risks associated with various pollutants.

A number of organisms act as *bioaccumulators* (Mitchell, 1992). Pollutants are concentrated in the tissues of organisms. These pollutants can be measured on site. Bioaccumulators can be placed in the environment and rates of uptake can be measured over a period of time. Pollution levels at different sites and at different times of the year can be determined. There are various examples of bioaccumulators.

- ❑ **Mosses** are used to monitor heavy metals such as lead, copper cadmium;
- ❑ **Bivalves** have been used to monitor pesticide pollution by dieldrin.;
- ❑ **Eels** accumulate mercury and can be used for monitoring its levels.

Microorganism Interaction with Pollutants

Micro-organisms interact with pollutants in many ways (Yuerrero and Pedros-Alio 1992 and Mason, 1991). Toxic metal wastes in water are detrimental to health. Such metals tend to get concentrated in cells of various micro-organisms, such as fish and micro-organisms. There are also several microbe-metal interactions that enable us to use microorganisms in bioassays (Bitton, 1994):

- ❑ **Intracellular accumulation:** metals are found concentrated within microbial cells.
- ❑ **Cell Wall Associated Metals:** this is due to the presence of specific functional groups.
- ❑ **Metal Siderophore Interactions:** these are excreted by microbes and have strong affinity to iron. Some bind to copper and molybdenum.
- ❑ **Extracellular Mobilisation/Immobilisation** of metals by bacterial metabolites resulting in leaching of metals as a result of acid metabolite production by microbes or through metal oxidation.
- ❑ **Extracellular Polymer-metal Interactions:** extracellular polysaccharides produced by microbes may bind strongly to some metals.
- ❑ **Transformation and volatilisation of metals:** eg formation of elemental mercury.

Pollutants may be detoxified by physiochemical or microbiological processes. Microbes are involved in transformations that reduce the effects of pollutants in the environment by *bioleaching, biosorption and bioprecipitation*. Microbes do this for the following reasons:

- ❑ To satisfy their nutritional requirements;
- ❑ To satisfy energy requirements;
- ❑ to detoxify their immediate environment as part of metabolic processes; and
- ❑ Physical/chemical characteristics of microbial cell may offer no advantage to microbial population.

Examples of Physiochemical or Microbiological Activities

Examples of these activities include the following:

- ❑ *Cyanobacteria* - base metals;
- ❑ *Algae (chlorella)* - base metals, lead, precious metals;
- ❑ *Fungi* - radionuclides; and
- ❑ *Pseudomonas fluorescence* - chromate;
- ❑ *Alternaria (fungus)* - selenium;
- ❑ Non-living bacterial, fungal, lead, zinc, nickel, cobalt, algal biomass;
- ❑ *Thiobacillus thiooxidans*-iron chromium (leaching by H₂SO₄); and
- ❑ *Thiobacillus ferrooxidans* - pyrite from coal (oxidation)

Biological assessment of water quality may be done in the field or in the laboratory.

In the field, this is done in three stages (Mason, 1991):

- ❑ **Surveys:** a programme of measurements that defines a pattern of variation of a parameter in space eg. measuring the level of a heavy metal 'X' present in effluent by determining its level in a sample gives information at a particular time.
- ❑ **Surveillance:** repeated measurements of a variable to establish a trend, eg. measuring for heavy metal 'X' in the effluent over a period of time.
- ❑ **Monitoring:** a policy for managing pollution might be put in place to lower the level of metal 'X' by some percentage. One must make observations of whether the reduction it adheres to standards.

Examples of Indicator Organisms

In the laboratory, one uses intrusive micro-organisms. For instance, in the monitoring of pathogens in water there is a heavy reliance on laboratory analysis. Several pathogenic microbes are associated with wastewater. The origin of these microbes are mainly faeces. These bacteria are grouped as follows:-

- ❑ Gram-negative facultatively anaerobic bacteria (eg *Vibrio*, *Escherichia*, *Klebsiella*, *Shigella*);
- ❑ Gram-negative aerobic bacteria (eg *Pseudomonas*, *Flavobacterium*);
- ❑ Gram-positive spore forming bacteria (eg *Bacillus*); and
- ❑ Non spore forming gram-positive bacteria (eg *Arthrobacter*, *Corynebacterium*).

A number of these micro-organisms cause diseases such as typhoid fever, cholera, *shigellosis*, *gastroenteritis*).

Proper sampling is important for accurate monitoring of water bodies:

- ❑ **Containers:** Samples are collected in bottles that have been cleansed and rinsed carefully. Final rinse should be with distilled water before sterilisation.
- ❑ **Dechlorination:** Add a reducing agent to containers intended for collection of water or wastewater effluents having residual chlorine or other halogens. Sodium thiosulphate neutralises residual halogens and prevents continued bactericidal action during sample transit.
- ❑ **Sampling:** Leave enough space in the bottle when sampling to enable adequate shaking of sample before examination. Samples should be representative (use sampling locations at critical sites). Sampling frequency is also critical. One can use manual sampling or sampling apparatus.
- ❑ **Size of sample:** The volume of sample should be adequate to carry out all tests. The normal size is 100 ml;
- ❑ **Sample identification:** Samples must be properly identified (location of sample, date and time of collection etc).

Proper laboratory analysis is also as important as sampling. One has to decide on which method of analysis to use: a heterotrophic plate count is done using either the pour plate or spread plate method. Sample should give 30-300 CFU/Plate (using a Quebec colony counter for manual counting or automatic plate counting instruments that use a television scanner coupled to a magnifying lens and an electronics package). One can use general, selective or differential media, to identify specific microorganisms.

- ❑ **Direct total microbial count** are obtained from counting stained cells under the microscope. Counts include viable and non-viable counts, and therefore tend to be exaggerated.
- ❑ **Membrane filter method (MF):** This method uses a microbiological filter. Large volumes of water are filtered through 47 mm, 45 m gridded MF, under partial vacuum. The filter is later placed on agar in a petri dish, incubated and the colonies that develop are counted.
- ❑ The most probable number method is used routinely in water analysis. Normally, this test is done in three steps, the presumptive, confirmed and

completed test. Most Probable Numbers (MPN) tables are used to read the results of the three tube or five tube method. The MPN tends to give higher counts than other methods.

Table 2.2: Examples of Indicator Mechanisms

Indicators	Examples	Purpose	Character
Total Coliforms	<i>E.coli</i> Enterobacter Klebsiella	Determining Quality of potable water recreational waters	Aerobic & Facultative. Anaerobic gram negative, Rod-shaped bacteria, Ferment lactose with gas production within 48 Hrs @ 35°C
Faecal Coliforms	<i>E.coli</i> Klebsiella Pneumonia	Presence of faecal material from warm blooded organisms.	Ferment lactose at 44°C
Faecal Streptococci	<i>Streptococcus</i> <i>Faccalis</i> <i>S.bovis</i> <i>S.equinus</i> <i>S.Avium</i>	Faecal contamination in <i>water</i>	
Anaerobic Bacteria	<i>Costridium</i> <i>Perfringens</i>	Indicator of past pollution tracer to follow fate of pathogens eg faecal pollutions in marine environments	Gram-positive spore forming rod pores are resistant to many environmental stress
Bacterio-phages	Colihages	Water quality indicators in estuarie, estuaries, seawater, recreational water, potable water. Provides information of water treatment process such as coagulation, flocculation sand filtration absorption to activated carbon & disinfection.	

	Androphages	Index of Contamination.	Resists disinfection Present in high numbers.
Yeasts and Acid Fast Organisms	Mycobacterium Fortuitum M. phlei	Indicators of Disinfection, Efficiency.	Resistant to chlorine/ ozone than <i>E.coli</i> .
Heterotrophic plate count	Pseudomonas Aeromonas Klebsiella Flavobacterium Proteus Citrobacter	Sensitive for the removal & activators of microbial pathogens in wastewater.	Influenced by temperature chlorine residual assimilable organic matter.

When monitoring pathogens in water, indicator organisms are used. (Table 2 2). Micro-organisms may be used as indicators for the following reasons:

- ☐ Occurrence of faecal contamination;
- ☐ Efficiency of the treatment process;
- ☐ Efficiency of wastewater treatment plants; and
- ☐ Post process contamination of water during distribution.

For an organism to be used as an indicator in water analysis, it must satisfy the following criteria:

- ☐ It should be a *member of the intestinal microflora* or warm blooded animals.
- ☐ It should be *present when pathogens are present* and absent in uncontaminated samples.
- ☐ It should be *present in greater numbers than the pathogens*.
- ☐ It should be at least *equally resistant as the pathogen* to environmental insults and to disinfection in water and wastewater treatment plants.
- ☐ It should *not multiply in the environment*.
- ☐ it should *be detectable by means of easy rapid and inexpensive methods*.
- ☐ The indicator organisms *should be non pathogenic*.

Chemical Indicators of Water Quality

Some laboratories use chemical indicators to determine if a water body is polluted. Table 16.3 shows some chemicals that are used as indicators.

Table 16.3: Chemical Indicators of Water Quality

Indicators	Examples	Purpose
Faecal sterols	Coprostanol Coprosterol Cholesterol Coprostanone	Indicate faecal contamination

Total coliforms are detected by the most probable numbers (MPN) technique or by the membrane filtration technique. The MPN generally overestimates the coliform numbers. The recovery of coliforms depends on: type of medium, the diluent and membrane filter used, presence of non coliforms, turbidity, occurrence of injured bacteria in environmental samples (due to physical, chemical or biological factors).

Enzymatic Assays

The assays are specific, sensitive and rapid.

1) Galactosidase Activity

Galactosidase activity is deployed for total coliforms in water and wastewater. Based on the hydrolysis of o-nitrophenyl - B-D-galactopyranoside (ONPG) to yellow nitrophenol.

2) Glucuronidase Activity

Glucuronidase activity is deployed for detection of *E.coli*. The method is based on the hydrolysis of a fluorogenic substance. 4-methylumbelliferone glucuronide (MUG) by glucuronidase, an enzyme found in *E.coli*. End products are fluorescent and are detected using UV light.

Monoclonal antibodies: *E.coli* can be detected by using **monoclonal antibodies** against outer membrane proteins or against phosphatase in the periplasmic space. This technique still needs to be developed further.

Polymerase Chain Reaction (PCR)/Gene Probe Detection: This is a very

sensitive method. Specific genes of *E. coli* are amplified by the PCR and subsequently detected with a gene probe. (one can detect 1-5 cells/100ml water).

When one uses the MPN method, a change in the fermentation medium and temperature of incubation, can select for specific indicators. This method is simple and can be relied upon.

In many laboratories in developing countries, the methods that are used for monitoring faecal pollutants in water are: the HPC, MF and the MPN. These can be performed with basic equipment and when carefully done, they give reproducible results. They are therefore within the reach of most laboratories in the developing countries.

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CHAPTER 17

COASTAL AND MARINE POLLUTION WITH REFERENCE TO THE RIO DEL REY BENIN IN THE CAMEROON

Georges Ekosse

**Geology Department
University of Botswana
Private Bag 0022
Gaborone, Botswana**

**Phone: 267-3552524 Fax: 267-356591
E-mail: ekosseg@noka.ub.bw**

Coastal and Marine Pollution with Reference to The Rio Del Rey Benin in the Cameroon

Introduction

Coastal and marine pollution is of growing concern to environmentalists, governments, inter-governmental organisations (IGO) and non-governmental organisations (NGO). Most *coastal areas* of the world are contaminated especially with untreated or inadequately treated sewage and sediment from land clearing and erosion. *Seas and oceans* are polluted with hydrocarbonated effluents and the dumping of industrial wastes. Due to high levels of pollution indicators, oceans and seas take longer time in the dilution, dispersal and degradation of sewage, sludge, oil, and industrial wastes.

This chapter *discusses the geochemical and environmental implications resulting from environmental terrorism, spillage, seepage, acid rain, secondary porosity, heavy ions migration, false geochemical anomaly and contamination of subsurface waters in the light of coastal and marine pollution.* The geochemical implications of discharging untreated hydrocarbonated industrial effluents is considered with special reference to the Cameroon coastal and marine waters.

Short-term and long-term measures to reduce and prevent the pollution of coastal and marine areas are recommended. Useful pollution prevention methods are suggested in the paper. Some ways of cleaning up hydrocarbonated spills in coastal and marine areas are highlighted. The roles to be played by government and inter-governmental agencies as well as non-governmental organisations in monitoring and controlling coastal and marine environments as well as implementing policies and regulations that aim to make the seas and coasts to be pollution-free areas are emphasised.

General

The oceans cover 70% of the surface of the earth and play a very vital role in the survival of life on earth. The ocean waters form an integral part of the global hydrologic cycle, influence the earth's climate and participate in many biogeochemical activities.

The ocean peripheries form the coastal zones which are characterised by warm, nutrient rich, shallow water that slopes gently into the continental shelf. Coastal zones occupy 10% of oceanic area and probably water, and contains 90% of all ocean dwelling organisms. The open seas contain 90% of ocean area and about 10% of ocean species. The coastal areas are more susceptible to pollution than the open seas.

Until recently, pollution was not a concern in developing countries. The degree of pollution of coastal and marine waters is reaching an alarming stage which calls for action. There is every probability that if unchecked, may pose serious danger to our public health and socio-economic development. The effects of coastal and marine pollution have far reaching consequences and cannot be overemphasised.

Seepage and Heavy Ions Migration

Heavy metals in their ionic state migrate. It is possible to have “natural pollution” of streams, rivers and soils due to anomalously high concentrations of the metals. Migration of anomalous ionic concentrations of heavy metals into the seas and oceans eventually leads to regional coastal and marine pollution. Heavy metal such as mercury poses dangerous problems for human health and marine ecosystems: the Minamata disease that started in Japan (Fergusson, 1990), and Iraqi who died of mercury poisoning (Kazantis, 1980) are documented reminders of the kind of tragedy that can befall the humankind. *The discharge of heavy metals into seas and oceans causes an increase of concentration of the metals in living organisms. When threshold values are exceeded, toxic consequences occur, and humanity is not left out.*

Oil Pollution

In 1989 three billion tons of oil was consumed worldwide (Alloway and Ayres, 1993), and the consumption has been on the increase. Crude and refined oil are either accidentally or intentionally discharged into the seas and coasts. *Studies (Miller, 1993) show that more than 50% of the oil polluting the seas and coasts comes from waste oil. Oil is the main pollutant in most seas, oceans and coastal areas.*

The Mediterranean Sea is probably on the way of becoming a dead sea. An International Conference in 1971 on the island of Malta selected the Mediterranean Sea as a prototype of a polluted sea. Scientists and diplomats from 30 countries agreed on the need for multilateral pollution control legislation to help save the Mediterranean Sea. *The consensus was that oil is a serious pollutant and new legislation should be formulated to control oil tankers, refineries, terminal pipelines and the discharge of tank washings from all carriers (Lansford, 1979).*

Oil Spillage and Environmental Terrorism

Oil Spillage

Oil spillage is not technically waste disposal but is an important pollution event

(Alloway and Ayres, 1993). About 5% of oil discharged into the seas and oceans is due to tanker accidents – 23% from operational discharges, 40% associated with transportation and 45% for land and coastal refineries (Alloway and Ayres, 1993). Oil spills associated with tanker accidents must be seriously considered because of the strong potential for ecological and economic damages. The concentrated slick affects fisheries and tourism industries, and marine ecosystems.

Oil slicks can spread either very rapidly or very slowly depending on a number of factors: oil quality, oil quantity, ocean and sea conditions, rate of evaporation of volatile components and rate of dissolution of certain classes of aromatic hydrocarbons. Floating oil mousse is transported very fast to beaches as tar balls.

Examples of Spillage

A number of documented cases of oil spills with huge ecological and economic losses were from:

The Atlantic Express released 276,000 tons of oil affected Tobago in 1979. The *Castello Belver* released 256,000 tons of oil and affected South Africa in 1983. The *Amoco Cadiz* released 2,239,000 tons of oil and affected France in 1978.

The Exxon Valdez released 45,000 of oil and affected Alaska in 1989. The *Brear* released 85,000 tons and affected Scotland. The *North Cape Oil Spill* released 828,000 gallons of oil and affected the USA in 1997. The *Exxon Valdez* and *North Cape Oil* spills are further discussed.

The Exxon Valdez Oil Spill

On 24 March, 1989, the *Prince William Sound* was so far the biggest oil spill in the United States Waters. The full consequence of the disaster may never be known for decades. Research so far carried out reports of the fate, transport, effect of oil on biotal and archeological sites resulting from the incident. A comprehensive analysis of the water has been carried out to verify the containment of hydrocarbons. Results reported on the Internet showed that the extent of oiling declined substantially between 1989 and 1992 and the oil was located in the biologically least productive upper tidal and supratidal zones. Pockets of subsurface oil could probably still be found in the intertidal or supratidal zones. Clay flocculation created solids-stabilised oil-in-water emulsions on shoreline sediments and these emulsions of complex and varied floc aggregates reacted with hydrodynamic forces beneficiating and accelerating the removal of oil from shoreline sediments.

Investigation proved that immediate cause of the accident could be the result of a drunken captain. The oil company (Exxon) pleaded guilty to federal felony and misdemeanour charges. Exxon has spent about \$500 million dollars and still faces lawsuits to the tune of \$59 billion dollars.

The North Cape Oil Spill

On 19 January, 1997, the North Cape barge was grounded after the tug boat pushing it caught fire in a very severe winter storm. Oil spill has treated the main ecosystem affecting lives of fish, birds and recreational beaches. Although the EPA regulations stipulate loppin of hydrocarbon in marine and coastal waters to be considered harmful to marine life, yet there is damage to the fragile ponds and marshes which serve as breeding places for shellfish. Clean-up exercises were prompt. That notwithstanding, there is evidence of damage and until the next few decades a thorough damage evaluation will not be realised.

Environmental Terrorism

It is reported widely that during the Gulf war, the Iraqi's deliberately discharged oil into the Persian Gulf. Fires which were difficult to put out in war time, were set on many oil wells. Marine life was destroyed and smoke rich in polycyclic aromatic hydrocarbons (TAH) was discharged into the atmosphere affecting regional weather patterns.

These acts of environmental terrorism caused very serious damage to the ecosystem and may affect posterity if not abated.

Oil Spill Management

Because of the economic and ecological implications of oil spills, there is need to have spill response operations on board oil tankers. Effective customised courses tailored to meet this need have been implemented at the Centre for Marine Training and Safety in the United States of America.

Training programmes incorporate aspects like movement, containment and clean up of oil; use and operation of boom and skinullers; shoreline protection, clean-up and restoration; oil recovery from soil and oily debris disposal; containing and recovering of oil from surface waters; and prevention of oil spills. A number of companies are engaged in the manufacturing of propylene absorbents for oil and chemical spills, and a range of oil skimmers and oil water separation systems.

Environmental Implications

Lansford (1979) reported that new and complex chemical processes used in industry have increased the possibility of releasing pollutants that are hard to detect and control. Wastewater from municipalities, schools and colleges and industries, feed lots and swarms, may be sources of bacteria and other micro-organisms capable to producing diseases in human beings and animals including livestock. These pathogens cause infection of the intestinal tract namely typhoid and paratyphoid fever, bacillary and amoebic dysentery, cholera and viral hepatitis.

Mercury, a waste product of a variety of industries, moves along the food chain from water and plants to fish, birds and humans. Marine life, especially fish in mercury polluted waters become contaminated with methyl mercury (CH_3Hg) as a result of mercurial waste discharge. Contaminated fish is eaten. Methyl mercury as a result of mercurial waste drain through the blood, resulting in severe neurological diseases such as blindness, deafness and intellectual deterioration. Obidiwe (1990) pointed out that it is not common to find polychlorinated biphenyls (PCBs) in industry effluents discharged into seas and oceans. PCB is highly resistant to both heat and biological degradation, soluble in water, carcinogenic, mutagenic and teratogenic. Polyvinyl chloride (PVC) and polythene are not biodegradable and they cause serious aesthetic and carcinogenic problems.

Most coastal areas serve as *drainage deltaic and estuarine river basins*. Coastal areas are generally shallow and serve as *pollution acceptors*. High levels of phosphate and nitrate plant nutrients have risen sharply in polluted coastal areas causing *algal blooms and oxygen depletion*. Industrial toxic wastes that find themselves in marine and coastal environments have posed as *vectors of health hazards*.

The Chesapeake Bay in the USA is the largest source of blue crabs in the world and of oysters in the United States (Miller, 1992). It is also an important recreational sporting area for shipping, boating, sailing and sport fishing. The bay has experienced a population growth of 500% within the last 50 years. Nine large rivers and 141 streams and creeks serve as pollution channels to the bay. With less than 1% of waste entering the bay flushed into the Atlantic ocean, it is evident that agents of pollution from domestic, recreational and industrial activities are at play. Million (1992) reports that point source discharge of numerous toxic wastes is a major problem, and this has affected the commercial harvesting of sea food in the area. The Federal and State Government of the United States are engaged in a clean-up exercise of the area which will eventually cost several billion dollars!

Geochemical Implications

Not until recently, the geochemistry of migration of hydrocarbon fluids has been discussed from a more or less theoretical standpoint by many investigators such as Banker (1967), McAuliffe (1966), Cordel (1973) and Price (1976). Although advanced technology and improved methods of instrumentation have facilitated the study of geochemical aspects of oils occurring in the natural environment, the circumstances under which meaningful information relating to oil exploration and pollution can be gathered are rather restrictive.

Secondary porosity is significant to dominant in many reservoirs. Zuhair (1981) reported that secondary porosity is as a result of dissolution of carbonate minerals, feldspars, rock fragments, aggregates and pellets. Carbonic acid is considered to be the primary agent responsible for dissolution of these materials. Continued reaction of constituents with carbonic acid results, in the long run, in changes in water composition and corresponding partial dissolution of silica. The availability of carbon dioxide in the hydrodynamic system accompanies changes in fluid pressure. Generation and migration of hydrocarbons and carbon dioxide creates abnormal pore pressure which results in the formation of open fractures.

The baseline distribution of hydrocarbons over a wide area is an important factor to be considered when prospecting techniques to locate any anomalous occurrences of hydrocarbons. Anomalous hydrocarbon compositions of surface and subsurface sediments could confirm seepage which may aid in locating previously unidentified petroleum sources for future exploration.

Alternatively, such measurements could also indicate pollution resulting from fossil fuel development or other anthropogenic activity (Venkatesan, 1983).

The dissolution of feldspar is enhanced by increasing concentration of carbon dioxide in the reservoir fluid, and dissolved silica are the main constituents released into solution. The solubility of silica may be accompanied by the following mechanisms:

- ❑ An increase in pH of the solution as a result of consumption of feldspar
- ❑ Shift in the reaction of silica and water to favour dissolution of quartz
$$\text{SiO}_2 + 2\text{H}_2\text{O} \rightarrow \text{Si(O)}_4$$
- ❑ Dissolution of quartz occurring as a result of reaction between silicic acid and bicarbonate ion
$$\text{H}_4\text{SiO}_4 + \text{HCO}_3 \rightarrow \text{H}_3\text{SiO}_4 + \text{CO}_2 + \text{H}_2\text{O}$$
- ❑ Increase in solubility of quartz with increasing temperature.

Major alteration products such as kaolinite, illite and chlorite depend mainly on the concentration of carbon dioxide, the resident time of reaction the primary minerals and initial composition of formation of water. Detailed core description data on the visual redox boundaries, mineralogy, and hydrostratigraphy constitute the foundation for geochemical investigations of contaminant migration from waste dumps (Bimal, 1989). Unstable geochemical parameters such as pH, redox couples, alkalinity, specific conductance, temperature, major and minor elements are useful parameters in monitoring and controlling of contaminant migration in subsurface waters along coastlines.

Point Source Study: The National Refinery Corporation, Limbe, The Cameroon

The National Refinery Corporation in Cameroon is located within the outskirts of Linibe Municipality which is part of the Rio Del Rey Basin, at the shores of the Atlantic Ocean.

The Geology

The sedimentary basins of Cameroon are mentioned. Further discussion of the structure and stratigraphy is focused on the Rio del Rey Basin due to on-going oil exploration activities.

Sedimentary Basins

There are five major basins in Cameroon: Three coastal basins (The Rio Del Rey, Kribi and Douala basins) and two in-land basins (The Garoua and Logone-Ribni basins). The coastal basins form a string of basins which extends from the north along the Gulf of Guinea in Nigeria to the south of upper limits of the Cameroon-Equatorial Guinea. These basins form a composite Cameroon Basin which is triangular in shape with its widest part being about 60 km in the vicinity of the Cameroon Mountain. It narrows to the north of Kribi covering an area of 700 km² and further extends within the sea on a continental platform with an average of 25 km (Ngoune, 1984). The Logone-Binii and Garoua basins are located in similar geologic environments as the Benue basin in Nigeria and the Chad basin in Chad.

Structure

The Rio Del Rey basin is an eastward extension of the Niger Delta and is located geographically between 80°20'-80°55' longitude east and 4°05'4940 latitude north. Regionally, it is flanked in the west by the Cameroon St. Helene Volcanic and in the east by the 27' Fracture Zone.

Stratigraphy

There are four main formations (The Isongo, Akata, Agbada and Benin formations) covering a depth of 2.5 km. The sediments span from Lower Tertiary to recent. The Isongo formation is encountered mostly in the south east of the Rio Del Rey basin. It represents a mixed facies of marine shale and fan sands and could be a prospective target in future exploration programmes. The Akata formation succeeds the Isongo formation. It consists of marine shales and clays that have been overpressured (Lamoro, 1981). The Agbada Formation overlies the Akata Formation and consists of alternations of sands and shale. The coarse clastic beds are the oil reservoirs of the up-to-date discovered oil fields. The Tertiary sequence of the Niger Delta continues eastward in the Rio Del Rey basin as the Benin formation occurring in a fringe zone of shale diapirs, sandy clays, dark green sandstone, lignite and fragments of volcanic rocks.

Effluent Treatment and Disposal

Effluent Type

There are two categories of wastewater's generated at the refinery area. They are:

- ☐ Used water containing hydrocarbon from different units in the refinery and from oil tankers.
- ☐ Industrial and domestic sewage which contains waste resulting from human activities such as washing, cooking, and allied industrial processes taking place at the refinery.

Standard of Pre-treated Hydrocarbonated Wastewater

The treatment line for hydrocarbonated water handles 250 m³/hr of wastewater which should have the following properties:

A.	pH	5.9-9.0
B.	Temperature	30°C Max.
C.	Hydrocarbon	300 ppm
D.	Suspended matter	200 ppm
E.	Phenol	0.5 ppm
F.	BOD	40 ppm
G.	COD	150 ppm

The effluent leaving the treatment line should contain less or equal to 5 ppm of Hydrocarbon, using the hexane extracting method.

Treatment and Disposal

The collected wastewater and industrial effluent is treated with *anti-foaming chemicals*. The foam is a product of decomposition of oils, sewage and humic matter and it is an indication of high alkalinity.

Dissolved air flotation machine is used for the treatment of the wastewater collected. Dissolved pressurised air released causes bubbles which promote migration of solid particles to the top. The solid floats as a scum at the surface of the tank which is removed by a skimming mechanism. Hydrocarbons float at the surface, are harvested and recycled by fractional distillation in the plant. The treated wastewater is vomited into the ocean.

Before discharge, the treated hydrocarbonated wastewater should have a pH of 5.5 - 7.5 and should contain at most 30 ppm of suspended matter.

Geochemical Implications

The treatment of hydrocarbonated effluent from the refinery *reduces pollution*. However, there may be non point-source contamination that may cause ecological imbalance and reduce the aesthetics of the beach which is used as a recreational facility. Further discussion is centred on arising geochemical implications due to pollution resulting from hydrocarbonated effluent along the coastal line.

The Isongo formation is believed to be the main oil reservoir. Due to its position in the stratigraphic sequence, hydrocarbonated effluent may cause a false geochemical anomaly that may be interpreted as higher oil reserve in the formation. Sub-surface groundwater contamination in its aquifers have called for special treatment requiring the removal and extraction of obnoxious odour and hydrocarbons.

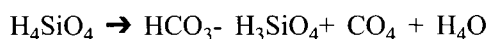
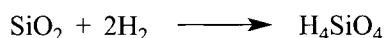
The Akata formation consists of impermeable overpressured marine shale and clays. The absence of sandstones and carbonates in this formation makes it difficult for seepage and secondary porosity to occur.

Hydrocarbonated effluent can penetrate the Agbada formation at different points of exposure of sandstone layers. The trapped pollutant gradually dissolves the layers of sandstone, causing secondary porosity, false geochemical signatures and contamination of aquifers.

The Benin formation is the most vulnerable to pollution. High seepage rates would occur because of unconsolidated sands and consolidated sandstone. With the release of carbon dioxide as one of the final products of fractionation of hydrocarbons, condensation takes place with the formation of carbonic acid which maintains an ionic equilibrium:



The H^+ reacts with SiO_2 to form H_4SiO_4 represented in the following equations:



Since the Benin formation is the youngest formation occurring in the stratigraphic sequence of the Rio Del Rey basin, inhabitants may find it difficult to harvest subsurface water for human consumption due to possible high values of HC ppm in the water.

Recommendations

A number of recommendations that *address ways of protecting marine and coastal waters* have been advanced by concerned parties. Miller (1992) forwards the following suggestions for protecting marine and coastal waters from being polluted, and in cleaning up pollutants:

- ❑ *Municipal sewage treatment plant, and industrial facilities should stop discharging their toxic pollutants into the sea.* MDCs may overcome this problem but not the LDCs. Budgetary constraints make it difficult for LDCs to carry out effective treatment and disposal of their waste.
- ❑ *Water should be managed properly by industries and homes.* This type of measure reduces the amount of water consumed and hence the amount of wastewater flowing into treatment plants which eventually is discharged into seas and oceans. The use of disposable plastics should also be reduced.
- ❑ *The seas and oceans should not be used as the ultimate dumping site of pollutants.* The dumping of sludge and hazardous material into coastal and marine environments should be prohibited and enacted by national and international laws. Also, sludges from empty oil tankers should not be dumped in the sea as well as garbage and plastic items from sailing

vessels.

- ❑ *Thorough and verifiable Environmental Impact Assessment (EIA) should be carried out to ascertain the extent of environmental damage before development projects can be carried out.*
- ❑ *Vulnerable marine areas should be declared marine sanctuaries and human activities drastically minimised.*
- ❑ *Governments should increase taxes on coastal development projects in a bid to discourage entrepreneurs from executing the project.*
- ❑ *Financial institutions are encouraged to promote unfavourable financial conditions which will tend to regulate the types and density of development projects in coastal and marine environments.*
- ❑ *National and international energy policies should be institutionalised which encourage the use of alternative and renewable energy resources instead of oil.*
- ❑ *Used oils should be recycled and reused.*
- ❑ *Most oil spills in seas and oceans are as a result of damage on the hulls of ships. All oil tankers should be required to have double hulls. The navigation routes of oil tankers should be far from sensitive coastal areas that may be suspected to have submerged rocks.*
- ❑ *Oil companies should bear heavy financial responsibilities for oil spills. Companies may be closed either temporarily or permanently if the accident rate is on the increase. Oil spill clean-up capabilities should be greatly improved in terms of technology and time response of emergency clean up crews.*

Conclusion

Although coastal and marine pollution is an issue of serious concern in more developed countries, it is an apparently growing environmental problem in the less developed countries that have primary and secondary industries. Regulations need to be enforced protecting coastal and marine environments in these countries before the situation gets out of hand.

- ❑ The Cameroon government and its National Refinery should continue to monitor the hydrocarbonated effluent, and continuously carry out EIA within the coastal waters and environs.
- ❑ Similar monitoring exercises should be conducted in other oil producing

coastal areas in neighbouring countries.

- ❑ Most seas and oceans are polluted with industrial effluent and oil slicks with the potential of upsetting ecosystems including some endangered species, causing huge economic and environmental damages, coupled with a wide variety of health hazards. Coastal and marine pollution should be reduced as much as possible. We owe an obligation to hand an unpolluted earth to posterity.

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CHAPTER 18

TECHNIQUES OF DEALING WITH ENVIRONMENTAL POLLUTION: BIOREMEDIATION

Hillary M Masundire

**Biological Science Department
University of Botswana
Private Bag 0022
Gaborone, Botswana**

**Phone: 267-3552524 Fax: 267-356591
E-mail: masundireh@noka.ub.bw**

Techniques of Dealing with Environmental Pollution: *Bioremediation*

Introduction

Pollution may be defined as *the introduction, through human activity, deliberately or accidentally, of substances which harm the biotic and/or abiotic components of the environment* (Suter 11, 1993, Moriarty, 1990). The agent of pollution may reduce or entirely stop some normal processes e.g. the existence and/or growth of some organism(s). From a human perspective, pollution is mostly seen in the light of loss of environmental benefits such as use, productivity, aesthetic appeal or economic value. The substances that cause pollution are called pollutants.

Not all substances released by humans into the environment are necessarily pollutants. Some are mere contaminants. **Contaminants** are *substances which do not have any known direct or indirect biological effects*. For some pollutants, their mere qualitative presence in the environment is potentially harmful while the harmful effects of others can only be felt if they are present in appreciable quantities. Some are lethal in small quantities with their effects being felt after only brief exposure of the victim to the pollutant while some victims may be able to tolerate sub-lethal concentrations of some pollutants.

Pollutants can be categorised into two groups on the basis of the mode of their biological effects.

- ❑ *Some pollutants have no apparent direct deleterious biological effects.* However, they affect biological organisms by altering some aspect(s) of the physical and/or chemical environment in a manner that will reduce the ability of some species to survive (Moriarty, 1990). Examples include the effect of increased carbon dioxide concentration in the atmosphere, accumulation of sulphur in the atmosphere and the over supply of nutrients to inland or coastal waters leading to eutrophication. Accumulation of such pollutants alters the environment to an extent such that species compositions and distribution are altered (Lund, 1971).
- ❑ *Other pollutants have direct lethal effects based on exposure and dose.* These are described as toxicants or toxins.

The effect of pollutants may be so severe as to cause death of some biota. Such lethal pollutants are then described as being toxic substances. The same substance may be harmless, a pollutant or a toxicant depending on its concentration in the environment.

Managing Pollution

Managing pollution often involves prevention or reduction of entry of pollutants into the environment. It may also involve the removal or reduction of pollutants already in the environment. The former is the more desirable while the latter is reactionary and may only achieve short term benefits unless it is attempted in conjunction with prevention or reduction. Pollution clean-up may involve physical, chemical or biological methods.

Biological methods of dealing with pollution include a suite of biological techniques such as *biomanipulation*, *biological control*, *biological treatment*, *biotransformation* and *bioremediation* which all, in one way or another, use biological organisms to control, reduce or remove pollutants from the environment. Some of these applications have been in use for hundreds of years but using such trendy names. For example, sewage treatment has always used organisms such as bacteria, fungi, algae, protozoa, micro- and macro-invertebrates and higher vertebrates to convert domestic and industrial wastewater non-polluting. Improvements that have been made in biological treatment of sewage have involved all or several of these bioprinciples.

More recently, **bioremediation** has been used to refer to *the process by which biological organisms, chiefly micro-organisms are used to decontaminate soils and aquifers, treatment of oil spills or biodegradation of xenobiotics and metals*. Xenobiotics are compounds of synthetic origin. They are mostly resistant or recalcitrant to biological degradation (Bitton, 1994). **Xenobiotics** may also be of organic origin such as humic substances and lignin. Bioremediation usually involves improving or speeding up normal biological process that would, if left alone, take much longer.

Living organisms have different tolerance levels to factors of their environment, including pollutants. Concentrations of a pollutant which may be toxic to one species, may not have any observable negative effect on another. *In some cases, a pollutant could be a metabolite for another species*. Such species could then be used to remove those pollutants that they can metabolise. By so doing, the organisms are remedying the environment by ridding it of a pollutant, thus providing bioremediation. *Some species can absorb and accumulate high quantities of a pollutant from the environment without themselves suffering an effect*. They rid the environment of the pollutant by **bioaccumulating** pollutants within their tissues from whence the pollutants may be subsequently excreted. *Some organisms alter the chemical structure of a pollutant into a form that they can metabolise*. In such cases bioremediation is preceded by **biotransformation** or **bioconversion**.

The concentrations of pollutants may increase per unit of tissue of organisms higher in a food chain involving intake of such a pollutant. That phenomenon

is known as **biomagnification**. The concentration of DDT has been known to reach near lethal levels in fish-eating birds that are at the top of the food chains that involve the passage of DDT or its residues from algae, crustacean zooplankton and fish, especially piscivorous fishes such as tiger fish (*Hydrocinus vitattus*).

In order to manage or reduce pollution or effects thereof, the composition of species in a community may be deliberately altered in order to remove or reduce specific pollutants from the environment. This is called **biomanipulation** and has been attempted in reversing the effects human induced eutrophication of inland waters. Particular species of plant, animal, bacteria or fungi may be cultured to be used to clean up specific pollutants from the environment. This is termed biotechnology or sometimes environmental biotechnology. By and large all these different modes of operation of biological systems represent examples of bioremediation.

Sewage Treatment

*All forms of sewage or wastewater treatment are based on the ability of some species to selectively reduce or remove specific pollutants from the environment. The symbiotic association between bacteria, algae, protozoa, aquatic invertebrates and sometimes higher life forms in sewage treatment is a well-known example of **bioremediation**.*

In **oxidation ponds**, bacteria, both aerobic and anaerobic, oxidise the organic matter in wastewater. This bacterial metabolism results in the release of carbon dioxide and the mineralisation products from the breakdown of complex organic compounds such as proteins, carbohydrates and lipids. New bacterial cells are formed i.e. bacteria increase in population with a concomitant increase in the breakdown of the incoming organic matter. The products of the bacterial metabolism are utilised by plants, mainly algae, in the ponds. The algae photosynthesise during the day releasing oxygen required by aerobic organisms in the ponds. In the absence of light at night, photosynthesis ceases and anaerobic conditions prevail, favouring the activity of anaerobic bacteria.

In **trickling filters or biological filters**, sewage treatment is effected by the activity of biota forming the biofilm around the filter medium, usually rock. Microbial flora of the biofilm includes **bacteria**: *Zooglea*, *Pseudomonas*, *Flavobacterium*, *Achromobacter*, *Alcaligenes*, *Spaerotilus*, *Nitrosomona* and *Nitrobacter*; **fungi**: *Fusarium*, *Penicillium*, *Aspergillus*, *Mucor*, *Geotrichium* and several yeasts; and **algae**: *Ulothrix*, *Phormidium*, *Anacystis*, *Euglena*, and *Chlorella* (Bitton, 1994). **Animal species** belonging to the groups Protozoa, Rotatoria and several macroinvertebrates constitute the fauna of the biofilm. Their collective action on sewage results in an effluent with low BOD, low nitrate concentrations, low coliform counts i.e. a less polluting effluent.

Activated sludge treatment systems are based on the principle of creating optimum conditions for the existence, growth and functioning of micro-organisms that are involved in the wastewater treatment. **Nitrification**, the conversion of ammonium compounds to nitrate, is a two stage process involving conversion of ammonium to nitrite by *Nitrosomonas spp.*, *Nitrosospira*, *Nitrosococcus* and *Notrosobilus*. This is followed by the **oxidation** of nitrite to nitrate by *Nitrobacter spp.*, *Nitrospira* and *Nitrococcus*. This process occurs best at pH between 7.0 and 8.5 and temperatures between 15°C and 35°C. On the other hand, **denitrification**, the breakdown of nitrate to gaseous nitrogen, occurs optimally under conditions of high nitrate concentrations, anoxia, high amounts of organic matter, pH between 7.0 and 8.5 and temperatures between 35°C and 50°C. These are the conditions that favour the growth of the mediating micro-organisms: *Pseudomonas*, *Bacillus*, *Spirillum*, *Acinetobacter* and other genera. Biological phosphate removal is effected by bacteria that can accumulate phosphate in excess of their cell requirements. Inorganic phosphate is released under anaerobic conditions and micro-organisms such as *Acinetobacter*, *Pseudomonas*, *Mycobacterium* and a few other genera take up this phosphate and accumulate it in polyphosphate granules within their cells. The activated sludge treatment process therefore involves the sequential creation of these conditions.

Pollution Control

Not all the contents of wastewater are easily biodegradable. There are a number of synthetic compounds that may be in wastewater which are resistant to biodegradation. Because of their non biological origin, such compounds are described as being foreign to biological systems. They are called xenobiotics (Bitton, 1994). These recalcitrant chemicals include halogenated hydrocarbons, halogenated aromatics, pesticides and polychlorinated biphenyls (PCBs). They may be toxic, mutagenic or carcinogenic. Some of them accumulate through food chains, their lethal effects being felt in high trophic levels. There are micro-organisms with special abilities to breakdown these resistant compounds. The xenobiotics are transformed by micro-organisms resulting in mineralisation, accumulation or polymerisation.

Biodegradation of xenobiotics is effected by micro-organisms that use the xenobiotic as a sole source of carbon and energy. Exposure of wastewater microbes to xenobiotics leads to selection of resistant species that possess the appropriate array of enzymes to enable them to utilise the xenobiotic as a metabolite. TABLE 17.1 summarises some of the microorganisms with the ability to degrade xenobiotics which have been isolated (Kumaran and Shivaraman, 1988; Bitton, 1994).

Oil Spills

Bragg, *et al.* (1993) unequivocally demonstrate the effectiveness of bioremediation in degradation of polynuclear hydrocarbons in cleaning up an oil spill in Alaska, USA. Naturally occurring micro-organisms were responsible for this both in surface and intertidal sediments. The rate of breakdown of both total resolvable hydrocarbons (TRHC) and polynuclear hydrocarbons was found to increase with the application of nitrogen fertiliser. Bragg *et al.* showed that both total resolvable hydrocarbons (A) and polynuclear, in hydrocarbons would more rapidly degrade fertilised beaches than in the unfertilised controls.

Such forms of bioremediation where the activity of indigenous micro-organisms is enhanced by the addition of nutrients are referred to as *in situ* bioremediation. The degradation of xenobiotics in soils has been effected by adding micro-organisms such as *Arthrobacter*, *Rhodococcus chlorophenolicus*, and *Flavobacterium* (Bitton, 1994).

A number of fungus species have also been known to be able to use hydrocarbons as a source of carbon for their energy requirements. Cooney *et al.* (1993) found that each of 13 marine fungi could grow with a single hydrocarbon as the only carbon source. There is therefore potential to use such fungi in cleaning up oil spills in the seas.

Mixed cultures of micro-organisms can be used to clean up contaminated aquifers by enhancing biodegradation of pollutants. Such commercial blends of hydrocarbon degrading bacteria have been used in bioreclamation of soils and aquifers. After several months of operation, this mode of biorestitution achieved 93% removal of hydrocarbons (von Wedel *et al.*, 1988).

How quickly a synthetic chemical will be biodegraded depends on several factors including (i) immediate utilisation for growth or energy, (ii) utilisation and transformation after a lag period, (iii) transformation only by cometabolism with other chemicals utilised for growth and (iv) completely nonbiotransformable due to some unusual structure or presence of a structure that is inaccessible to the micro-organisms. Biotransformation rates are affected by adaptation, nutrients, oxygen, moisture, pH and temperature, often in combination rather than singly. *Biotransformation of chemicals*, characteristically leads to, in a stepwise more oxygenated products that are more rapidly oxidised, ultimately resulting in mineralisation i.e. the conversion of organic carbon to carbon dioxide, which is not common in abiotic processes.

Table 17.1: Some micro-organisms with the ability to degrade xenobiotics

Organic Pollutant	Bioremedial Organism
Phenolic compounds	<i>Achromobacter</i> , <i>Alcaligenes</i> , <i>Acinetobacter</i> , <i>Arthrobacter</i> , <i>Azotobacter</i> , <i>Bacillus cereus</i> , <i>Flavobacterium</i> , <i>Pseudomonas putida</i> , <i>P. aeruginosa</i> , <i>Nocardia</i> , <i>Candida tropicalis</i> , <i>Debaromyces subglobus</i> , <i>Trichosporon</i> <i>cutaneoum</i> , <i>Aspergillus</i> , <i>Penicillium</i> , <i>Neurospora</i> .
Benzoates and relateds	<i>Arthrobacter</i> , <i>Bacillus spp.</i> <i>Micrococcus</i> , <i>Moraxella</i> , <i>Mycobacterium</i> , <i>P. putida</i> , <i>P. fluorescens</i> .
Hydrocarbons	<i>Escherichia coli</i> , <i>P. Putida</i> , <i>R Aeruginosa</i> , <i>Candida</i> .
Surfacants	<i>Achromobacter</i> , <i>Alcaligenes</i> , <i>Bacillus</i> , <i>Citrobacter</i> , <i>Clostridium resinae</i> , <i>Flavobacterium Pseudomonas</i> , <i>Nocardia</i> , <i>Candida</i> , <i>Cladosporium</i> .
Polychlorinated biphenynls (PCBs)	<i>Achromobacter</i> , <i>Pseudomonas</i> , <i>Aspergillus</i> , <i>Phanerochaete</i>
Pentachlorophenol (PCP)	<i>Flavobacterium</i> , <i>Pseudomonas</i> , <i>Phanerochaete</i>
Pesticides	
DDT	<i>P. aeruginosa</i>
Linurin	<i>Bacillus sphaericus</i>
2,4-Dichlorophenol	<i>Arthrobacter</i> , <i>Pseudomonas cepacia</i>
2,4,5-Tricholorobenzene	<i>Pseudomonas cepacia</i>
Parathion	<i>Pseudomonas spp.</i> , <i>E. coli</i> , <i>P. stutzeri</i> , <i>P. aeruginosa</i>

Heavy Metals

Some metals such as copper, cadmium, mercury and chromium are highly toxic at certain concentrations. These heavy metals are very important and significant pollutants in environments that receive industrial wastes. A number of micro-organisms which can transform some of these metals have been identified. *Pseudomonas fluorescens*, *E. Coli*, *clostridium sp.*, *Asp[ergillus niger* and *Saccharomyces cervisiae* can transform mercury to methyl mercury by methylation. Methyl mercury is biodegradable.

Biotransformation and ultimately **bioremediation** of metals are effected in one or more of several including production of micro-organisms. These include production of strong acids, production of organic acids, production of ammonia, production of hydrogen sulphide, production of extracellular polysaccharides able to chelate (bind metal ions and maintain them in solution) heavy metals. TABLE 17.2 summarises some micro-organisms and can be that are known to biotransform metals used in bioremediation.

One major current concern is the contamination of soils and aquifers by some of these pollutants. Bioremediation lends itself to ridding oils and aquifers of these toxicants.

Table 17.2: Micro-organisms with ability to biotransform metals (Bitton, 1994)

Metal Pollutant	Metal Biotransforming Micro-organisms
Mercury (Hg)	<i>Pseudomonas flourescens</i> , <i>E. coli</i> , <i>Clostridium</i> , <i>Aspergillus niger</i> , <i>Saccharomyces cerevisiae</i> .
Cadmium (Cd)	<i>E. coli</i> , <i>Bacillus cereus</i> , <i>Aspergillus niger</i> .
Lead (Pb)	<i>Pseudomonas</i> , <i>Alcaligenes</i> , <i>Flavobacterium</i> .
Arsenic	<i>Aspergillus</i> , <i>Fusarium</i> .
Selenium	<i>Aeromonas</i> , <i>Flavobacterium</i> , <i>Penicillium</i> , <i>Aspergillus</i> .
Chromium	<i>Enterobacter cloacae</i> .

Bioremediation of Soils and Aquifers

Bioremediation could be applied *in situ*. This is a technique that enhances the ability of natural micro-organisms to biodegrade pollutants by adding nutrients and an increasing supply of oxygen. This involves addition of nutrients, nitrogen and phosphorus followed by physical turbation of the soil e.g. by ploughing to increase aeration (oxygen supply). This technique can be effectively used to biodegrade diesel oil and grease in soil. It has been recorded to reduce hydrocarbons by 95% within 5 months (Want *et al*, 1982; Vance, 1991). Piotrowsir (1989) demonstrated that bioremediation of aquifers contaminated with pentachlorophenol (PCp) and creosote could be significantly

improved by injection of hydrogen peroxide and nutrients (nitrogen and Phosphorus).

Another technique often used is that of addition of micro-organisms and/or enzymes to contaminated soils or aquifers. The micro-organisms may be added as single species or as consortia of several species. *Arthrobacter*, *Rhodococcus chlorophenolicus*, and *Flavobacterium* grown in large fermenters from where they are harvested and inoculated into contaminated soils or aquifers (Bitton, 1994, Thonlas and Ward, 1989).

Biomanipulation

This involves the *deliberate altering of species composition of communities with the intention of selectively removing specific pollutants or to manage specific environmental problems*. It requires knowledge of the community's functional groups as well as trophic linkages. Biological control of pests and/or weeds may be cited as examples of biomanipulation, in such cases an organism, bacterium, fungus, invertebrate etc. is deliberately introduced in order to selectively kill an undesirable organism in the environment.

In managing **eutrophic waters**, biomanipulation may be applied to reduce the concentration of target nutrients which ultimately, hopefully lead to recovery of such eutrophic waters. Eutrophic waters are usually characterised by high concentrations of phosphorus and nitrates which lead to overproduction of plants, algae or macrophytes and general loss of biodiversity. The plant species that thrive best under such conditions are usually unpalatable to most herbivores and, in the case of some blue-green, may produce toxic products. Removal of zoo-planktivorous fishes has been shown to lead to improvement in the quality of eutrophic waters particularly with reference to species diversity (Ryding & Rast, 1989).

Bioremediation – A Way Forward

Current trends in the field of **bioremediation** are the *identification and isolation of genes or portions thereof in the form DNA in those micro-organisms that can biodegrade pollutants followed by subsequent transfer of those genes or DNA into naturally occurring but non biodegrading micro-organisms so as to confer the ability to biodegrade*. Other efforts concentrate on ways of improving those microorganisms known to have the ability to biodegrade. There is a need for more illustrative success case studies in order to convince environmental managers about the viability of applying the technique of bioremediation.

Caution is necessary against taking bioremediation at face value especially with

regards to potential dangers such as may arise from introduction of “foreign” microbes into new environments. This calls for comprehensive research on potential impacts of such alien species of microbes are used in bioremediation.

The brief discussion above attempted to highlight the fact bioremediation has been known and used to control and/or manage pollution for a long time. In a number of cases bioremediation has been applied without necessarily using the term bioremediation. As a concept, bioremediation is not at all new. However, some of its applications may be new. In other cases, bioremediation is being used to solve new problems. New discoveries are being made of species that can be used in bioremediation of special problems. It is these last two phenomena that may lead recent converts to bioremediation to consider it to be a new concept. It certainly is not.

As a way forward, it can only be advocated that more research into finding those species of organisms, micro and macro, that can be used to clean up the myriad of pollution problems facing us today be strengthened.

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PART 4

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CHAPTER 19

CLIMATIC FACTORS AFFECTING POLLUTANTS IN WASTE DISPOSAL SITES IN DEVELOPING COUNTRIES

Prof J O Ayoade

**Department of Environmental Science
University of Botswana
Private Bag 0022
Gaborone, Botswana**

**Phone: 267-3552524 Fax: 267-356591
E-mail: ayaodej@noka.ub.bw**

Climatic Factors Affecting Pollutants in Waste Disposal Sites in Developing Countries

Introduction

In many cities in the developing countries, the collection and disposal of solid wastes has become a perennial problem faced by municipal authorities. Solid wastes are being generated by the inhabitants of these cities at rates that exceed the capacities of the municipal authorities to collect, transport and safely dispose them off. The rapid increase in solid waste generation is due primarily to the high rates of growth of the population in these cities as a result of high natural growth rate and the high rates of rural-urban migration. The rapid rates of the physical expansion of these cities and their poor physical planning evident in the development of slums have made the collection, transportation and safe disposal of solid wastes a difficult exercise for the municipal authorities. The problem is compounded by the fact that many of these municipal authorities lack the necessary executive capacity because of inadequate finance and lack of adequate manpower and equipment.

Solid Wastes and Pollution

Solid wastes constitute a veritable source of air, water and land pollution in many urban areas of the developing countries because of their poor management and disposal. Open and over-filled waste dumps dot the urban landscape of many developing countries. Some of these wastes are blown about by wind while others are washed by runoff after rainstorms into urban river channels. In some cities, residents even dump their household wastes directly into urban river courses. Such wastes leading to flooding of the adjacent land often clog urban river channels. Poor solid waste disposal is the major cause of pollution of the water in the urban river courses in developing countries.

In most developing countries solid wastes are disposed off either by incineration or sanitary landfill. Often incineration takes place in open waste dumps. Whether wastes are burnt in the open or in incinerators, both gaseous and particulate pollutants are produced when wastes are burnt. Our major concern in this presentation is to examine the meteorological factors that affect the concentration in the atmosphere of pollutants generated at waste disposal sites.

Meteorological Factors Affecting Air Pollution

There are two factors that determine the level of concentration of pollutants in the air over a given location in the absence of convection. These are (i) the rates at which pollutants are generated and emitted into the atmosphere and (ii) the rates at which these pollutants are dispersed and diluted within the atmosphere. Weather and climate play an important role in both especially the latter.

With regard to solid waste generation, climate may have an effect on the composition of waste generated. The moisture content of solid wastes in wet climates may be up to 50% by weight. Organic wastes also tend to be higher in quantities during the wet season than during the dry season. Under warm moist conditions as in the humid tropics, organic wastes serve as breeding grounds for disease vectors such as flies, mosquitoes and rats.

Weather conditions may also affect the type of gaseous pollutants produced at waste dumps. When solid wastes are land-filled the organic matter initially decomposes aerobically and then degrades anaerobically when oxygen is used up. In wet climates, aerobic decomposition lasts for only a few weeks but may last up to a year in dry climates. Also, under moist conditions large quantities of leachate are produced by the decomposition of wastes at waste dumps.

Anaerobic decomposition of organic wastes in landfill generates gases such as methane and carbon dioxide. Methane is an odourless gas but it is very efficient as a greenhouse gas. It is also a combustible gas that becomes explosive when its concentration in the atmosphere exceeds 5% by volume. Carbon dioxide may combine with water under moist conditions to create an acidic environment, in which minerals such as calcium, magnesium, lead, cadmium and zinc present in the wastes or soil are dissolved giving rise to the contamination of groundwater.

However, *it is in the rate of dispersal and dilution of pollutants in the atmosphere that climatic factors play a crucial role.* The factors include the following:

- (i) Wind speed and direction;
- (ii) The vertical temperature profile of the atmosphere which determines its stability or otherwise;
- (iii) Precipitation; and
- (iv) Other meteorological and non-meteorological factors which may affect (i) and (ii) above. Such factors include *insulation, humidity, cloud cover and*

local topography including the shape, size and height of nearby structures.

The dilution of pollutants in the atmosphere is inversely proportional to the wind speed. This is because wind speed affects the volume of air that passes over a given location during a given period of time. If the wind-speed over a location doubles, the volume of air passing over the location also doubles. Thus, the greater the wind speed the more the volume of air within which the pollutants will be diluted. Pollutants whether gaseous or particulate are carried in the atmosphere by wind. Hence, the direction of a airflow is also of significance as wind direction determines where the pollutants will be advected. Airflow is determined primarily by the pattern of atmospheric pressure. Pollutants emitted by point sources like waste dumps are normally carried downwind of the prevailing wind. In a perfectly smooth airflow, pollutants would travel downwind in a narrow plume with nearly uniform level of pollution concentration within the plume. However, because of the effect of turbulence airflow is never smooth. There is usually turbulence both in the horizontal and vertical directions. The plume consequently usually spreads out in form of a cone with the level of pollutant concentration decreasing progressively downwind. It is turbulence that ensures the mixing of the plume air with the surrounding air ultimately. There are two types of turbulence namely mechanical and thermal turbulence. Mechanical turbulence is caused by obstructions to airflow by buildings, trees and rough terrain. In other words, the friction between the atmosphere and the underlying surface of the earth generates it. Thermal turbulence is the stronger turbulence and is caused by thermal instability in the atmosphere.

Within the troposphere, temperature generally decreases with height at the average rate of 6.5 degC per km. This is what is known as the **Environmental Lapse Rate** (ELR). If a parcel of unsaturated air is lifted in the atmosphere as a result of convection, orographic or frontal displacement, it expands as atmospheric pressure decreases and cools at the **Dry Adiabatic Lapse Rate** (DALR) of about 9.8 degC per km of ascent. When the rising air parcel is cooled to its dew point temperature, the moisture it is holding starts condensing and the latent heat of condensation is released to the air parcel. The rate at which the rising air parcel cools then decreases to between 4 and 9°C per km depending on its moisture content and temperature. This is what is known as the **Saturated Adiabatic Lapse Rate** (SALR). The relationships amongst the three types of lapse rates described above determine the stability condition of the atmosphere over a given location at a given time.

Three stability conditions are the most relevant in air pollution assessment, These are the conditions in which the atmosphere is *unstable* ($ELR > DALR$), *neutral* ($ELR = DALR$) and *stable* ($ELR < DALR$). These conditions will now be briefly described.

- ❑ **In an unstable atmosphere**, the vertical dispersion or spread of pollutants is rapid and efficient because pollutants are mixed in a deep layer of the atmosphere and are consequently well diluted. Conditions of atmospheric instability occur mainly near the earth's surface in the lower layers of the atmosphere and are associated with sunny daytime conditions or the advection of cold air over warm surface. The former conditions occur regularly in most parts of the tropics particularly during the dry season or in semi-arid areas where the sky is usually cloud free.

- ❑ **Neutral stability** conditions occur during cloudy, windy weather or briefly after sunrise before the onset of thermal convection and just before sunset when thermal convection ceases. These conditions do not encourage vertical dispersion of pollutants in the atmosphere. Air pollution problems usually occur during period of stable atmosphere characterised by temperature inversion in which temperature increases with height. Inversion acts as a lid preventing vertical motion of air. Pollutants therefore cannot rise in the atmosphere. Rather they concentrate at the base of the inversion layer. Air pollution potential is very high under inversion conditions especially if such conditions are also accompanied (as they are often are) by calm winds. Temperature inversions can occur in the tropics under a variety of conditions of which the following are the most common:
 - (i) Near the earth's surface at night when the sky is cloud free and winds are light;
 - (ii) After afternoon rain showers when the earth's surface is cooled by evaporation;
 - (iii) When there is advection of warm air over a colder surface;
 - (iv) When there is drainage of cold air from mountain slopes to the valley bottom or depression; and
 - (v) In areas under warm subtropical anticyclone trade wind inversion occurs at a height of between 1000 to 5000 metres in the middle troposphere.

Precipitation is another weather element relevant in air pollution studies and assessment. *Precipitation removes pollutants from the atmosphere by the physical processes of washout and rainout.* Washout is the term used to describe scavenging by rain while the process of scavenging by cloud droplets that eventually grow into precipitation is called rainout. Precipitation also removes pollutants from the atmosphere by the chemical processes of oxidation and hydrolisation. Acid rain commonly occurs within or downwind of industrial areas where sulphur dioxide and oxides of nitrogen are emitted in large

quantities. These gases are transformed in the atmosphere into sulphate and nitrate particles. These combine with water vapour to form mild sulphuric and nitric acids that are precipitated on to the earth's surface as acid rain.

Assessing Air Pollution Potential

Given a certain quantity of pollutants, the chances of the atmosphere getting polluted are determined by the prevailing meteorological conditions that control the atmosphere's dispersive capability or what is known as its air pollution potential. As mentioned earlier, air pollution potential is primarily controlled by the stability status of the atmosphere and wind speed. The main meteorological indicators of air pollution hazard are temperature inversions and low wind speeds. These are often characteristic of anticyclonic weather conditions. Such synoptic weather conditions also tend to suppress precipitation.

In contrast, *thunderstorms form when the atmosphere is very unstable.* Heavy downpours that help "wash" down pollutants accompany these storms. Thus, conditions that favour the occurrence of thunderstorms also favour low pollution potential. The frequency of thunderstorms is highest in the tropics because of the intensity of solar radiation that encourages convection. Compared to the middle latitudes, air pollution potential in the tropics is generally low. However, air pollution potential could be high in the night and early morning in areas with little or no cloud when low-level temperature inversions develop. The trade wind inversion also occurs in many areas of the tropics although not close to the earth's surface. Radiosonde data are needed to assess the stability of the atmosphere, to calculate the thickness and height of any inversion layer and to calculate the height of the afternoon mixing layer, a major determinant of air pollution potential. Unfortunately, radiosonde data are few and are not available for most parts of the developing world, which is also practically synonymous with the tropics.

Summary and Conclusion

In this chapter, *attempts have been made to highlight those meteorological factors that affect the dispersal and dilution of pollutants in the atmosphere. They are basically the vertical temperature profile of the atmosphere and wind speed. These are themselves controlled by other meteorological processes.* The process of precipitation helps to wash out many pollutants from the atmosphere. It is quite clear from the preceding discussion that meteorological factors need to be taken into account in the location of waste disposal sites by the municipal authorities. Waste dump sites like industrial sites should be located downwind of the residential areas. *Incineration of wastes should take place only when the atmosphere is unstable and wind is appreciable to ensure quick dispersal and*

dilution in the atmosphere of pollutants that will be generated by incineration. Studies have shown that the maximum concentration of air pollutants at ground level varies inversely as the square of the height of a chimney stack. Also that the effective height of a chimney stack can be increased if the temperature of the effluent gases is greater than the ambient air temperature. It is therefore recommended that incinerator stacks should be high and that open burning of solid wastes should be discouraged. Also, incineration should be done at very high temperatures to make the resulting gaseous pollutants buoyant and destroy their odours. This may require refuse sorting/drying before burning since refuse materials are not homogeneous and vary widely in their fuel value.

Finally, *there is need to estimate the air pollution potential of the atmosphere in and around waste dump sites, existing and potential.* This will assist in the choice of suitable sites for waste dumps as well as the best time for waste incineration. This exercise requires data not only on wind speed but also on the vertical temperature profile in the atmosphere, which only data from radiosonde can provide. It is therefore recommended that weather stations in the major urban centres should be equipped to send radiosondes into the atmosphere regularly to provide the necessary data to assess the stability status of the atmosphere and hence its air pollution potential.

CHAPTER 20

WASTE MANAGEMENT: THE ROLE OF NON- GOVERNMENTAL ORGANISATIONS (NGOs)

E M Segosebe

Waste Management: The Role of Non-Governmental Organisations (NGOs)

Introduction

Industrialisation and its consequences helped to increase knowledge in natural sciences about the effects of industrialisation and urbanisation on natural systems (McCormick 1995). Testimony to this development is manifest in the fact that concern about environmental issues were first raised by the industrial world of Europe and North America. The greatest lessons that organisations based in the developing world can learn from the experience of the industrial world is that there is a number of possibilities through which environmental pressure can be exerted on society to raise environmental awareness. For example, Western environmental movements adopted three directions (Feenstra, Hoozeboom, and Vellinga 1995). Two of these directions sought societal change such as (1) action oriented activities aimed at transforming societal values through public mobilisation and awakening and (2) a reformism approach aimed at influencing government policy. The latter sought to bring about public awareness through education. A third direction emphasised personal transformation that would promote individual stewardship toward environmental conservation. This chapter takes the position that a holistic approach to waste management that draws on the strengths of the different approaches holds the greatest potential for non-governmental organisations (NGOs) to influence development particularly if they can bring on board the larger public. It reviews the evolution of the environmental movement in the west and shows how the experience from the west can help strengthen the work of organisations in the south.

Non-Governmental Organisations (NGOs) *are those organisations that act independently outside formal government sectors. They may include groups with wide interests such as conservation, religions, human rights, and research. NGOs may adopt a national or a local character, by operating at the national or local level, respectively.* In industrial countries some of the NGOs are so rich that they operate on international terrain. This is largely a legacy of the World Commission on Environment and Development (1987) that called for NGOs to be more active at the international arena. In the developing world, NGOs tend to be small and use as their domain of operation local communities. They concentrate on the well being of the poor who are struggling against the destruction of their land and culture. This chapter focuses on NGOs that act on environmental issues and that so without link to governmental structures or political affiliations. History shows that environmental NGOs in the North have had great influence in changing public and political attitudes towards environmental problems by placing environmental issues high on government agendas.

The Evolution of the Western Environmental Movement

An account of the development of NGOs in the industrial countries reveals that they went through fluctuating periods of successes and lows that spanned nearly two centuries from the early nineteenth century to the late twentieth century (Feenstra, Hoozeboom, and Vellinga 1995). The first period of environmental awareness was, according to this source, characterised by a cultural shift in the upper class when *an idealised view of nature became the norm and nature became romanticised*. It was in vogue for the upper class people of this period to go out to the countryside in order to enjoy nature. It was on the basis of these newly founded environmental values that nature conservation groups were founded in Europe and North America. *The first of these movements aimed at protecting biologically valuable areas in terms of specific flora and fauna*. Two types of conservation groups emerged from this development. The first conservation groups focussed on the conservation of wildlife especially birds as exemplified by the formation of the Dutch Association of Bird Protection (1899), the Audubon Society in America (1886), and the Royal Society for the Protection of Birds in the UK (1904). *The second group lobbied for the preservation of areas of natural significance*. This group is characterised by the likes of the Sierra Club in the USA that sought public support for the preservation of forests and other features of the Sierra Nevada Mountains and the Association for the preservation of Natural Monuments in the Netherlands (1906).

The most important achievements of these early conservation efforts was that they succeeded in getting many countries to develop national legislation on wildlife protection. In the USA, several national parks and wildlife refuges were established. Following this period of success the activities of the environmental movements slowed down. In addition to this success, the lapse in the activities of the movements is explained by the emergence of World War I and the Great World Depression of the 1930's (Feenstra, Hoozeboom, and Vellinga 1995) that drew peoples' attention away from environmental concerns.

The environmental movement experienced another resurgence in the period following the two World Wars. In particular, the 1960s were very important for this development due to a combination of factors. During this period, there was a general shift of attitude toward modernity as people began questioning the association between industrialisation and good life. The post world war period brought about unprecedented peace and prosperity that enabled society to focus on non-material factors of well being. *At the end of the 1960's people started questioning the assumption that linked well being to material prosperity. Concern on such issues as pollution, destruction of nature, loss of environmental amenity and depletion were raised*. On the basis of these new concerns the then accepted superiority of economics was challenged.

Several factors were instrumental in encouraging the development of the environmental movement at this particular juncture in time. Scientific writings such as *Silent Spring* (Carson 1962) and many others were important and are credited with transferring environmental concerns from academic debates into the public arena. Of particular importance were the hazardous events in raising public conscience about environmental problems. Some of the important hazardous events at the time included the oil spills in the English Channel (1967) that killed large numbers of birds and wild life and the spill of toxic chemicals into the Rhine River that led to massive fish destruction. Another event is related to the Minimata disease in Japan that was associated with the dumping of mercury in the area by a chemical company. These events were important in that they demonstrated that environmental problems affected the quality of life.

International acceptance of environmental problems and increase in environmental deterioration led to increased public consciousness about the environment. The emergence of the environmental movement thus resulted from the conservationist movement. Although the conservationist movement raised public conscience about environmental problems they did not feel obligated to deal with them. On their part the environmentalists took it upon themselves to see to it that society acts on causes to reduce environmental problems as exemplified by earlier writings. There were protests for example about nuclear fallout that led to the partial ban on nuclear tests. The success of the environmental movement at this time came about because there was consensus with the public thus indicating the strengths a consensus movement. According to Feenstra, Hoogeboom, and Vellinga (1995) such a broad consensus was possible because of a number of reasons such as declining confidence in political institutions. Environmental problems were seen as a failure of the system. Another reason is that there was no opposition against environmental lobby. Most of the effort in the industrial countries aimed at reducing consumerism and associated pollution at a time of abundance and plenty.

The slow progress in the 1960s gave way to rapid changes in the 1970s when a breakthrough in environmental awareness was realised. For the first time the environment became a political problem. Political parties incorporated environmental issues in their party programmes. It was for this reason that the 1970s saw changes through the development of new environmental policies in such countries as the United States of America. The National Environmental Policy Act was enacted and required environmental impact statements for all federal projects. An Environmental Protection Agency was established as an independent pollution control agency with responsibility to enforce and regulate programmes on pollution, wastes, pesticides and environmental radiation. In Europe the Council of Europe declared 1970 the year of conservation in order to stimulate environmental awareness. Consequently many European countries formulated environmental laws. The formation of environmental NGOs

flourished over the industrial world in the 1970s because of the environmental ideas that arose in the 1960s. Among some of the organisations that came into existence by the 1970s are Friends of the Earth in the USA (1969) and Green Peace in Canada (1970). Some of them developed political ideas through which they sought to achieve political influence. Hence, NGOs were part of the Stockholm Conference and for the first were given a greater involvement in the discussions about political, social, and economic questions. The NGOs were relieved that they had at last managed to attract government attention.

Despite this seemingly obvious success reflected in the sense that public concern was increasingly being recognised in public policy NGOs felt that there were still a number of issues that were not addressed by existing regulatory agencies and laws. This was because signs began to emerge that showed that the environment was deteriorating. Some of the NGOs started calling for a fundamental change in society. This resulted in a conflict because the values espoused by the new environmental movement contradicted the social values of this time. Effectively, the environmental movement had changed from a consensual approach to a confrontational one. As the 1970s progressed, the environmental movement lost momentum due to changing economic conditions. Unlike the 1960s, the global economy of the 1970s started experiencing problems of depression, especially following the oil crisis in the early seventies. This event forced governments to concentrate on economic problems because they were more urgent vis-a-vis environmental quality, which was a long-term goal. For the first time some scientists and politicians were challenging the doomsday predictions of the environmentalists. Victim to this new challenge was the non-growth approach (McCormick 1995) which was attacked by economists and the developing world on the basis that it lacked scientific grounding.

Attacks on the environmental movement gave governments a leverage on which to temporarily withdraw from environmental reform. General withdrawal of government support seemed to point to the demise of the environmental movement. However, this was not to be, for the activities of the 1970s had adequately raised public awareness about environmental issues. Never the less the attitude of the environmental movement changed due to the declining economic conditions of the 1980s. People and government thought the creation of employment was more important than environmental problems. The public started seeing the environmental movements as concentrating on single issues rather than addressing all factors that affect their well being. In other words they lacked a comprehensive political programme that would address environmental issues in a broader social framework. This led to the formation of green parties in several countries. The success of these parties took the initiative from the environmental movements. The movement also weakened as the membership could not agree on acceptable strategies of actions. Part of the membership supported confrontation, which led to violence particularly at

nuclear installations while others sought a peaceful approach to the problem. Thus the movement was divided: the radical wing reached a deadlock while the reformism took part in consultative bodies and became part of the decision making process.

Despite the weakening of the environmental movement in this period, environmental problems remained impressed in the public conscience for a number of reasons: (1) Action against nuclear energy attracted more and more attention and support. (2) Electoral success of green parties forced other parties to address environmental issues, and (3) the persistence of environmental disasters supported the claims of the environmental movement and undercut government efforts to underplay the importance of environmental problems (Feenstra, Hoogeboom, and Vellinga 1995). Events such as the dumping of toxic chemical wastes at Love Canal (USA), massive destruction of forests in Europe due to acidification, and several industrial disasters (nuclear accident at Three Mile Island (USA), Bhopal (India), and the Chernobyl nuclear accident in the Ukraine once more placed environmental threat on the international agenda.

The Role of NGOs in the Developing World

Until recently, NGOs here were not primarily concerned with environmental issues. But they were concerned about water, land/soil erosion, and forest destruction and related issues. Environmental action is generally tied to people's survival needs and activities; a lot of effort targets the promotion of community development and empowerment. *The environmental movement in the South emerged (Feenstra, Hoogeboom, and Vellinga 1995) mainly as a motivation and/or protest against development projects, that generally tend: (i) to displace people from their lands, causing an inevitable destruction of traditional ways of life; and (ii) to result in the exploitation of resources by multi-national organisations.*

It should be noted that the success of NGOs depends to a large extent on a democratic system of government. The fact that the environmental movements made more headway in Western Europe and North America than say in Eastern Europe testifies to this fact. Given the autocratic nature of governments in the developing world, NGOs have to be extra cautious in choosing their environmental campaigns lest they find themselves in conflict with governments (Potter and Taylor 1996). *The demise of the radical environmental movement in industrial countries during the last two decades is a good example of what may happen where values espoused by radicalism may bring division in society.* Furthermore, non-democratic government may not feel comfortable with NGOs if some of them are too radical. *The fact that the majority of NGOs in the developing world call for community empowerment and the improvement of the well being of the poor people not only challenges the policies of current*

governments but also the interest of rich and powerful people. For example, these NGOs often challenge private resource ownership. This may lead government to suppress NGOs and force them to adopt illegal actions. On the basis of this, it would seem that the best approach for NGOs in developing countries should be reformist in nature. In other words they should seek to be part of the system in order to change it from inside. It is through information exchange that NGOs here can succeed because that way they can change the attitudes of the existing powers without antagonising larger societal values.

The potential for what NGOs in the developing world can do for the environment is not in doubt. They have a strong local base and can mobilise local support. Local NGOs are also better placed to make a better judgement on the need to meet the short-term survival needs of the people and long-term environmental quality requirements for sustainable resource management. This brings up the fundamental difference between the environmental movement in the North and that in the South. While the former questions unbridled economic growth, the latter see it as a prerequisite for the development of an effective environmental movement (McCormick 1995).

The Case of *Somarelang Tikologo* (Environment Watch Botswana)

One of the first environmental movements to directly address the question of waste management in Botswana is *Somarelang Tikologo* (Environment Watch). The emergence of this organisation was largely, if not solely, influenced by the desire to address environmental problems in the country. *Somarelang Tikologo* adopted a multi-pronged approach to the problem of waste management. At the lower level it is a grass root organisation that organises community activities such as cleaning campaigns and tree planting activities in the greater Gaborone area. This is normally done in conjunction with community leaders. Environmental issues of public interest are occasionally set up for public scrutiny through public lectures or debates. A newsletter is published to maintain regular contact with the membership.

At another level *Somarelang Tikologo* deals with the business community and engages them in discussions about environmental problems related to their business activities. For example, regular contacts were kept with a local brewery and a can recycling company to make them aware of the need to raise the deposit system for soft drinks and beer cans to encourage the public to collect them and sell them to the can recycling company. This campaign has proven to be a success.

At yet another level the organisation has applied varying strategies to the city authorities (workshops, media releases, direct involvement in environmental

health meetings of the city council) to encourage a change of approach in waste management. Such efforts partially contributed to the closure of the old landfill in Gaborone. The organisation also manage to bring into the government agenda, the issue of used oil as exemplified by workshops on used oil hosted by the Ministry of local government and lands in the early 1990s. Collection of relevant information was instrumental in enabling the organisation to adopt an agenda that was at least partially acceptable to all concerned. For example, the study carried by Segosebe and Vanderpost (1990) provided a basis for the campaign on waste management reforms in Botswana. It would therefore seem that much of the success of this organisation was due to its ability to deploy the many strategies it adopted to the different publics that constitute our society.

Conclusion

This chapter has shown the evolution on the environmental movement in the North and the beliefs behind strategies adopted thereof. It has shown that pointed to some of the pitfalls that environmental NGOs in the developing world must avoid if they are to survive. The case of *Somarelang Tikologo* has demonstrated how applying different strategies to the different publics (particularly reformisms, can bring fruition to efforts of the environmental movement in the developing world where governments do not take well to criticism. It is, however, acknowledged that unique conditions existing in different countries would need to be treated based on conditions prevailing locally.

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CHAPTER 21

TOWARDS EFFECTIVE WASTE DISPOSAL IN DEVELOPING COUNTRIES

Yvonne Gotlop Bogatsu

**Department of Environmental Science
University of Botswana
Private Bag 0022
Gaborone, Botswana**

**Phone: 267-3552524 Fax: 267-356591
E-mail: gotlopyk@noka.ub.bw**

Towards Effective Waste Disposal in Developing Countries

Introduction

Waste can be disposed of effectively only after usable resources have been reclaimed from it and once it has no adverse effects on the environment. Discarding waste involves use of transportation from the collection site to the disposal location. Developing countries, in general, hardly ever have special sites designed for disposing of different waste types, as such solid and hazardous wastes are all dumped in a common location. Hazardous wastes primarily originate from more developed countries, and reach less developed countries as imports and through technology transfer. Less developed countries (LDC) have different waste disposal practices which may be determined by environmental awareness and availability of resources.

In rural areas waste is dumped in pits dug on household backyards, or at dumpsites designated by local authorities. **In larger towns and cities** there may be sanitary landfills where wastes are disposed of. Other than disposal on land, waste also undergoes incineration, which is practised mainly on medical waste. It is clear that *LDCs are confronted with dilemmas between providing basic needs such as shelter and food supply for their countries and handling the responsibility of ensuring that wastes are disposed of efficiently.*

In this chapter suggestions are made on the use of disposal methods appropriate to the conditions in developing countries. Most developing countries are in arid environments; therefore their climates differ from those in wet areas of UK or USA. The climatic effects on wastes should be studied and relevant disposal methods applied in developing countries. An example can be the use of constructed wetlands to treat wastewater from septic tanks or other primary treatment processes.

Overview

The effective disposal of wastes may be attained after waste has been sorted for resource recovery; the remaining matter then is discarded. For waste to be efficiently disposed of, it should have no negative impacts on the environment. Waste disposal comes as a final step in the processes of waste management; that is, after attempts have been made to apply the “3Rs”, namely, *reduce, reuse and recycle*. Solid wastes that have been generated may be sorted for resource recovery prior to disposal. Hazardous wastes on the other hand hardly ever require any sorting; they usually undergo treatment and disposal.

This chapter will *focus on modes of transporting solid wastes to the disposal sites; it will assess the disposal practices that are in use and their effectiveness in developing countries*. Methods used to dispose of hazardous wastes will also be scrutinised. Suggestions will be given on how to effectively dispose of wastes in developing countries. Solid wastes may be transported for disposal by means of ordinary trucks or compactor collector vehicles. The waste must be well contained to avoid spills or falling off of loose material along the way.

In more developed countries (MDCs) wastes are transferred from collector trucks to larger forms of transportation to the landfills. These may be huge trucks, trailers, or rail carriages (Economopoulos, 1992). This transfer is prompted by the distant location of landfills in most developed countries. *The situation differs in most developing countries where the collecting trucks transport wastes to the disposal area.*

Ideally solid and hazardous wastes are discarded at different landfills; this is the case in most developed countries where numerous quantities of hazardous waste are generated. *Developing countries generally do not have separate disposal systems for solid and hazardous wastes; all wastes tend to be dumped into single dumping location.* Recently Botswana introduced guidelines for waste disposal using landfills. These contain procedures for handling solid and hazardous wastes separately (National Conservation Strategy Agency, German Technical Co-operation, 1995).

Developing countries still lag behind when it comes to handling hazardous waste, especially because these wastes reach these countries as some form of imports. Most African countries, for example, do not manufacture hazardous products. In some of these countries imports of such substances were introduced during the colonial period. One example relates to Mauritius, where European colonialists introduced pesticides, and since then Mauritius became an internationally known importer of agro-chemicals (Government of Mauritius, 1992).

Developing countries seem to have difficulties when it comes to handling wastewater: this type of waste seems to be the most threatening to handle in the developing world. For instance Harare is recorded to have experienced heavy pollution from effluents to the extent that there have been fish kills reported in the receiving reservoirs such as Lake Chivero. The fish kills are suspected to have been due to domestic wastewater pollution in the lake (Zava, 1996).

Transportation of Wastes

Trucks usually transport solid wastes from the point of collection to the

disposal site. The nature of the waste and the availability of the resources determine the means of transportation. For instance, paper waste is transported in open trucks that have wire mesh surrounding the truck, this just keeps the loose materials from falling off. Compactor trucks also collect waste materials that can be compacted easily. Individuals transport solid wastes such as rubble on privately owned trucks, tractors or other vehicles.

In rural areas there are more means of transporting wastes than through trucks, the use of horse or donkey carts is quite convenient especially when trucks are not easily available. As rural communities develop awareness for sanitary management of waste, novel methods of transporting wastes also mushroom. This is quite an appropriate method for LDCs since there is no need to worry about costs of purchasing vehicles and paying for fuel. The method also protects the environment from atmospheric pollution caused by fuel combustion when vehicles are used. These carts have a few limitations though. Horse carts cannot carry all waste categories; for instance hazardous waste cannot be transported in such a cart. The carts are not designed such that compaction of waste may be possible. Governments in developing countries should encourage and improve these means of transporting wastes.

The effectiveness of waste transfer to disposal areas is determined by the availability of resources as, for example, the mode of transportation for collection and disposal. *Developing countries are confronted with the pressure of maintaining a habitable environment. On the other hand they struggle to meet the basic needs in their countries i.e. shelter, clothing, food supply.* Basic human requirements must be given priority over environmental management and other secondary factors. As such this creates a dilemma for poorer countries.

Hazardous wastes including wastes from medical centres may require special equipment for transfer to disposal sites. Plastic bags may be used for transporting swabs and other similar wastes. More rigid plastic containers and boxes are used for other wastes, for example, human tissue, sharps and so forth. It is recommended that these wastes be pre-treated prior to disposal. *Developing countries are shifting towards managing their wastes effectively. Historically there has been misinformation about hazardous waste handling and disposal.* Since such wastes were mostly generated in more developed countries (MDCs), they would be transferred directly for dumping in developing countries or indirectly through technology transfer. When one considers disastrous effects such material has had on developing countries, such instances as when the French tested their nuclear weapons on the Sahara desert, the radiation from the waste generated had severe health impacts on the communities in Nigeria and neighbouring countries.

Disposal of Solid and Hazardous Wastes

Municipal solid waste is usually dumped in pits, local dumpsites or landfills. Individual households in rural areas dig pits in their backyards to dispose of wastes generated in the homes. Dumpsites are typical open spaces designated by local authorities for waste disposal. These do not necessarily follow sanitary means of managing waste; they are, nevertheless, useful for dumping inert wastes. An example of a typical local dumpsite in Botswana can be observed in Ramotswa village, in Southeast Botswana. At such dumpsites sorting of recyclable matter remains a necessary undertaking.

Disposing of hazardous wastes tends to be more complicated due to the nature of the waste. In countries like Botswana these wastes are incinerated or eliminated by open burning. In some areas they are just dumped at local dumpsites without pre-treatment. Open burning proves to be quite ineffective for certain types of hazardous wastes as the temperature cannot be controlled (NCSA, GTZ, 1996). *Simplified incinerators exist in developing countries. These may be constructed using bricks or metal.* There are also Type II incinerators (Low Technology Manufactured Incinerators). These are used in major hospitals and certain clinics in Botswana. Type II incinerator reach up to 900 degrees Celsius. The multi-hearth surface is another type of incinerators, functionally useful for hydrated industrial wastes and for sewage sludge. *The use of sanitary landfills for discarding wastes is a new technique being adopted by developing countries.* The Botswana government, for example, undertook pilot studies to assess ways of introducing sanitary landfills in the country. This resulted in guidelines and recommendations of appropriate disposal of wastes in the local environment. Wastes can be sorted at the landfill or at source of generation. For instance, the Gaborone landfill has sorting centres for tyres, metal scrap, construction waste (or rubble). Construction waste is crushed and reused as cover material for wastes. A separate area is routinely demarcated nearer to the domestic and other food waste disposal cells, for sorting and storage of beverage cans to be recycled.

Disposal of Liquid Wastes

The complications related to the disposal of liquid wastes seem to threaten the developing countries. That may be due to the arid conditions of most LDCs, which then experience less pollution from leachate emanating from dumpsites or landfills. A typical situation exists where oil wastes and wastewater appear impossible to handle in an environmentally safe manner.

Used Oils are stored in various size containers and in underground storage containers for resource recovery. These waste oils cannot be dumped anyhow, so they accumulate in storage containers, from which minimal amounts are

collected for reuse and recycling (Central Transport Organisation, 1998). No alternative method of handling or recycling these oils has been attained, but there are small-scale reuse practices that can still be expanded further. Used oils have tended to be stored in a way that helps little to combat damage to the environment: their result spills and flows into neighbouring streams. It is recommended that containers of used oils, particularly customary 200 litre drums containing oil should be stored in a place with a concrete slab, and an impenetrable wall that can safely prevent spillages or leakages.

Wastewater also becomes disposed of not in landfills but in other ways. Sludge from wastewater treatment plants sometimes ends up in landfills or dumpsites. The understanding of the effects this has on the soil, air or groundwater is not much known. There may be contamination from methane gas due to high organic content of such wastes. Contribution to groundwater contamination may only be confirmed through research or field studies carried on in affected areas. The disposal of wastewater usually follows a different system from that of solid wastes. The effluents discharged into the environment must not in any way deteriorate the quality of that receiving stream. As such developing countries, such as Botswana, carry out routine monitoring of treated effluent to control pollution of receiving waters and of the environment.

Treated effluents usually flow into existing channels or are disposed of in open environment. Effective disposal of wastewater implies treatment to compliance levels prior to disposal. It may also imply reusing such wastewater in an environmentally safe method. At present wastewater from Gaborone, Botswana, for example, undergoes treatment in the activated sludge treatment plant, which commenced operating late 1997. Whether this is an effective method of waste disposal is debatable. It depends on whether the method is the best suitable for the environment of Botswana and whether it is economically viable not only to operate the plant but to maintain it as well. However the plant is operating well and discharges effluents within the required quality.

Suggestions for Achieving Effective Waste Disposal

There is yet more that LDCs ought to do to attain the goal of effectively discarding or eliminating wastes. The common practices of indiscriminately dumping wastes in the open environment, though fading away, results in serious health and pollution problems in developing countries. As LDCs aim for efficiency in handling and disposal of wastes, efforts should be made by local authorities and policy makers to develop appropriate methods and techniques for these wastes. One of the problems with the current methods of treatment/disposal through open burning is that the process does not proceed to completion. Similar and even worse problems result from open dumpsites. The process of digging pits in back yards may only temporarily solve the waste

problem, but in areas where topography and hydrological conditions are unfavourable, pollution may result.

The author wishes to suggest to developing countries to avoid re-inventing the wheel. MDCs have already encountered complications that result from indiscriminate dumping of wastes. LDCs may learn their methods of handling wastes but not adopt them as raw as they are. It will be prudent for developing countries to assess their waste situations and develop methods which are applicable to their country circumstances in the handling and discarding of wastes. For instance innovation centres, such as the Rural Industries Innovation Centre (RIIC) in Botswana, can be encouraged and supported for developing waste handling techniques as well as waste containers applicable to a sub-region. Developing countries should promote waste disposal methods which suit their environments, and which they can efficiently run without resource limitations. Taking advantage of warm temperatures and climates, biological methods of wastewater treatment using reed-beds in constructed wetlands to treat sewage may be widely practised, can be novel and innovative.

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CHAPTER 22

ROLE OF *EIA* IN WASTE DISPOSAL AND MANAGEMENT

F T K Sefe

**Department of Environmental Science
University of Botswana
Private Bag 0022
Gaborone, Botswana**

**Phone: 267-3552524 Fax: 267-356591
E-mail: sefef@noka.ub.bw**

The Role of EIA in Waste Disposal and Management

"Your destiny is a mystery to me. What will happen when the buffaloes are all slaughtered? And what is it to say goodbye to the swift pony and the hunt? The end of living and beginning of survival. We love this earth as a new-born loves its mother's heartbeat. Care for it as we have cared for it. Hold in your mind the memory of the land. Preserve the land for all children and love it."

**- A Native Indian Chief,
to one of the Presidents of the United States**

Introduction

The above quotation was reported to have been sent to one of the Presidents of the United States of America by one of the native Indian Chiefs. It is a poignant message. *The world is confronted with two major environmental problems, which are inter-related. These are how to use available resources in a sustainable manner given the increasing demand on these resources and how to manage the waste generated by the increasing population so as to maintain the integrity of the environment and its ability to sustain the future generations and us.* Had the world listened to that Indian Chief? Perhaps we would not be as hard-pressed as we are now in regard to the environmental problems we have to contend with. This chapter will focus on the issue of how to manage the mounting waste that we are generating.

All living things generate some form of waste. Generally, the volume and complexity of waste generated increase in quantum proportion to the level of complexity of the species' living pattern (or life-style as far as humans are concerned) as determined by the species' biological requirements of sustenance and maintenance and social imperatives. It is obvious now that the waste is generated in our living space, although it was not so obvious not long ago. Earlier conceptions of the environment were compartmentalised: a 'closed clean' living space with all the materials that we require for comfortable living and another space, often considered 'remote', into which the undesirable by-products of our living are discarded. We may even wonder whether this mentality is a thing of the past considering the shipment of waste of all types from one area for disposal in another that we hear of these days.

This mentality, despite the headline grabbing demonstrations of it, is surely dying. Several developments are responsible for this situation. One of the

notable causes of the change in this mentality is the *phenomenal increase in global population during the 20th Century*. Associated with this is an equally *phenomenal increase in resource consumption and, therefore, a commensurate increase in waste generation*. This worldwide trend has demonstrated to us, in rather graphic terms, that the living space we crave on this planet cannot be isolated from the space in which we discard the by-products of living. Of course, we can throw this by-products over the fence, into the public pathway, vacant land, gutters, rivers, wetlands, etc. However, sooner than later, we come to realise that in terms of natural processes, we cannot closet ourselves in a 'clean' living space. That is, we have to live with our waste in the same space.

This realisation implies that, if we want to improve our standard of living and maintain it at an optimum sustainable level, commensurate with the optimum benefit we can derive from the resources of our environment, we *need to develop systems to manage our waste in such a way that our very existence is not threatened*. In order to do this successfully, **EIA methodology** has to be adopted. This methodology has a major role to play in decisions pertaining to where to locate a waste disposal site, how to foresee likely impacts and how to mitigate these.

What is Waste?

Waste can be considered as *the by-product of our living*. We can distinguish between solid and liquid waste. Either type may occur individually although often they are inter-related or both associated. We can therefore define waste, in the broadest sense, as *all the discarded solid materials, either dry or wet or water-borne where the water itself was not of a discarding quality and discarded liquids which result from municipal, industrial and agricultural activities*.

In legal terms, we distinguish a category of wastes referred to as '**controlled waste**'. This may include *all waste from any or all of the above sources which a regulating authority wishes to control the disposal of*. Normally, however, *waste waters and mining wastes are excluded from municipal controlled wastes*.

Wastes are classified into four categories: *inert, general, wet and hazardous*. **Inert wastes** have the attribute of *little, negligible or no chemical interaction with the environment*. Inert wastes are also expected to have very little impact on the environment. Examples are builder's rubble (excluding plastic pipes and similar materials), excavation spoil, and material from the desilting of drains.

Hazardous waste comprises *waste that has the potential, even in low concentrations, to have a significant adverse effect on public health and/or the environment*. This categorisation is based on the inherent chemical and physical

characteristics such as *toxic, ignitable, corrosive, carcinogenic or other properties*. The range of wastes considered hazardous are further divided according to type as follows:

Inorganic Waste

- ☐ Acids and alkalis;
- ☐ Cyanide waste;
- ☐ Heavy metal sludge and solutions as Cr(6+) from tanneries; and
- ☐ Waste containing appreciable proportions of fibrous asbestos.

Oily Waste

- ☐ Wastes resulting primarily from the processing, storage and use of mineral oils

Organic Waste

- ☐ Halogenated and non-halogenated solvents residues;
- ☐ Phenolic and PCB waste - paint and resin waste; and
- ☐ Biocide and other organic chemical residues regarded as waste which contains less than five percent of biodegradable organic compounds and which are neither wet or hazardous. Any waste that will support combustion is excluded from this category

General Waste

General Waste is a generic term applied to all controlled waste that is not inert, wet or hazardous. It may comprise garden, domestic, commercial and general dry industrial waste. It may contain greater than five percent of readily biodegradable wastes, as well as small quantities of hazardous substances dispersed within it, e.g. batteries, insecticides, weed killers and medical waste discarded on domestic and commercial premises.

Wet waste is characterised by a high moisture content and a high leachate generation potential. Such wastes include liquid wastes, sludge and abattoir wastes.

Miscellaneous Waste

- ❑ Waste from the production of edible oils, slaughter houses, tanneries and other animal and vegetable based products;
- ❑ Infectious waste such as diseased human/animal tissues, soiled bandages and syringes - redundant chemicals or medicines;
- ❑ Explosive waste from manufacturing operations or redundant ammunitions.

Waste reflects the socio-economic status of a community in terms of volume generated and the composition of the waste. If we measure the volume of waste generated and analyse its composition in different suburbs of Gaborone, we can tell the socio-economic status of the respective suburbs. The same goes for regions of the same country and from one country to the other, in general terms considering all wastes.

What Is EIA?

One other term that needs some clarification from the outset is environmental impact assessment or EIA, for short. In simple terms, EIA is a process and a tool which is used to identify, predict and evaluate both positive and negative environmental impacts of any proposed development activity or policy (Department of Environmental Science, 1995). Munn (1979) has proposed a more precise definition. They defined EIA as:

".. an activity designed to identify and predict the impact on the biogeophysical environment and on human health and well-being, of legislative proposals, policies, programs, projects, and operational procedures, and to interpret and communicate information about the impacts."

What Role can EIA Play in Waste Disposal?

Waste disposal means the deposition of a stream of waste at a site which has the facility to handle the type of waste and is biogeophysical-conducive to receiving that type of waste. The qualification that the disposal site be biogeophysically suitable for receiving, the type of waste is an important one. It is this requirement which makes an EIA exercise very crucial for waste disposal. There are, normally, three objectives in selecting a waste disposal site. These are:

- (i) **The economic objective** - The site should be within an economic

haulage distance of the waste generation points. Because capital investment is required, the site should be suitable for use over a sufficiently long period to enable capital amortisation to be effected at normal market rates.

(ii) Environmental acceptability - The site selected should be environmentally acceptable for the particular type of waste envisaged. It should also provide for a simple, cost-effective design.

(ii) Social acceptability - The site should be socially acceptable to the majority of the community.

It should be clear that objectives two and three fall into the domain of EIA. The techniques of EIA are applied at a number of stages leading to the establishment of a waste disposal site.

Site Selection - Normally one starts with a number of possible sites. Even at this stage, a decision is required as to which sites to select as candidate sites. This decision can be facilitated by a preliminary EIA. The preliminary EIA at this point should be largely a desk study. Issues such as a description of the environment of the potential site (baseline description) its size and general location are considered. The description of the environment of the potential sites could come from personal knowledge of the area, books or other reports previously written. It is not necessary to undertake any elaborate study at this point.

Size should be considered in relation to the intended life of the disposal site bearing in mind whether or not compaction or burning will be allowed. Generally, the size of sites where compaction and/or burning is not possible would be larger than where such activities are allowed, for the same life span.

The general location of the waste disposal site is determined by the waste generation areas to be served. The disposal site should be as close to the generation point as possible in order to minimise transport costs.

After candidate sites have been determined in the above manner, the real work now is to eliminate unsuitable sites.

Elimination of Unsuitable Sites: The information gathered about the candidate sites is now utilised to eliminate the most unsuitable sites as follows:

- ❑ Disposal sites must not be close to airports as dumps attract birds which may prove hazardous to aircraft. A distance of 1 km is the minimum recommended separation between a dump and an airport.

- ❑ A disposal site must not be below the 1-in-50 - year return period flood level. This condition would exclude dry riverbeds, wetlands, swamps, pans and floodplains from consideration as waste disposal sites.
- ❑ Geologically unstable areas such as fault zones, seismic zones and dolomite and karst areas where sinkholes and subsidence are likely must be excluded.
- ❑ Sensitive ecological and/or historical areas. These include nature reserves ecological and cultural or historical significance. Waste disposal sites must not be sited in these areas.
- ❑ Catchment areas for important water resources must be avoided.
- ❑ Flat areas must be avoided as they would not allow drainage control to prevent up-slope and runoff from entering the waste body.
- ❑ Areas characterised by shallow or emergent groundwater, e g: swamps, pans, and springs where a sufficient unsaturated zone separating the waste body and the groundwater would not be possible. There should be a minimum 5m unsaturated zone between the waste and the groundwater. Areas that do not meet this specification must be eliminated.
- ❑ Areas of groundwater recharge must be avoided.
- ❑ Areas overlying or adjacent to important aquifers must be avoided.
- ❑ Areas to which the community attaches some importance whether tangible or not must be avoided. This will include residential areas, cemeteries and parks.
- ❑ Areas upwind of a residential area are also excluded.

This exercise should eliminate most of the unsuitable sites. The remaining sites are then subjected to an impact assessment.

Feasibility Study: The level of the EIA activity at the site selection stage is increased at the feasibility stage. At this stage, design of the facility is involved and so the EIA process is utilised to evaluate design options as well as a more detailed assessment of the proposed site(s). However, the EIA is still at the preliminary stage.

Final Stage: At the final decision point, EIA is very crucial to making the right choice of site. The objective of the EIA process at this stage are two-fold:

- ❑ To identify and evaluate the various ways in which a proposed waste

disposal site will affect its receiving environment; and

- ❑ To assist the designer in addressing any identified impacts by means of manipulation of the appropriate design parameters.

This stage will culminate into an environmental impact report in which short and long-term impacts will be clearly spelt out and measures to mitigate the adverse impacts are also articulated.

Monitoring: Once the facility has been constructed and is operational, it needs to be monitored. Elements such as leachate or runoff emanating from the site, gas discharge, air quality, impact on nearby vegetation and others are routinely monitored and compared to the preproject situation. Particular attention is paid to groundwater contamination because, depending on the climate, there can be a continuous stream of leachate in to the saturated zone. Due to this, EIA reports normally include the construction of monitoring boreholes close to the site of the dump.

Another area where attention is also focussed is surface runoff. Surface runoff from waste disposal sites is like a flowing cesspit. It has a great potential to contaminate large areas even far away from the dumpsite. For this reason, cut off drains should be constructed on the upslope side of waste dumps and surface runoff should be regularly monitored.

The monitoring routine must be specified in the EIA report. The report should also provide threshold values of the monitored items beyond which alarm bells would ring. For effective management, the results of the monitoring exercise must be reviewed periodically by the authority tasked with supervision of waste disposal sites in the municipality.

Decommissioning: Waste disposal sites eventually get filled up. At this stage where the site is closed, EIA plays an important role. The site would have to be remedied and rendered useable for other activities. The particular activity that can be carried out on the site has to be decided in such a way as to minimise adverse impacts. The decision on how best to use a decommissioned dumpsite is a typical EIA process.

Monitoring, however, continues even after decommissioning for varying periods of time. In some US states and certain European countries monitoring, can be carried on for as long as 30 years after decommissioning.

The Role of Modelling in Waste Management

The above description of EIA procedures in waste management can be modelled on a computer. You will be hearing about the use of computers in environmental management at a later date. However, let us take a brief look at models in waste management.

The main principle upon which all EIA is based is the concept of a system. The environment is organised as a system. There are inherent response mechanisms that trigger off reaction to stimuli created by action in one part of the environment. Considering the environment as a system, therefore, provides the mechanism by which the environment can be 'taken' apart, analysed and synthesised again. Thus by adopting the system viewpoint, we are able to predict what the likely impact of waste disposal site in any part of the environment might be. Then appropriate remedial action can be considered even at the stage of planning of the site.

Computer models provide a ready tool by which all the intricate environmental processes that have a bearing on waste disposal can be unravelled. Such models can be based on any part of the environment, which is of concern in terms of impact. Most are based on groundwater for obvious reasons. Recently, such a model was developed for the South African Water Research Commission using only geohydrological criteria. It is used in the assessment of waste sites suitability in terms of groundwater. It is called WASP (Waste-Aquifer Separation Principle).

Conclusion

The above discussion has illustrated the vital role that EIA plays in the process of waste disposal and management. The involvement starts at the conception stage of the project through to its operation. It need not be over emphasised, therefore, that EIA is an important tool in waste management.

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CHAPTER 23

ENVIRONMENTAL AND HEALTH IMPLICATIONS OF WASTE MANAGEMENT IN DEVELOPING COUNTRIES

Dennis Bella Sr

Environmental Health Unit

Ministry of Health

Private Bag 00269

Gaborone, Botswana

Phone: 267-374351 Fax: 267-374354

Environmental and Health Management in Developing Countries

Introduction

The aim of this chapter is to present an overview of the current waste management strategies employed in developing countries, highlight the environmental and health implications and suggest ways of improving the situation. Many developing countries are faced with varying stages of their development, from the need to accelerate socio-economic development on the one hand and how to deal with the effects of rapid growth in population, land use, resource use and increased waste generation on the other. Notwithstanding the complexities of developing countries' situation, *waste management poses new challenges and opportunities. Waste Management is a tool for environmental protection, preventive medicine and urban hygiene.* Waste avoidance and recycling also help conserve scarce natural resources. Waste, simply defined as "useless remains or by products" in themselves, with the exception of a small percentage of toxic or potentially infectious materials, do not pose a direct threat to health. The biggest threat to health from waste is when it is left uncollected, or improperly stored or disposed. They can attract vermin and insects, which are carriers of disease and pose real threats to public health. They also have the potential to contaminate water sources, air and land (soil), bringing aesthetic, environmental and health risks. The most commonly encountered risks associated with urban waste in developing countries are summarised in the paper. The most significant risk from improper waste management is that of health as the majority of deaths in developing countries are caused by diseases transmitted by human waste (infections and parasitic diseases) and airborne wastes (respiratory diseases). The identification of the sources and types of waste helps to limit the potential for harm as it enables the correct handling procedures to be followed which are appropriate to waste type.

Waste in developing countries can, for practical purposes, be divided into the following categories: Municipal Solid Wastes, Building and Construction Wastes and Industrial Wastes and Liquid Wastes. Proper treatment of wastes can help to protect health and minimise environmental risks. *The most common methods of waste treatment and disposal in developing countries are sanitary landfills, composting, incineration and anaerobic digestion.*

For developing countries whose limited resources are already over stretched in dealing with the HIV/AIDS, famine and refugees crisis, the adoption of the Waste Reduction, Reuse and Recycling, the 3R's of environmental conservation strategy present the most prudent way forward.

Background

It is often said, and certainly is true, that development is a two-edged tool where its effects on health and the environment are concerned. While it is proven, that the economic and technological outcomes of development have helped raise standards of living and health, uncontrolled, hazardous side effects have resulted in health impairment and extensive environmental changes. On the other hand, a lack of development usually means that society is unable to provide the basic services necessary to improve the people's well being.

Developing countries, most of which are already troubled by HIV/AIDS, Famine and refugee crises, find themselves under increasing pressure (both internal and external) to accelerate their socio-economic development and industrialisation processes. Most of these countries lack the requisite resources (human, financial and infrastructure) to adequately forecast, cater for and deal with the negative effects of development, rapid population growth and urbanisation.

Waste, simply defined as “*useless remains or by products*” is one of the by-products of the development processes that presents new challenges and opportunities especially for developing countries. Most human activities create waste. Waste takes many forms, and is derived from many sources: municipal wastes, from households, shops and offices; health care wastes; industrial waste; agricultural wastes; waste from construction and demolition; and special or hazardous wastes. Assessing the waste quality and composition is an important first step before deciding on a waste management strategy, and will also provide an opportunity to evaluate the implications for health and the environment. The majority of these wastes are not, in themselves, a direct threat to health but their correct management can help to minimise or avoid associated risks. The greatest threat to health from waste is when it is left uncollected, or improperly stored and or disposed. They can attract vermin and insects, which are carriers of disease and pose real threats to public health. They also have the potential to contaminate water sources, air and soil.

Generally, there is no single “correct” way to collect, handle and dispose of wastes, but a range of options. These must be tailored to local circumstances, such as the amount and climate, and economic conditions. In any case, proper treatment of wastes can help to protect health and minimise environmental degradation. Waste management authorities must encourage the minimisation of both the quantity and toxicity of wastes as a matter of expediency. Sound management of the remaining wastes will help to protect the environment, prevent disease and promote urban hygiene.

Risks Associated with Waste

There are three *major categories of risks associated with waste*, namely: aesthetic, environmental and health. The most significant is that of health as the majority of deaths in developing countries are caused by diseases transmitted through human waste (infections and parasitic diseases), i.e. Malaria, Cholera, Dysentery, Salmonellosis, Helminthic diseases, etc. and airborne wastes (respiratory diseases), i.e. aggravation of asthma, bronchitis, Acute Respiratory Infections, etc. The most commonly encountered risks and their effects are exacerbated by the processes of urbanisation and industrialisation increase these risks.

Waste Management

The best way to manage waste is to avoid its generation (if it's possible). Developing countries have the opportunity to learn from the mistakes of developed countries in the management of wastes; they can adapt cost effective and environmentally sound waste management techniques, using available appropriate technologies.

Action to improve waste management should be integrated, with a need to consider health, safety, environmental and economic aspects from “cradle to grave” or the Life Cycle Management approach. This approach is based on the principle that, in order to minimise the adverse environmental impact of the use of manufactured products; it is necessary to manage what happens to the physical resources (i.e. materials and energy).

Waste Minimisation

Waste minimisation or reduction is recommended as the most important management technique to be applied to solid wastes. The easiest and most environmentally friendly way to manage waste is to avoid its production (waste avoidance). Although it will never be possible to completely avoid the generation of waste, the local authority's objective should be to encourage waste producers to take a series of steps, each of which contributes to the avoidance of some amount of the waste, or perhaps reduces the toxic or harmful portion.

Waste minimisation measures may range from quick simple action without cost to long-term measures with higher capital investment. For example, some of these may involve small behavioural changes such as writing on both sides of a paper, etc or initiating an investment scheme, ie purchase of a photocopier which automatically prints on both sides of paper sheets.

Waste *Re-use and Recycling* Waste materials, *Re-use and Recycling* the other 2R's of environmental conservation technique, represent an important component of any serious attempt to address the waste management problem in developing countries. The first step will be to introduce appropriate legislation and economic opportunities with respect to encouraging recycling and re-use activities.

Recommendation - Waste Management Strategy for Developing Countries

A sustainable and proactive approach to waste management needs to take into consideration the complete process of gathering and assessing information on wastes and their management, setting objectives, determining legislative, economic and organisational requirements and communicating the appropriate information to the public.

Such an integrated strategy ought to include the following objectives:

To minimise Wastes:

1. Stabilise or reduce production of wastes for final disposal;
2. Reinforce procedures to quantify amounts/types of wastes;
3. Set target for capacity building and ensure the implementation of waste minimisation policies;
4. Provide incentives to reduce unsustainable; and
5. Waste production, develop national waste minimisation plans

To maximise Environmentally Sound Waste Re-use/Recycling:

1. Strengthen national re-use/recycling systems;
2. Ensure availability of relevant information;
3. Put in place policy instruments to encourage re-use/recycling;
4. Develop national programs with re-use/recycling target; and
5. Initiate public information and awareness programs.

To promote Environmentally Sound Waste Disposal:

1. Develop national waste management plans;
2. Encourage waste management within each major settlement; and
3. Apply the "Polluter Pays Principle" to the disposal of waste.

Conclusion

There are a number of risks associated with waste management. Waste left uncollected are the ones which have the most potential for harm. Those which are improperly managed or stored also present hazards. Good management practices can minimise most health and environmental risks and their implications. Consistent with the Agenda 21 philosophy, waste management strategy should therefore aim to ensure that sustainable and environmentally sound waste management practices are put in place to support such principles: as preservation, protection and improvement of the quality of the environment, and contribution towards the protection of human health.

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CHAPTER 24

BIOMEDICAL WASTE MANAGEMENT IN DEVELOPING COUNTRIES

M F Simpanya

**Dept of Biological Sciences
University of Botswana
Private Bag 0022
Gaborone, Botswana**

**Phone: 267-3552569 Fax: 267-3552784
email: simpanyam@noka.ub.bw**

Biomedical Waste Management in Developing Countries

Introduction

With increasing populations in most African and developing countries, there is a parallel expansion of medical and laboratory services to meet demand. But waste management has received little attention despite the potential environmental hazard and public health risk. For example, in Botswana with an estimated population of 1.4 million, the projected biological and medical wastes is estimated at 11000kg/day by the year 2004 from the current 8000 kg/day. Accordingly, if proper disposal methods are not implemented, there will be an accompanying risk to community health and environmental pollution. Consequently, *there is an urgent need for governments to enact laws and provide adequate facilities for treatment of hazardous and biomedical wastes in order to reduce associated health and environmental risks.* There is also a need for human resource training in waste management of biohazardous wastes.

General

Anthropogenic exposures to biological, medical or chemical wastes have become an important socio-economic and environmental factor, either at regional, national or global levels. The collection, storage and disposal of biomedical waste are a growing environmental problem. With increasing efforts to expand medical and laboratory services, the management of wastes has received little attention despite their potential environmental hazards and public health risk (Mato and Kassenga, 1997). Since wastes pose a danger to vital human activities, such as reproduction and health of individuals and large populations, the problem of prevention and elimination of technogenic exposures hazardous to human health has grown beyond medical competence to an environmental issue (Berry and Bove, 1997). A well-documented case of environmental pollution was the presence of mercury in Minamata Bay and Agano River in Japan. Methylmercury is a highly toxic form of pollution produced by micro-organisms from mercury accumulated in fish and shellfish. Many local inhabitants who consumed the contaminated fish were poisoned and developed neurological disorders, such as impaired vision in adults and cerebral palsy syndrome in children (World Bank Report, 1989). A study by Berry and Bove (1997) examined relationships between birth weight of children and mother's residence near hazardous waste landfill. They found that parents closest to landfills had a statistically significant lower average birth weight than the control population.

Furthermore, experience in a number of developed countries has also shown that cleaning up the "sins of the past" is much more expensive in the long term (World Bank Report, 1989)

Definitions and Biomedical Waste Classification

Biomedical waste includes preparations made from living organisms and their products such as serums, vaccines, antigens and antitoxins, **while medical waste** includes all of the following:

- ❑ **Biohazardous Waste or Sharps Waste.** This is waste which is generated or produced, as a result of the diagnosis, treatment, or immunisation of human beings and/or animals. Some of the medical waste generated may be infectious if it contains infectious agents such as viruses or bacteria, giving rise to **Infectious Medical Waste**. An infectious agent is any organism (such as a virus or bacteria) that is capable of being communicated by invasion and is able to multiply in body tissues resulting in disease or adverse health effects in humans and/or animals. **Sharps Waste** comprises any device having acute rigid corners or edges, or projections capable of cutting or piercing, including hypodermic needles, syringes, blades and needles. Broken glass items, pipettes and vials that are contaminated with other medical waste.
- ❑ **Infectious Biomedical Waste** is solid waste produced by medical and dental treatment facilities which should be specially managed because it has the potential for causing disease in humans and may pose a risk to both individuals or community health if not managed properly, and this includes the following categories:
 - (a) **Microbiology waste**, including cultures and stocks of etiologic agents which, due to the species, type, virulence, or concentration are known to cause disease in humans;
 - (b) **Pathology waste**, including human tissues and organs, amputated limbs or other body parts, fetuses, placentas, and similar tissues from surgery, delivery or autopsy procedures. Animal carcasses, body parts, blood and bedding are also included;
 - (c) **Human blood and blood products** (including serum, plasma, and other blood components), items contaminated by blood or blood products that are capable of releasing these materials during handling;
 - (d) **Potentially infectious materials** including human body fluids such as semen, vaginal secretions, cerebrospinal and amniotic fluid, saliva in dental procedures, or any body fluid where a risk of infection exists; and
 - (e) **Sharps**, which include hypodermic needles, syringes, biopsy needles and other types of needles used to obtain tissue or fluid specimens, needles used to deliver intravenous solutions, scalpel blades, Pasteur pipettes,

specimen slides, cover slips, glass Petri-plates, and broken glass potentially contaminated with infectious waste.

Sources of Biomedical Waste

Biomedical waste arises from establishments such as referral, district, mental, primary and private hospitals, health clinics and posts, blood transfusion centres and medical research and teaching laboratory centres (National Conservation Strategy, 1995)

Health and Environmental Risks

There are two main types of risks associated with biomedical waste. *Foremost is the risk to health due to infection or injury* (NSC, 1995), particularly health care workers involved in handling of biomedical waste. *The second type of risk is an environmental risk, if there is no proper disposal of biomedical waste.* This can lead to pollution of water, air and soil resulting in long-term exposure of the population which may lead to severe adverse health effects due to poisoning (World Bank Report, 1989, NSC, 1995). The risk to water can be due to heavy metals, such as mercury, silver or expired pharmaceuticals for disposal. Therefore, one of the major environmental risks includes leaching of chemicals and subsequent contamination of water sources (World Bank Report, 1989). The risk to air can arise from emissions from improper incineration of the pharmaceuticals, burning of metal such as mercury which creates emissions of dangerous mercury and infectious biomedical wastes to minimise the potential for infection (NSC, 1995).

Handling of Biomedical Wastes

Biomedical wastes, for the potential health danger associated with it, requires special procedures for its management. The indicated establishments and premises, at which biomedical waste is produced, also generate general waste that is disposed by normal waste disposal methods without pre-treatment. This includes garbage and rubbish. Garbage being putrescible waste resulting from handling, preparation, cooking, or serving food, while rubbish is the non-putrescible solid waste which falls into two categories; combustible and noncombustible, such as paper and metal respectively (DDEAMC, 1993).

For these reasons, *biomedical waste requires segregation both between the different categories and from general waste.* Biomedical waste should be segregated from general waste at the point of origin into red biohazard bags conspicuously labelled with the words “biohazard waste” or the international

biohazard symbol with the word “biohazard”. While sharps containers must be rigid, puncture and leak resistant when sealed, and cannot be reopened without great difficulty, and properly labelled. Sharps containers may be placed in the red biohazard bag (Coast Community College District, 1997).

Storage

Storage enclosures must be secured to deny access to unauthorised persons, preferably posted with a sign “caution - Biohazardous waste storage”. Biohazardous waste and sharps containers may be stored up to 7 days above 0 degC.

Treatment of Biomedical Waste

This relates to *any method, technique or process designed to render infectious biomedical waste non-infectious, such as use of an autoclave, incinerator or microwave technology*. Any department treating biomedical waste on-site using autoclaves or similar forms of sterilisation must establish treatment procedures. The following biological and medical waste treatment protocol using an autoclave is after the Coast Community College District (1997):

1. Standard written operating procedures for steam steriliser, including time, temperature, pressure, and type of waste, type of container, method of loading, water content and maximum load quantity;
2. Check the recording during each cycle to ensure 121 degC for 30 minutes or longer. The thermometers should be checked annually for calibration;
3. Operating parameters for each autoclave must be documented;
4. Use heat sensitive tape for each container that is processed to indicate attainment of adequate sterilisation conditions;
5. Use of *Bacillus stearothermophilus*, a thermophile capable of growth at deC (Van Demark and Batzing, 1987) placed at the centre of a load processed under operating conditions at least monthly to check adequate sterilisation;
6. An emergency action plan must be in place at locations where biomedical waste is being treated.

Biomedical waste that has been treated becomes solid waste, which is not hazardous.

Table 24.1: Treatment Methods and Methods of Disposal of Biomedical Waste.

Type of Biomedical Waste	Method of Treatment	Method of Disposal
1. Microbiological.	Steam. Sterilisation. Chemical disinfectant. Incineration.	Municipal solid landfill (MSLF).
2. Pathological.	Incineration. Cremation.	MSLF. Burial.
3. Bulk Blood.	Incineration. Steam sterilisation.	Wastewater. Treatment Plant.
4. Suction Canister.	Steam Sterilisation.	Waste Water. Treatment Plant.
5. Sharps in Sharp Containers.	Steam Sterilisation.	MSLF.

Note 1 : Bulk blood known to be infectious must be treated by incineration or steam sterilisation before disposal.

Regional Experience

The Republic of South Africa uses extensively low technology incinerators combined with one medium technology plant located in Durban and one planned for Johannesburg as of 1995. In Zimbabwe, by 1995, there was no national policy and no legislation on medical wastes. Essentially, individual hospitals developed their own system of disposal. Biological and infectious waste being packed in plastic bags and incinerated. This is a similar situation obtaining in Botswana. In Zambia as of 1995, there was no national policy, nor legislation nor standards with most medical waste being dumped (NCS, 1995).

Record Keeping

Departments with on-site waste treatment must have information on-site, an emergency action plan for spills on-site and treatment facility operating records for three (3) years.

However, if a department is using a hazardous waste hauler for off-site waste treatment, they must have; information document on-site, records of quantity,

type of waste and date of transport and the name of a hazards waste hauler. Similar to on-site treatment, tracking documents must also be kept for three (3) years.

Conclusion

There is an urgent need for governments to enact laws, train skilled manpower in waste management, provide guidelines and standards for proper disposal of biological and medical wastes. At establishments where biomedical wastes is generated, proper segregation of wastes should be implemented and use of steam sterilisers, such as autoclaves and low technology incinerators encouraged. If the current haphazard waste management continues, there is likely to be an increased health risk to the community and pollution of the environment from improper disposal of biohazardous wastes within a foreseeable future.

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CHAPTER 25

A REVIEW OF NUCLEAR AND RADIOACTIVE WASTE MANAGEMENT WITH REFERENCE TO AFRICA

Georges Ekosse

**Geology Department
University of Botswana
Private Bag 0022
Gaborone, Botswana**

**Phone: 267-3552569 Fax: 267-3552784
E-mail: ekossege@noka.ub.bw**

A Review of Nuclear and Radioactive Waste Management with Reference to Africa

Introduction

*This chapter highlights and defines the types of nuclear and radioactive waste generated based on internationally accepted standards and terminology. It discusses the few African countries, which produce nuclear and radioactive waste, and those that have the potential to produce nuclear and radioactive waste. Some of the most likely factors such as technical, economic, institutional, aesthetic and ethical affecting the handling, treatment, storing and disposal of these categories of waste are considered. A justification is argued for very minimal nuclear and radioactive waste production in the less developed countries compared to that of the more developed countries. *Laws and legislation on nuclear and radioactive waste management are either lacking or not stringently applied in African countries.* Multinational corporations (MNCs) from the developed countries tend to exploit the economic situation of less developed countries in attempting to involve agencies, institutions and private companies in illegal trade of nuclear and radioactive waste. With increasing global demand for the use of nuclear energy (research, civil and military reactors), it is debatable if Africa will continue to remain a continent with the lowest level of nuclear and radioactive waste generation.*

Overview

The Allied Powers forced the Second World War to an end when two atomic bombs were dropped in Hiroshima and Nagasaki, both cities in Japan. Uranium-238 was converted to Plutonium-239 with the release of energy having the capabilities of destroying living cells. The tremendous catastrophic aftermath resulting from the radioactive ionisation release opened the eyes of Western Powers to a new era and application of nuclear energy. With the introduction of nuclear technology, humankind's living standard has been ameliorated in the areas of energy supply, medicine, economic development and environmental protection. New applications of nuclear technology are researched on and introduced at an accelerated rate.

With increasing global demand for this form of energy and the discouragement in the usage of fossil fuel, a tendency is ensured towards the generation of more nuclear and radioactive waste. It becomes inevitable for man to clean his

habitat for both himself and posterity. The politics, methods and techniques, laws and legislation and safety of cleaning humankind's environment due to the generation of nuclear and radioactive material is nuclear and radioactive waste management.

This form of waste management deals with the treating, storing and disposing of nuclear-related spent fuel and waste generated during the application of nuclear and radioactive material for individual and national benefits. Radioactive waste is any material having a concentration of radionuclides greater than those deemed safe by national and international authorities, with an unforeseen use (World Atom, 1998).

This chapter reviews from existing literature and available data through the Internet, the generation and classification of nuclear and radioactive waste. It discusses how nuclear and radioactive waste is currently managed. It focuses on the prevalent African situation and attempts to forecast a future trend worldwide in the application of nuclear and radioactive energy and their disposal.

Generation of Nuclear and Radioactive Waste

Basic Nuclear Chemistry

In any radioactive reaction or nuclear reaction, at least one of three types of emissions occurs during the reaction. These are:

- ❑ *Alpha-Radiation* which gives rise to **alpha particles**, which are Helium-4 nuclei;
- ❑ *Beta-Radiation* which gives rise to **beta particles**, which are fast electrons emitted from nuclei; and
- ❑ *Gamma-Radiation* which gives rise to **gamma photons**, which are very high frequency short wavelength electromagnetic radiation.

In these reactions, either a nucleus splits into two or more daughter nuclei (radioactive decay), a nucleus is caused to disintegrate (nuclear fission) or two or more nuclei are caused to combine to form one nucleus (nuclear fusion). In all the three types of nuclear reaction, nuclear energy and nuclear waste are released. The number of radioactive nuclei in a radioactive decay series decreases exponentially with the law of radioactive decay.

Generation of Waste

Nuclear and radioactive waste can be generated in six different ways. These are as follows:

- ☐ Naturally occurring;
- ☐ Tailings dump;
- ☐ Mining activities;
- ☐ Research for new applications and increase in knowledge;
- ☐ Civil applications; and
- ☐ Military applications

Naturally occurring isotopes of radioactive elements, such as Uranium, exist in nature although their isotopic percentage compositions are usually less than 5%. This explains why radioactive isotopes need to be enriched in order to have a high concentration required for their various applications. Uranium-235, most needed isotope in nuclear technology, occurs naturally as 0.7% of the three isotopes of Uranium, and must be enriched to 3% before it can be of any nuclear application.

Tailings dumps from the exploitation of certain types of mines may be constituted of certain percentages of nuclear and radioactive substances such as oxides of uranium. In some deposits of precious and semi precious minerals, radioactive substances may occur at levels profitable for exploitation as by-products. In the extraction of gold, for example the East Rand Gold and Uranium Company in South Africa, uranium is a by-product. The most commonly mined uranium mineral is pitchblende (Uranium oxide).

Universities and research institutions generate nuclear and radioactive waste substances. In a variety of civil applications of nuclear technology (medicine, energy, agriculture, water quality etc.), and in the manufacturing of nuclear weapons, and in the researching with radionuclides high level and low level waste are generated. *Main sources of radioactive wastewater emanate from nuclear reactors, isotope laboratories, nuclear research centres, and from the processing of uranium ore, laundering of protective clothing used by workers of radioactive materials, and from laboratories in which radioactive substances are applied for therapeutically* (Jorgensen, 1979). Ionisation radiation equally releases waste in what is now known as electronic smog: cannot be seen or even felt! Recent revealed statistics show that nuclear power generation facilities in the world produce about 200 000 metres cubed of low and intermediate level (LILW) and 10 000 metres cubed of high level waste (HLW) annually (World Datom, 1998).

Classification of Nuclear and Radioactive Waste

All nuclear waste contains at least a quantity of long-lived radionuclides. The wastes are categorised based on their origin. It should be noted that all transuranic elements are artificial, unstable and radioactive in nature, emitting alpha-particles with very long half-life. To this effect, five categories of radioactive waste are identified (Institute for Energy and Environmental Research, 1998). These classes are:

- ❑ **High Level Waste (HLW):** This class includes irradiated commercial reactor fuel (spent fuel), and reprocessing liquid waste;
- ❑ **Transuranic Waste (TRU):** This class of waste contain elements with protons greater than 92. The half-life should be greater than 20 years and concentrations greater than 100 nanocuries. These radioactive (unstable) elements are neptunium, plutonium, americium, curium, berkelium, californium, einsteinium, fermium, mendelevium and nobelium;
- ❑ **Naturally Occurring and Accelerator Produced Radioactive Materials:** These are orphan waste such as Radium-226 and Thorium-230 produced outside the nuclear fuel cycle.
- ❑ **Low Level Waste (LLW):** This category of waste includes all other representations of nuclear and radioactive waste not mentioned in the three categories above. This class is broad and includes short-lived and long-lived radionuclides;
- ❑ **Mixed Waste:** This contains both radioactive and hazardous materials.

An analytical study (Canadian Coalition for Nuclear Responsibility (1996) of one of the sources of nuclear and radioactive waste, found a total of not less than seventy-nine poisonous isotopes from forty-five chemically identified elements to occur in spent nuclear fuel. The list includes six isotopes of Uranium, five isotopes of Plutonium, seven isotopes of Thorium, Tritium, Lead-205 and Lead -206.

Nuclear and Radioactive Waste Production in Africa

Africa is not as involved in nuclear technology as Europe, Asia or North America. However, there are a number of mining activities and nuclear energy utilisations, particularly in South Africa, which demand the management of waste. Two most used radioactive elements that generate waste are Uranium and Plutonium. Uranium is the principal fuel for nuclear reactors and main raw material for nuclear weapons. In 1996, close to 35 200 tons of Uranium were

produced in 38 countries around the world, of which about 22% was from Africa (Uranium Institute, 1998), (see Table 25.1). Canada alone produced 11 788 tons. South Africa has Africa’s largest reserve. amounting to 317 000 tons, followed by Niger and Gabon.

Table 25.1: Uranium Production in Africa.

Country	Tonnage	%age
Gabon	565	1.6
Namibia	2452	7.0
Niger	3320	9.4
South Africa	1440	4.11

Apart from the four countries mentioned in Table 25.1 above, sixteen other African countries including Nigeria and Cameroon are known to have significant Uranium deposits.

Uranium mining and its isotopic enrichment are complex industrial processes requiring the use of nitric acid, hydrofluoric acid and magnesium. Plutonium (Pu) is the second transuranic element and is not known to exist naturally although a case has been reported in Gabon. It must be produced artificially from Uranium. One kilogram of Plutonium-239 produces heat energy equivalent to 22 million-kilowatt hour of heat. To detonate a kilogram of it, an explosion is produced with the equivalent of 20 000 tons of chemical explosives. Plutonium has been used in space missions (Apollo series) to empower seismic and other equipment on the lunar surface.

Waste Management Techniques

Handling

Owing to the instability of radionuclides, and the health and socio-economic implications of their waste occurrences, nuclear waste management involves highly specialised technical skills, appropriate disposal facilities and good economic planning. The radioactive nature, health hazards and the amount of energy release associated with both natural and induced decay of these substances demand that they be handled with very great caution.

Treatment

The main concern in treating radioactive waste is to reduce its volume and render it inactive or immobile. Treatment options in volume reduction include

chemical precipitation, incineration and compaction. The immobilisation phase includes any one or a combination of the following techniques: bitumen application, concretisation, polymerisation and vitrification.

The liquid HLW is immobilised in a stable matrix of borosilicate glass and stored before disposal in a geological repository. Glass, being amorphous, is preferred because it forms network with its oxygen and silicon atoms instead of crystals, which can be penetrated in cracks by radioactive substances.

Waste Recovery

The processing of Spent Nuclear Fuel (SNF) is much more complex and expensive than the preparation of the fuel for a nuclear application. Uranium and associated radioactive substances such as Plutonium are very expensive. In the processing of spent nuclear fuel, any minute quantity that can possibly be recovered is recuperated. *There are however three problems areas in its recovery.* These concerns are *first, the recovery of any left over Uranium-235, second, Plutonium extraction if produced, and third, the disposal of highly and largely useless products* (Atkins and Beran, 1990).

Uranium and Plutonium can be recuperated from SNF by solvent extraction (purex process): a process that makes use of their differing solubilities in various solvents. A composition of 80 % kerosene and 20 % triter-butyl-phosphate with water are used to process the spent fuel and to recuperate plutonium and uranium separately. Plutonium (IV) and Uranium (VI) oxides dissolve preferentially in the organic solvent while most of the other fission products dissolve in water. Plutonium (IV) is then reduced to Plutonium (III). Plutonium (III) and Uranium (VI) are mixed with water whereby Plutonium (III) oxide solution dissolves preferentially in the water. Further purification and reaction stages produce Uranium Oxide and Plutonium Oxide.

Storage and Disposal

The international scientific community is carrying out research to ascertain the most suitable ways of storing and disposing of nuclear and radioactive waste. While most of the LILW is being contained through near-surface disposal facilities and geologic repositories, the management and disposal of HLW still poses a threat to human life and the environment due to their long-lived radionuclides. Geological repositories are used as disposal systems for HLW and they tend to contain radioactivity within engineered barriers and natural barrier. Engineered barriers are human-made and they consist of multiple components, which includes solid waste, metal canister and clayey backfill material (most probably bentonite). Natural barrier is usually a thick geologic formation: granite rock, or some sedimentary impervious rock such as shale.

Some generators of SNF do not have the appropriate disposal facilities and may have to provide interim storage for up to ten years before exporting it to a country having the right facilities. The used fuel may be stored in facilities for up to one hundred years during which it must have been treated and conditioned for the appropriate decay period then disposed off in a geological repository.

Bredell and Fuchs (1997) propose an international waste management system whereby countries producing HLW and SNF can establish and share regional geological repositories for the disposal of their waste. It should be noted that currently there are no geological repositories for HLW and long-lived radionuclide waste. It is anticipated that by year 2010, the first ones will become operational and within the next twenty years thereafter, twenty additional similar systems would have become functional as well.

South African Situation

The Atomic Energy Corporation of South Africa was established in 1948 to undertake nuclear research and development. In 1965, SAFARI-1 (the nuclear research reactor) was in operation and by 1985, there were a couple or more Uranium enrichment plants in the country providing both weapons grade material and fuel for nuclear power stations. The AEC has directly or indirectly been involved in the manufacturing of over 200 products which are being marketed in South Africa and twenty other countries (AEC, 1998). With these on-going activities, radioactive waste is generated.

The National Radioactive Waste Disposal facility of the AEC, Vaalputs, is 120-km Southeast of Springbok. Only LILW from Koeberg nuclear power station in the Western Cape Province is processed and stored in near surface trenches (AEC, 1998). In a recent study on radioactive waste disposal carried out by Bredell and Fuchs (1997), it is projected that 322 960 tons of spent fuel will be generated in the world by 2010, of which 830 tons will come from South Africa.

Factors Affecting Radioactive Waste Management

National Policies

Although intergovernmental agencies and more particularly the International Atomic Energy Agency (IAEA) have set up regulations in the management of nuclear and radioactive waste, countries differ in approach in implementing these regulations. More than thirty one countries are listed in an inventory of SNF (Bredell and Fuchs, 1997), and the administration of their waste will some what differ in as much as a baseline on global safety is agreed by all the generators.

In the United States, the Department of Energy is mandated with the management of radioactive waste. It has technical challenges to overcome, which primarily are the construction of storage and disposal facilities and their management.

The plan considers the risk of transporting waste from one site to another, storing waste on-site, and ensuring worker safety while handling the waste. It works closely with the Environmental Protection Agency (EPA), United Nations, local governments, the military, academic and research institutions, concerned citizens, regulators and the public in the implementation of a national policy on nuclear and radioactive waste management. The South African government through the AEC is committed to establishing policies, programmes and practices for conducting operations in an environmentally sound manner.

Institutional Approach

Governments, NGOs and IGOs have different approaches to nuclear waste management. In 1996, the governments of Canada and Ontario commissioned Atomic Energy of Canada to evaluate the HLW disposal concept. The committee reported that socially, the public does not embrace this disposal system. More scientific tests have been carried out since then. The Alliance for Nuclear Accountability with its office in Washington DC has an affiliation of forty grassroots and national organisations working to address issues of nuclear weapons production and waste clean-up. It was founded in 1987 and concerns itself with:

- ☐ Public and worker health and safety;
- ☐ Environmental cleanup and restoration of contaminated nuclear weapons production sites;
- ☐ Dismantling and disarmament problems;
- ☐ Research, development and testing (actually experimenting); and
- ☐ Nuclear waste disposal.

The IAEA (Managing Radioactive Waste, 1998), plays a pivotal role in nuclear waste management. Primarily, the agency concentrates on the following:

- ☐ Collecting, reviewing and publishing up-to-date scientific and technical information;
- ☐ Providing direct services, particularly to developing Member States and the newly independent states of the former Soviet Union, through technical assistance, training, and other programmes to strengthen national infrastructures, including the demonstration of waste management techniques;

- ❑ Fostering and co-ordinating research and development through co-ordinated research programmes;
- ❑ Establishing safety standards for the management and disposal of waste by building international consensus;
- ❑ Implementing international codes of practice and safety conventions; and
- ❑ Providing a forum for the dissemination and exchange of information at international conferences, symposia and seminars including the promotion of education, public information and training; developing and implementing special projects, including assessment of the environmental and radiological impacts of waste disposal.

Economics

One of the main reasons why African countries have not developed nuclear capabilities is finance. Nuclear facilities including their waste are very expensive to manage. The US Department of Energy requested for three billion dollars in 1989 for the management of its nuclear waste. Between 1990 and 1994, the Department spent an additional seven hundred and forty six million dollars in constructing a waste isolation pilot plan. In 1995, it spent more than six hundred million dollars in the construction of underground storage tanks. The US Government has been collecting a levy to finance the disposal of nuclear waste and eleven billion dollars is earmarked!

South Africa can commit herself into some huge expenditure in Nuclear Technology. Other African countries will find it extremely difficult as they have to cope with hunger, health, unemployment, and education and civil strives. On the other hand, Western Powers may construct such facilities in Africa, if the need for imbalance of regional and global powers surface as a threat to the concerned nation.

Health and Social Factors

Radioactive substances are carcinogenic and the main type of cancer associated with it is lung cancer. Radium-226 and heavy metals such as magnesium and molybdenum leach into and contaminate groundwater at levels considered to be pollution. The use of plutonium in space operations has met serious emotional and emotive problems from the United States in particular.

Many native Americans working in mines producing radioactive substances have died of lung cancer. Others continue to suffer the effects of land and water contamination resulting from seepage, spills and tailings pile (UIC

Newsletter, 1995). South African gold mines extract large quantities of uranium as a secondary product thereby exposing neighbouring black communities to cancer-causing radium and radon that leak from uranium mine waste.

Environmental Factors

The environment has been artificially contaminated as a result of a number of manrelated activities. These activities include:

- ☐ Accidents such as the radioactive spill from Chernobyl nuclear reactor in 1986;
- ☐ Nuclear weapons production;
- ☐ Testing of nuclear weapons at some atolls;
- ☐ Nuclear energy generation and supply;
- ☐ Mining and milling;
- ☐ Poor radioactive waste management practices; and
- ☐ Abandoned radioactive facilities

The above-cited activities have not only contaminated but also caused marine, aquatic, terrestrial and air pollution. To this effect, the International Atomic Energy Agency (IAEA) conducted a symposium to review studies aimed at reconstructing radiation doses. Discussions were held under the “Precautionary Principle”, which encourages precautionary measures to be taken in protecting the environment from potentially harmful contaminants even if there are no concrete evidence that those contaminants have an adverse effect. Studies have shown that global and regional release of radionuclides from dumpsites affect local environments.

Bain (1998) discusses the commitment of South Africa’s AEC to the environment. In his discussion, it is mentioned that the AEC has always sought to improve its environmental management procedures. Currently affiliated to the International Chamber of Commerce (ICC), South Africa’s AEC is a signatory of the Chamber’s Charter for sustainable development safety, health and environmental aspects, and evaluates its compliance in terms of their environmental self-assessment programme. Recently, the South African corporation adopted a policy of zero effluent and release (AEC, 1998).

Safety

Generators of radioactive waste are concerned with individual and national safety. An argument may be raised regarding the international and national standards in the implementation of safety. Of past poor safety standards and human error have been the main cause of a number of accidents at nuclear reactor facilities and ocean vessels. A need emerged for an international body

to be responsible in formulating safety standards and procedures in the handling, treating, conditioning, storage and disposal.

IAEA has stepped into the shoe of regulating the safe management of radioactive waste. The Radioactive Waste Safety Standards (RADWASS) programme of the IAEA seeks to provide a series of documents in the fields of radioactive waste management, decontamination, decommissioning, and environmental restoration which is periodically reviewed by the International Radioactive Waste Management Advisory Committee (INWAC) (IAEA, 1994). There are about forty near-surface disposal facilities which have safely been operating for the past thirty five years, and thirty more related facilities will be added within the next decade (Managing radioactive waste, 1998). The IAEA operates its own nuclear research and service laboratories to support the safe and effective transfer of technologies to its member states. Their laboratories are based in Vienna and Seibersdorf in Austria, and Monaco.

Other Factors

Some other factors affecting the management of nuclear waste include research and development, availability of technical expertise and technological tools, aesthetics and legal/legislative implications. Some of these factors have been discussed in different sections of this chapter and need not be repeated.

Nuclear Waste Shipment

Not all generators of nuclear waste do have nuclear waste recovery facilities. Such institutional arrangements give vent to the need to have in place facilities to enable export of waste to be processed in waste recovery facilities in other countries. In 1992, Japan committed herself to return shipment of her nuclear waste presently to France. In January 1997 forty canisters containing twenty and a half million curies of radioactivity and weighing about twenty metric tons of reprocessed Japanese SNF was shipped from France. Other shipments had occurred prior to the 1997 lot that increased global concern for safety. One metric ton of weapons-usable Plutonium-239 was shipped from France to Japan through the Cape of Good Hope, Australia, New Zealand, and the Pacific Islands and to the final destination. In April 1995, a consignment of 28 logs of high level vitrified glass weighing about two hundred and fifty kilograms each, containing nuclear waste was shipped from France through the Atlantic to South America, Pacific, Hawaii and finally to its destination in the Aomori Prefecture in Japan. The same year, a consignment of SNF was shipped from Japan to France passing through the Panama Canal. It was estimated that there would be between one hundred and twenty to one thousand two hundred shipments by the end of the first decade of the new millennium according to

reactors are decreasing and there is on-going restoration of outused nuclear sites for other friendly purposes. Other countries are struggling to belong to the club of “Nuclear Power” states. Recently, India carried out three nuclear tests which was condemned by most of the nuclear powers of the western world and Japan. With on-going conflicts in the Middle East, many of those countries will likely develop their nuclear capabilities. In Africa, Nigeria may likely join South Africa in the “nuclear power club” which will force one of the African countries (most likely Cameroon) to develop her nuclear capabilities with the direct support of France.

On the other hand, scientists and institutions should be engaged in a two-fold research objective:

- ☐ To develop complex substances that can immediately counteract any effect of nuclear energy through military applications; and
- ☐ To develop new forms of applications that will advance the human-kind to the “cradle of technological civilisation”. These activities will generate more waste.

Nuclear and radioactive technology will continue to find new applications in a number of areas, including the following:

- ☐ Soil fertility, irrigation and crop production;
- ☐ Plant breeding and genetics;
- ☐ Animal production and health;
- ☐ Insect and pest control;
- ☐ Agrochemicals and residues;
- ☐ Food preservation;
- ☐ Nuclear medicine;
- ☐ Radiation biology and radiotherapy;
- ☐ Radiation dosimetry;
- ☐ Nutrition and health;
- ☐ Research reactor support;
- ☐ Radiation engineering and technology;
- ☐ Control systems and radioactive tracers;
- ☐ Analytical techniques and quality control;
- ☐ Borehole logging and rock characterisation;
- ☐ Radioactively-labelled pharmaceuticals;
- ☐ Development of water and mineral resources; and
- ☐ Applications in chemical, oil production, steel, cement, automotives, and maritime industries.

New electrical generation from wind is beginning to exceed that from nuclear power (Barnard and Terreblanche, 1998). Modern information technology

the operating Japanese-French contract towards the beginning of the new millennium (Van Dyke, 1998).

As at the end of 1997, radioactive waste was being shipped for reprocessing in accordance with Japanese and French venture cited. Brendell and Fuchs (1997) suggest establishing regional repositories. The implication of this move would mean more shipments of radioactive waste to their reprocessing and recycling, and storage destinations. International institutions and national governments would have to enforce stringent safety factors so as to avoid accidents in the course of transportation.

The Battlefield

Countries and corporations have been exploiting the loophole of the "Precautionary Principle" in transporting their nuclear waste. The Precautionary Principle also known as Principle 15 of the 1992 Rio Declaration on Environment and Development states that:

"In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Whereby there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation"
(Agenda 21, 1992).

On the other hand, nations have the right under international law to block passage through their maritime waters of an ultra-hazardous transport (Van Dyke, 1998). Countries that are used for passage of nuclear waste could use force to divert the course of a freighter. An example is the Chilean gunboat, which forced a British nuclear waste freighter to change course and leave Chilean maritime territory. According to Van Dyke (1988), there is need therefore to create an international set of rules to govern the transportation of ultra-hazardous substances (which includes nuclear and radioactive substances). Such rules and regulations will accommodate countries that generate the waste, those that process and recycle the waste, and also those whose maritime waters are used for passage.

The Way Ahead

On a global perspective, the quantity being generated of nuclear and radioactive waste is on the increase. Many more military weapons are being dismantled. Presently, there is no economically, environmentally, and politically acceptable way long-term storage of radioactive waste containing plutonium-239 hundreds of thousands of years (Miller, 1996). The numbers of nuclear

facilities make nuclear technology knowledge to be easily accessible. The future in the use and types of applications of nuclear technology rests in the hands of the world leaders, the politics and economics of globalisation, and the sanity of minds of those in authorities worldwide.

Conclusion

This chapter has reviewed the management of nuclear and radioactive waste. Although 22% of world uranium production comes from Africa, the continental waste is not up to 1% of the HLW generated worldwide. Statistics could not be referred to for other forms of radioactive waste production in the continent. It has considered the African situation and argues more from an economic perspective why the continent lacks these facilities. South Africa however stands alone in the application of nuclear technology in the Africa.

The activities and commitment of IAEA regarding nuclear and radioactive waste management are recognised, and it is anticipated that through their research endeavours (collaboratively with other national, international and private institutions of like objectives), more man and environmentally friendly applications will be developed and implemented. Nuclear and radioactive waste contains radionuclides that are long-lived with intense radioactivity. Its disposal is a problem that concerns this generation and affects posterity. We have an obligation to leave our planet cleaner than we found it.

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CHAPTER 26

INDUSTRIAL WASTE MANAGEMENT WITH SPECIFIC ALLUSION TO THE MEAT AND MINING INDUSTRIES IN DEVELOPING COUNTRIES

Yvonne Gotlop Bogatsu

Department of Environmental Science

University of Botswana

Private Bag 0022

Gaborone, BOTSWANA

Phone: 267-3552524

Fax: 267-356591

E-mail: gotlopyk@noka.ub.bw

Industrial Waste Management with Specific Allusion to the Meat and Mining Industries in Developing Countries

Introduction

Developing countries tend to specialise in industries processing natural resources such as minerals. They also tend to be geared towards agricultural production, primarily due to a predominantly rural agrarian nature of their environments. The **meat industry** is one of the major processing industry types in developing countries. Botswana, for instance, ranks among the world's largest exporters of beef. *Handling wastes from meat industries may seem straightforward since the waste is purely of organic nature, but there are setbacks in managing these wastes.* The Botswana Meat Commission, for instance, practices resource recovery with most of its wastes. *Studies have shown that treatment of wastes from meat industries become efficient when anaerobic biological techniques are applied. This chapter focuses on environmental problems that are associated with the meat processing industry.*

Developing countries have rich mineral resources. This may be the result of the inherent nature of the predominantly warm environments, which enhance decomposing of organic wastes into fossils, and eventually to minerals such as coal and petroleum. **Mining industries** *struggle to handle and manage their wastes in an environmentally sound way.* When attention is given to a specific copper mine, for example, it becomes clear why wastes from this industry are difficult to handle. One must note that *mining industries by their nature damage the environment and produce pollutants.* The copper mine for instance produces solids, wastewater and gaseous wastes, all of which adversely affect the environment. In addition to the meat processing industry, this chapter focuses on treatment methods applied in mining industries in developing countries, and discusses some problems encountered in the process. Recommendations suggested for solving difficulties encountered along the way.

Overview

The types of industries in an area will dictate the characteristics of wastes that will be generated. Developing countries seem to experience a bloom of all sorts of industries, but waste management seems to lag behind.

Planning for economic development in developing countries appear to continue without the necessary waste management programme in place for the particular

development. A majority of developing countries produce natural resources in the form of minerals or rely on agricultural products for economic support. This is especially so in the African continent and in most developing countries elsewhere. As a consequence the affected industries produce large quantities of wastes that must be handled in an environmentally safe manner.

This chapter focuses on those industries common in developing countries. **Abattoirs or meat-packing and processing factories** exist in most developing countries especially since the communities have a culture of practising livestock farming for the production of meat and milk. Wastes produced from meat industries, particularly slaughterhouses are primarily organic. For instance blood contains biochemical oxygen demand in excess of 150 000 ppm (Anonymous, 1992).

The diversity of **mining industries and the method of mining** dictate the nature of wastes generated as a result of the processes of extraction, transportation, processing. *Due to the nature of the processes associated with the mining industry, lots of earth material is produced, there are also numerous amounts of solid wastes, liquid and gaseous waste products that are generated during the mining and processing stages.* The major constituents of mining industries are chemical substances, which become more complex and expensive to handle. An example of this type of industry is the one mining copper and nickel in northern Botswana. It produces waste rocks and earth, fissure water, waste oils from machinery, hazardous chemicals and gases from processing. There is also noise and vibration from blasting, which is not a waste per say but more of a pollutant.

The type of treatment method employed for industrial wastewater depends on a number of factors, including, for instance, the *characteristics of the wastes*, namely, whether for example the wastes contain numerous amounts of suspended solids or more dissolved constituents. The *quality of the effluent required* also determines the selection of the treatment process (Eckenfelder, 1989). For instance a number of developing countries, including Botswana, use the World Health Organisation (WHO) guidelines for wastewater quality prior to discharge into receiving streams. These guidelines, for example, require that the maximum biochemical oxygen demand (BOD) content does not to exceed 30 mg/l in ephemeral streams.

Another factor that will dictate the nature of treatment type selected for a given type of industrial wastewater is the extent to which the wastewater is biodegradable or toxic. Economic factors such as *cost effectiveness of the technique used* is a vital factor to consider when selecting a process of treatment, as such a cost analysis should be prepared before the selected process is designed. The type of method selected will also depend on *land availability* as, for example, when stabilisation ponds are selected, there must be consideration of the size of land required.

Generation and Treatment of Industrial Wastes

Wastes from Meat Industry

Wastes in abattoirs are produced in the form of blood during slaughtering, use of wastewater, and trimmings. There may also be sludge from ruminant wastes. Ruminant waste may be dried and used as soil conditioner or otherwise landfilled. The Botswana Meat Commission, the largest beef industry in Botswana, extracts fluids from paunch contents prior to disposal; the extracted fluids then undergo treatment. The factories under the Botswana Meat Commission reclaim blood and recycle it (Mannathoko, 1995). Blood is dried and processed to produce blood meal, which becomes used as animal feed.

Horns from livestock have found many uses, In Africa, for instance, horns are variously recovered and utilised to make buttons, ornaments, and various decorations such as lamp covers. Kasane, in Northwest Botswana, is a living testimony to this kind of waste re-use. According to Mannathoko, (1995) the Botswana Meat Commission reclaims trimmings, mainly fats collected from wastewater, which are channelled in wastewater to a treatment station, where fats are removed and processed to make tallow, which is a constituent used to make soaps and detergents.

Anaerobic biological methods of treatment *are preferred as the best and least expensive methods of treating wastes from meat industries.* The convenience of this technique is that it does not need oxygen supply, hence less energy cost requirement. Another advantage is that there is less sludge generated when anaerobic treatment is applied. **Anaerobic ponds** are a practical demonstration of the anaerobic biological method of treatment. The average depths for anaerobic ponds are 6 metres. The anaerobic contact “*process has also been used successfully for the stabilisation of meat packing and other high-strength soluble wastes*” (Metcalf and Eddy, 1992). The anaerobic contact reactor consists of a digester with mixing equipment, a degasifier in which biogas such as methane and sulphur dioxide are eliminated, and clarifiers for sludge separation from liquid. Anaerobic treatment techniques are known to have BOD removals of up to 95% (Eckenfelder, 1989). However, the selection of treatment processes varies according to the nature of the waste, the treatment efficiency required, economic factors and other limitations. The Botswana Meat Commission as an example treats its wastewater by applying the bio-filtration technique. Anaerobic treatment can be followed by aerobic treatment perhaps through lagoons for further treatment of the waste.

Mining Industry Wastes

The management of wastes in a mine set-up involves a number of elements, depending on the mineral being mined, the size and extent of mining, and the

processes applied to extract the mineral from the ore. A case study of a copper nickel mine in North Eastern Botswana will be used to assess the wastes dealt with in mining industries.

The mining process produces a number of substances, which become wastes, such material as waste rocks from the blasting and excavating processes. Fissure water from underground also must be pumped to the surface and treated prior to discharge to any water course. This water has high mineral content and is found to be low in pH particularly at the copper mine in Botswana. Waste oils are produced from machinery being used in the mine. The chemicals used in processing minerals also increase the chemical contents released to the environment.

Once the mineral ore has been brought from underground, it is sent for crushing in the concentrator. The rocks are crushed to powder form then water is added to aid in the separation process. The water from the concentrator is sent to a tailings dam. The tailings dam is just an earth embankment used to hold wastewater mixed with mud. The heavy metal concentration is usually high in this water. The minerals are then transferred to the smelter for further purification. Waste products from the smelter include heavy metals, hot wastewater containing acids and metals, gaseous sulphur products. Slag (solid) from the smelter is disposed of at the slag dump; these solid wastes contain a lot of iron.

The copper nickel mine in Northeast Botswana has measures in place to reduce pollution of the environment. Though these wastes have already damaged the environment, efforts are being made to control the adverse impacts on the environment. The hot water from the smelter for example is sent to holding ponds to cool prior to being discharged. Gaseous contaminants such as sulphur dioxide are not controlled but emitted levels are tested in the upwind and downwind sides of the mine, to assess if the mine complies with the required air quality standards. A portion of the fissure water is used in some of the mining processes, the rest is discarded.

Tests are being carried in order to assess the concentration levels of substances released to the environment, these are carried out on soil, vegetation and water. The results of this analysis are not yet interpreted to detect the extent of impact these wastes cause.

The tailings dam causes a lot of degradation to the environment. Tailing impoundments are bound to overflow during rainy seasons; they become eroded because of the slope, wastewater seeps easily from the embankment since it is constructed from unconsolidated material. A tailings dam in Spain failed during the late 1990s when parts of the dam collapsed. The accident released 5 million cubic metres of wastes containing heavy metals such as zinc, lead and cadmium. According to Hersh (1998), the accident contaminated aquifers, farmland as well as the Guadiana River in Spain.

Mining waste is quite expensive to handle. Constructing a tailing pond requires a properly designed stable structure. The pond should sustain pressures as wastewater and rainwater flow in, seepage must be reduced underneath to the barest minimum because seepage further weakens the structure, moreover the seepage contaminates the surrounding.

Treating heavy metals in mining effluent is quite expensive. Copper may be removed by precipitation to its hydroxide state; this is done at an alkaline pH value. A substance such as sodium hydroxide may be used for the precipitation. Other processes of removal include ion exchange and evaporation. On the other hand nickel may also be removed by precipitation. When lime is used, nickel forms the insoluble nickel hydroxide (Eckenfelder).

Conclusion

Industrial waste management should become part of the development of any industry. The common practise is that industrial structures are put in place yet the aspect of managing wastes that will emanate from them are not included as part of the plan. Inadequate management of industrial wastes results in hazardous effects on health and detrimental impacts on the environment.

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CHAPTER 27

AN OVERVIEW OF INDUSTRIAL AND MINING WASTE

G L Mosweunyane

BCL Limited

P.O. Box 3, Selebi

Phikwe. Botswana.

Phone: 267-810211 Fax: 267-810441

An Overview of Industrial and Mining Waste

Introduction

Mining and industrial activities are by their very nature offensive and unfriendly to the physical environment. There is emphasis on 'physical environment' because the *social well-being* and other *positive impacts* must be recognised. Industrial and mining technological developments have without doubt improved the living standards of people especially in developing countries, to the extent of, for example, improved life expectancy.

The question about wastes and negative environmental impacts associated with mining and industrial development is not about their existence, but rather about their management. These impacts are usually, to an overwhelming extent, unnecessary because they can be anticipated and avoided or mitigated.

This anticipation puts into the hands of responsible officials a simple, straight forward working tool that will allow them at the earliest stages of technological intervention to plan for the environmental consequences. The focus here pertains to the earliest stages: planning and predevelopment in the form of Environmental Impact Assessments (EIA). These would help to determine the Best Practicable Environmental Options (BPEOs) in dealing with and managing wastes and other impacts arising from any technological development.

Wastes normally found or arising from a generic industrial and/or mining concern include the following:

- ❑ **Aesthetic Pollution:** Deformation of natural landscapes e.g. open pits, waste rock dumps and slag dumps.
- ❑ **Air Pollution:** Air pollution in the form of Noise, Dust, Odours, Fumes and Gases, Volatile Organic Compounds, Ozone etc.
- ❑ **Land Contamination:** Contamination by Oils, PolyChlorinated Biphenyls (PCBs), Heavy metals, Salts etc.
- ❑ **Water Pollution:** Pollution of water by Acid Mine Drainage, Oils, Heavy Metals, Chemical and Toxic wastes and Thermal pollution.
- ❑ **Solid Waste:** This includes Waste tyres, Scrap metal, Waste paper, Electrical and Electronic waste.
- ❑ **Hazardous and Chemical Waste:** Includes Acid, PCBs, Pesticides,

Drugs, Chlorofluorocarbons (CFCs), Greenhouse Gases, Cement Dust, Radioactive Waste, Hydrocarbons, and Dioxins.

Preventive Approach to Pollution Control

A number of statements have been made in the literature, which supports a preventative approach to pollution control.

“Project planning and evaluation process will take environment processes fully into account at the same time as the economic factors are likely to produce better and more sustainable economic returns. Higher initial investment and research costs may well have to be accepted in order to achieve cleaner technologies and more efficient waste management, but when costs of expensive retrofits and restoration are taken into account such an approach will often be economically justifiable over the life of the project”

– **Norman, 1985.**

“There is a need for a dynamic, anticipatory approach to pollution problems, which seeks to avoid the closing of options for future generations.”

– **Royal Commission, 1984.**

It is predicted that anticipatory and preventative approaches to pollution problems are most likely and must feature strongly in future developments. In many Developing countries EIA Legislation is either scheduled to be put in place or is newly in existence. EIAs have been voluntary or as a requirement by the funding organisation such as the World Bank.

Activities in Mining and Industrial Development are likely to include: site construction, installation of ancillary services e.g. power lines and railway lines, pipelaying, storage of process liquids, fuel and chemicals, drilling and testing, waste disposal, processing, transport, storage of products, and decommissioning. These in turn may need analysis in terms of the implied movement of people and vehicles, landscape, physical pressure and visual intrusion, noise, discharges, emissions, solid waste generation, spill risk, and hazard risk. Any of these may lead to environmental problems; including effects on:

- ☐ Flora and Fauna;
- ☐ Habitats;
- ☐ Air, Soil and Water Quality;
- ☐ Landscape and Amenities;
- ☐ Archeological Sites;
- ☐ Residents;
- ☐ Agriculture and Forestry; and
- ☐ Tourism and Recreation.

The Political Economy of Industrial/Mining Development and Environmental Management in the SADC Region

Mining and Industrial Development has traditionally played a major role in the economic development of member countries of the Southern African Development Community (SADC) and will continue to do so given that the mining sector alone contributes more than 60% of the region's foreign exchange and more than 11% of the region's GDP (Warhurst, 1992). With some estimated 200 000 employees, excluding the many small scale miners, the mining industry is a major employer in the SADC region.

Environmental and Waste Management

To minimise environmental impacts in the form of wastes, companies should adopt a systematic approach to Environmental Management. This can help in the establishment of:

- ☐ A corporate environmental policy with clear goals, responsibilities, activities and target;
- ☐ Establishment of a structure to implement the ideals of the policy, e.g. Waste Management Program, to allocate adequate resources, to monitor effluents and emissions and to interpret and report results.

Legislation

In many countries, specific mining and industrial laws incorporate environmental requirements such as waste disposal, control of water contamination, as well as rehabilitation and occupational safety. In Botswana the following sets of legislation are applicable:

- ☐ Mines and Minerals Acts;
- ☐ Mines, Quarries and Machinery Regulations;
- ☐ Factories Act;
- ☐ Public Health Act;
- ☐ Air Pollution (Prevention) Act; and
- ☐ Water Act.

The National Conservation Strategy (Co-ordinating) Agency in Botswana has carried out a number of studies which have resulted in findings and recommendations, which are widely used as guidelines, including:

- ☐ Study on the management of oil containing wastes;
- ☐ Recycling of metal wastes;
- ☐ Study on management of medical wastes; and
- ☐ Guidelines on the disposal of waste by landfill.

Under consideration are the enactment of the Waste Management Act and the EIA Act. A new Department of Sanitation and Waste Management is to be set at the Ministry of Local Government, Lands and Housing (MLGLH).

Environmental concerns normally cover a range of ecological, conservation, pollution and health issues, each of which is covered by separate laws and regulations administered by different governmental agencies.

Current situation in SADC

Until very recently there had been no co-ordinated efforts to assess the environmental impacts of mining and industry or guidelines prepared to enable governments and industry to undertake appropriate environmental practice. Few or no specific standards exist which are pertinent to air and water quality. Air and water quality standards for Botswana are shown on Tables 27.1 and 27.2.

Sample Period	micro-grams per cubic metre	milli-grams per cubic metre	ppm
24 Hour Average	90% of the time <300	90% of the time 0.3	90% of the time <0.12
Monthly Average	160	0.16	0.06
Annual Average	80	0.08	0.03

Table 27.1: Sulphur Dioxide Standards

Parameters (mg/l) (or as specified)	Perennial Streams	Ephemeral Streams
Temperature (degC)	35	35
pH	6.5 - 9.5	5.5 - 9.0
BOD	75	30
COD	20	30
Nitrate	2.0	-
Copper	1.0	1.0
Lead	1.0	0.05
Cynade	0.1	0.1
Cadmium	0.005	0.05
Mercury	0.001	0.02
Iron	1.0	1.0
Manganese	0.1	0.5
Sulphate	400	600
Fluoride	1.5	2.5
TDS	1000	2000

Table 27.2: Waste Water Discharge Guidelines for Perennial & Ephemeral Streams in Botswana.

Mining and Other Selected Production Technologies

The waste impacts of mining are, first, that on any reasonable industrial scale, it *creates large cavities in the earth*. The problem is what to do with these cavities or open pits. Mines are often distant from populated areas and consequently one often finds problems arising and continuing simply because “out of sight is out of mind.”

Secondly, mining is carried out to *extract the mineral product which in one form or the other can be toxic*, such as nickel or copper. Thirdly, there is a problem of what to do with *mine waste in the form of waste rock, tailings and discard slag*. The more dramatic effect of mining is perhaps the *pollution of water bodies* connected to the mine sites, either directly or by rivers. The most common cause of water pollution is *Acid Mine Drainage* (AMD).

Biochemistry of Acid Mine Drainage

Acid Mine Drainage (AMD) may be defined as the *inorganic chemical water pollution* resulting from oxidation of sulphide-containing minerals mainly pyrite

and pyrotite. Consequently, acid effluents containing elevated levels of dissolved metals are produced.

AMD potentially affects the following:

- ☐ Sulphide ores underground and surface mine water;
- ☐ Drainage from sulphide bearing waste rock dumps; and
- ☐ Seepage and drainage from sulphide-bearing concentrator tailings.

AMD is a problem that not only takes place while the mine is in operation but also after closure. AMD formation involves chemical and biological phenomena which can simply be represented by the following equation:



Cement Manufacture

The negative environmental effect of Cement Manufacture is the uncontrolled release of cement dust from the Factory which can be a blight on the environment and a terrible aesthetic insult. The raw material is usually some form of limestone, other materials are sand, clay, coal ash and slag. The material is prepared and ground finer. This is the primary source of polluting dust from cement mills.

Pulp and Paper Manufacture

Pulp and Paper Manufacture use large amounts of water and product waste water containing substantial amounts of chemicals and fiber. Such chemicals could include ethyl alcohol, acetic acid, vanillin, dimethyl sulphoxide and others. The potential major source of pollution from paper making is the discharge of pulp waste into water bodies. The supporting technologies which must be monitored closely involve wood harvesting, movement and storage of chemicals and power generation.

Pharmaceutical Manufacturing

Pharmaceutical Manufacturing, as with chemical manufacturing, must be looked at as a total system. The material coming into the factory are themselves sometimes dangerous to human health, as solvents might be, or have chemical characteristics which make them dangerous. Close attention must be given to ISO 9000 Quality Control and ISO 14000/1 Environmental Management Systems as well as GMP/GLP “Good Manufacturing Practice” and “Good Laboratory Practice”.

Biotechnology

Biotechnology resembles a pharmaceutical manufacturing facility with very similar risks. Quality control must be very strong as in the pharmaceutical facility. The escape of bacteria or viruses if directed at human health and medicine are likely to have dramatic biological effects.

Oil and Gas Production

Oil and Gas production are similar. There are, however, special problems with each. However, gas production presents less an environmental risk than oil production since at worst the gas ultimately will evaporate or go off into the atmosphere. But Petroleum accidents tend to be around for a long time because of the viscosity and the volume of the liquid. There is often a risk of a well blowing, that may or may not be accompanied by fire. The Gulf War sparked a number of fires in Kuwait which resulted in a major air pollution occurrence. The waste arising are similar to mining waste such as noise, solid waste etc.

Environmental Mishaps

The following are a selected set of environmental problems directly related to mining and industrial technologies. Few mishaps are due to failure in technology in the narrow sense of the word. The failure is sometimes due to *management* (or mismanagement), *lack of training*, sometimes to *poor or no regulation*.

The Chicago Environmental Crime

“The owner of a Chicago metal plating plant orders a worker to pour 4000 gallons of cyanide and cadmium waste down a floor drum, delivering a toxic jolt that temporarily shut down a branch of the City Sewer System and killed 20000 fish in the Chicago river.” (Coates, 1995)

Cyanide Contamination

Galactic Resources Limited had set up a research arrangement using a technique called ‘Heapleach’. This process uses cyanide percolated through heaps of ore to extract gold. The company went bankrupt leaving behind pollution estimated at \$100 million in clean up. Included in the mess to be cleaned up were millions of gallons of cyanide contaminated water.

Chernobyl Disaster

“On April 26 1986, reactor No 4 of the nuclear power station reduced its power to below 25%, triggering an explosion and meltdown of the reactor core. Many people were killed and a land area of 1000 square kilometers was contaminated, 6000 buildings required decontamination and an emergency supply of safe water.” (Pope et al, 1991).

Minamata Bay Poisoning

The *poisoning of Minamata Bay* in Japan was one of the first major human disasters to highlight the *dangers of chemical pollution*. In 1953, inhabitants of Minamata fishing village were first diagnosed as suffering from *nervous diseases* caused by eating fish contaminated with methyl mercury, a disease to be later known as Minamata disease. Thirty years later, Minamata disease had more than 300 *people killed* and almost 1500 experienced symptoms including *blindness, convulsions and brain damage*.

The fish were contaminated by industrial discharge from Chisso Corporation Chemical Plant which had been dumping waste methyl mercury directly in the Bay (KATO).

Seveso Chemical Disaster

A Northern Italian village was the scene of one of Europe’s worst *air pollution disasters* when a nearby chemicals factory released a cloud of toxic TCDD gas into the atmosphere on July 10th 1976. The most poisonous of the dioxins, TCDD, was being produced as a by product of the manufacture of trichlorophenol (TCP), an active ingredient of some herbicides like 2/4/5-T. Five hundred people were affected and 700 *evacuated*, some 7000 *animals died or were slaughtered* as a result of the leak.

Bhopal Chemical Disaster

“December 2 - 3, 1984, poisonous gas escaped from a tank containing forty five tons of toxic isocyanate (MIC) at the BHOPAL pesticide factory in Madhya Pradesh, India. The disaster was caused by entry of a foreign substance into the MIC storage tank. This caused a runaway chemical reaction adding to an increase in temperature which turned the liquid MIC into gas. A total of 2352 people were *killed* and a further 80 000 *treated*.” Pope et al (1991).

Exxon Valdez Oil Leak

“The oil tanker that struck Bligh Reef, twenty five miles from Alaskan oil terminal of Valdez on March 24, 1989. The ship was grounded and spewed 11 million gallons of crude oil which contaminated at least 200 kilometers of shoreline and affecting four national parks. At least 1000 sea otters perished up to 36 000 sea birds were found dead in pools of oil.” Pope et al (1991)

Environmental Management

In order to improve industrial and mining environmental performance, and to take care of waste from predevelopment to decommissioning cost-effectively, new environmental concepts and management systems are continually being developed by governments, industry and NGOs.

Environmental management tools are structured or systematic instruments for improving decision making or information management or for effecting changes in the behaviour of others, with the overall aim of improving the environmental performance of industry. Thus environmental management tools can be used by companies to monitor, better manage or improve this environmental performance, and by governments to influence the performance of industry. The following are selected environmental management tools for consideration.

- ❑ **Corporate Environmental Benchmarking:** comparing and measuring a company’s business processes against the best in class to inspire movement.
- ❑ **Cost Benefit Analysis:** tradeoffs and complementarities amongst environmental goals.
- ❑ **Environmental Auditing:** There are numerous specific audits; Waste Audits are of two types. The first identifies and quantifies waste streams and is a precursor to waste minimisation programmes and collating an environmental effects register. The second assesses waste management practices and procedures.
- ❑ **Environmental Impact Assessment:** This is an activity designed to identify and predict the impact on the biogeophysical environment and on mans health and well-being of developmental prospects and to interpret and communicate information about the impacts.
- ❑ **Life Cycle Assessment:** This includes the entire life cycle of a product, process or activity encompassing extraction and processing of raw materials, manufacturing, transportation and distribution, use/re-use, maintenance, recycling and final disposal.

- ❑ **Risk Assessment:** This is a quantitative and qualitative evaluation performed in an effort to define the risk posed to human health and the environment by the presence or potential presence, or use of specific pollutants.
- ❑ **Environmental Management System** includes the organisational structure, responsibilities, practices, procedures, processes and resources for determining and implementing the environmental policy. [ISO 14000/1]
- ❑ **Corporate Environmental Reporting** can be a simple document written for formal and informal, internal education or detailed document for specific target audiences.
- ❑ **BATNEEC, BPEO, PPP, BATNEP, EnTA, Waste Minimisation and Recycling Strategies.**

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CHAPTER 28

SOLID WASTE REUSE AND RECYCLING

John E Gould

**Department of Environmental Science
University of Botswana
Private Bag 0022
Gaborone, Botswana**

**Phone: 267-3552524 Fax: 267-356591
E-mail: gouldje@noka.ub.bw**

Solid Waste

Reuse and Recycling

Introduction

The aim of this chapter is to examine the current status of solid waste reuse and recycling and to examine the advantages and disadvantages of these activities in economic, public health, social and environmental terms (with particular reference to Botswana). Having outlined these aspects, the role of government, industry and non-governmental organizations is explored and the framework for a strategy to increase reuse and recycling is outlined.

The need for increased recycling and reuse in Botswana is obvious. Indiscriminate dumping of waste and widespread littering have become serious environmental problems in recent years. In Botswana and many other African countries millions of cans, broken bottles, plastic bags, old tyres, building rubble and waste oil are despoiling towns, villages and once pristine countryside. Not only is such waste unsightly but it is also dangerous to wildlife, livestock and humans. Young children are especially vulnerable sometimes drinking the remaining contents of discarded cans or bottles. Injuries and accidents caused by broken bottles are also a problem.

Economically, these waste management practices are damaging. Not only does widespread litter discourage the development of a young and growing tourist sector, but local town Councils spend millions on potentially unnecessary litter picking and waste management activities. The consumer also pays a high price, P100 million every year in Botswana alone, just for the importation of non-returnable beverage containers.

From an environmental perspective some of the damage done by indiscriminate waste disposal are relatively superficial and short lived, but some are much more serious; for example, the *long term contamination of scarce groundwater supplies from waste oil and toxic materials. Leachate from landfill sites also pose a potential long term threat.* Despite the scale of the problem, the solutions are extremely simple. *Most of what people perceive as wastes are in fact valuable resources and can be reused or recycled.* Although some reuse and recycling of materials is taking place, the extent is limited and enormous potential for expanding these activities exists.

Waste Reduction, Reuse and Recycling the 3R's of environmental conservation represent an important component of any serious attempt to address the waste management problem in Africa. An important first step towards realising this will involve the introduction of appropriate legislation and economic instruments with respect to encouraging recycling activities. Hopefully the

implementation of the National Waste Management Strategy and enforcement of the Waste Management Act in Botswana will go some way to promoting more recycling activities at least in this country.

Overview

The world's population continues to grow rapidly and by the year 2000 it is anticipated to have surpassed 6 billion (four times its size in 1900). It is unlikely to stabilise until at least 2100 and then at somewhere between 8 and 12 billion. However, it is not sheer numbers alone that should concern us with respect to the impact on the planets environment and resource base, but more *per capita* levels of consumption and the way we manage the planets resource base and environment. Today for example, an individual human uses several magnitudes more energy and mineral resources compared with an average individual one hundred years ago. It is accordingly estimated to be perhaps not surprising that we are generating more waste than ever before and to date the waste management problems have become a major environment issue.

Certain societies consume more and create more waste than others. An average American for example consumes about 50 times more than an average Bangladeshi and generates at least 50 times more waste. The total ecological demand (or environmental impact) of any society can be approximated by the following simple equation.

$$I = P \times A \times T$$

where I = Impact

P = Population

A = Affluence

T = Technology (where T can be greater or less than 1)

Throughout the industrial revolution technology and the management of resources have been developed in a way which increases human impact on the planet. In the last few decades, however, there has been increasing effort to develop technologies and industrial systems which are more environmentally benign and help to lessen the impact of humanity on the environment. Examples of such technologies include, solar water heaters, catalytic converters and a range of recycling technologies which enable the recycling and/or reuse of everything from plastics to waste oil and old tyres to textiles.

An ancient Chinese proverb defines waste "as a resource we have simply not yet learnt how to use". Worldwide commercial "waste" recycling industries have a turn over of many tens of billions of dollars annually. It is likely that informal reuse and recycling of everything from glass jars to old tyres accounts for tens of billions more. Despite this only a small fraction of the materials

which could be reused and recycled is being utilised. The most common reason for this is that it is “un-economic” to do so. Unfortunately, the calculation of whether a certain activity is “economic” is based on a short-term determination of supply and demand. This is why for some materials it may be economic to recycle them this year even if it was not last. A different perspective, is gained if the long-term environmental costs including the price which may have to be paid by future generations to clean up pollution and contamination created by today’s wasteful activities, or the cost of finding more expensive substitutes to replace over exploited resources is considered. From a long term point of view many of today’s supposedly uneconomic activities may in fact make economic sense. Perhaps, the best illustration of this issue is the American “Superfund”, a multi-billion dollar fund which has had to be set up to start cleaning up toxic waste dumps across the United States. Some estimates for the total cost of doing a thorough cleanup of the many thousands of such sites across America run to as much as US\$500 billion, Miller (1992).

Advantages and Disadvantages of Reuse and Recycling

Given the immensity of the problems of effectively managing the waste created by modern society around the world, any activity which can help reduce the size of the waste stream is generally welcomed especially if it can pay for itself.

Environmental Aspects

The environmental benefits of reusing and recycling waste are obvious. With less waste oil, waste water, waste paper, beverage containers, plastics etc entering the environment either at formal dumping sites or generally through illegal tipping and littering, the negative impacts of pollution and visual untidiness would be reduced. Equally important is the fact that reuse and recycling reduces the demand for virgin materials, so fewer trees have to be cut or minerals mined. The environmental benefits of this are also clear: less pollution, less scarring of the landscape, fewer greenhouse gas emissions and so on.

In general reuse and recycling activities have few negatives on the environment although some processes may be relatively water and energy intensive or produce pollutants. Another negative aspect is that individuals and institutions that are actively involved in recycling activities may become convinced that they are doing far more vis-à-vis environmental protection than they are in fact doing. Reuse and recycling are only small components of environmental protection and it is important to remember that ultimately it is better to reduce waste than recycle it.

Social and Economic Aspects

The economic advantages of recycling enterprises may be both direct and indirect in nature. Direct benefits may include job creation and reduced demands on foreign exchange reserves for importing raw materials. Indirect benefits may include a decline in waste disposal costs resulting from reduction in total size of the waste stream and benefits to other sectors such as the tourism industry. The main negative aspect of recycling activities from an economic perspective is that due to the abrupt price fluctuations which can affect the price of both the waste being recycled and the recycled end-product, jobs and companies in the recycling industry are often short-lived.

Public Health Aspects

If beverage containers, old tyres and plastic bags are not recycled, invariably these may cause health problems for wildlife, livestock and humans. Young children are especially vulnerable to injuries and accidents caused by broken bottles and sometimes are tempted to drink the remaining contents of discarded containers. Cans and tyres trap rainwater and become ideal breeding sites for mosquitoes and other disease carrying vectors.

Furthermore, since reuse and recycling of waste reduces the quantity which has to be disposed of through more conventional methods such as land filling it reduces the extent of associated pollution risks. In the case of serious air or water contamination these may have serious health impacts and environmental impact associated with them. Certain products like waste oil are relatively easy and economic to recycle for direct reuse or alternative uses. Yet if dumped in an unlined landfill, waste oil can seep into groundwater where one litre of oil can contaminate a million litres of water.

A Strategy for Recycling: The Role of Government, Industry and NGO's

In order to ensure the effective adoption and sustainable operation of recycling activities it is essential that government, private enterprise and non-governmental organizations (representing the community) work in partnership. None of these three groups can operate effectively without the co-operation of the others. Ideally, these three groups should work together to formulate an overall strategy in which the role of each is clearly defined.

Any strategy designed to increased recycling and reuse of waste materials needs to incorporate specific targets which should be ambitious yet realistic. In the U.K. for example where in 1990 only approximately 5% of domestic waste was

recycled out of a total 50% considered recyclable, it was decided to set a target of recycling 25% of all household waste by 2000. Even if such targets are not achieved they do provide goals to work towards and standards against which progress can be measured. Both success in achieving the targets or failure to reach them can act as spurs for further action. What is important, however, is that targets are realistic and potentially achievable so that no one gives up. The roles of the various players should be clearly defined and normally the responsibilities would most probably fall along the following lines.

Role of Government

Government should provide the overall framework, legislation and economic instruments to ensure that the conditions are right to promote and encourage recycling activities.

The framework might take the form of a *national waste management strategy* with supporting legislation in the form of a Waste Management Act. In Botswana this approach is being adopted and the concept of a Waste Management hierarchy has been embraced as a valid basis for addressing waste management. Such a hierarchy is envisaged to encompass both *reuse and recycling of waste as well as waste reduction as key elements for effectively addressing waste management throughout the country.*

Economic instruments can be applied in a variety of ways, either in the form of incentives such as subsidies, grants or tax breaks or in the form of fines for illegal or unacceptable practices, such as illegal dumping of building rubble and other waste in the bush. The problem with fines is that they have to be enforced which may involve substantial policing resources and costs. Incentives are normally more effective at encouraging good practice. In the case of recycling the carrot is normally better than the stick.

There are many indirect ways in which Government both at a national level and local level can assist recyclers. At a national level in a country like Botswana where the railways are state owned the possibility for providing subsidised rates for transporting recycled materials exists. On the roads too, empty government vehicles could be made available to assist in transporting recyclable materials from small and remote communities, where the costs of employing private transport would be prohibitive. At a local level town and district councils can provide space in the form of fenced enclosures within the fenced perimeter of landfills for lease or rent at subsidised rates to recyclers. This form of assistance not only helps small entrepreneurs, and creates jobs but it may help to make recycling of certain materials more economically viable.

Role of Industry

It is normally the private sector through both small scale entrepreneurs and large scale recycling industries which actually implement recycling activities and also those involving reuse eg. use of returnable bottles etc. It is essential that industry profit from recycling activities to ensure the sustainability of these activities. This can be a problem since the market for recycled materials can be uncertain owing to high variable supply and demand. For this reason it is essential that industry liaise and work closely with government to ensure that where possible the two can work in tandem.

Role of NGO's, Communities and the Individual

NGO's and community based groups have an important role to play in promoting recycling activities through raising public awareness. This can be done through a variety of ways including *holding public meetings, seminars, environmental fairs and through publications, posters and the media.* Another important role for NGO's is to monitor recycling and waste disposal activities in general and alert the public and the authorities when problems or difficulties arise. NGO's can also act as a clearing house and information source for enquiries from the public, about how, what and where to recycle as well as sometimes providing facilities of their own. Ultimately, for recycling and reuse to play a major role in contributing to waste minimisation it is essential that it is also supported by the individual. In societies where the majority have been highly conscientised about the importance of individual actions vis-à-vis addressing environmental problems, recycling is most likely to be effective.

Current State of the Art and Prospects for the Future

The current state of the art of reuse and recycling in Southern Africa is one where although certain materials such as steel cans and paper are recycled quite extensively, many potentially recyclable materials are currently being landfilled, and even large quantities of paper and steel cans fail to be collected. For example in Southern Africa as a whole only about 25% of the two billion cans produced annually are actually recycled. In Botswana alone where 200 million cans are imported annually, (NCSA 1996a), at a cost of around P60 million the proportion recycled averages around 50%, this still only generates a meagre Pula 1 million in return revenue from South Africa where the used cans are sent for recycling. Many materials such as waste oil, plastics, organic materials, textiles are only locally recycled. Globally, the trend is towards greater recycling is increasing. In some places like Tokyo recycling rates already exceed 50%. With the possibility that the world's population could

almost double by 2100 and at the very least increase by 50% and increased levels of consumption virtually inevitable, we will have no choice in the future than to further adopt the 3R's waste management and reduce, reuse and recycle.

Conclusion

Worldwide recycling is a multi-billion dollar industry and there is a steady trend towards increased recycling and reuse of waste. In Africa and Southern Africa the same trend exists although the region remains some way behind the world leaders in this field.

Ultimately, "spaceship" earth has finite resources, and a growing number of passengers. If we are going to successfully complete our journey into the future without running out of resources or polluting and contaminating our planet, we had better start doing what every astronaut has to do, reduce consumption levels and recycle as much as possible.

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CHAPTER 29

A REVIEW OF SOLID WASTE MANAGEMENT IN DEVELOPING COUNTRIES WITH REFERENCE TO BOTSWANA

Kodise A Selotlegeng

**National Conservation Strategy (Co-ordinating) Agency
Private Bag 0068
Gaborone, Botswana.**

A Review of Solid Waste Management in Developing Countries with Reference to Botswana

Introduction

“Solid Waste Management is a serious issue which must not be treated lightly and its examination should not be confined to its narrow and technical definition”, said the Minister David Magang at the closing of a Waste Management Workshop at Gaborone Sun on June 8th, 1993. The Minister said it was *“essential to take a broad approach of waste management because of waste’s impact on the environment and natural resources”*.

The statement made above indicates quite vividly that waste management has in the past been treated in a callous matter-of-fact manner and largely regarded as mere waste, which did not have any specific valuable use. In fact the adage “Out of Site Out of Mind” tends to portray the contextual understanding within which waste was handled. The renaissance of Waste Management in the Developing Countries and most importantly in Botswana has resulted from a diversity of directives: *legal local authority impositions; fiduciary responsibilities, constraints and limitations in resources allocations; slow but definitive incremental approaches*. Other significant approaches and potential growth patterns in the waste management sector could be associated with the political prescriptions; Government contribution to stimulate service provisions; Private Sector initiatives; and most importantly for Botswana, the NCS/GTZ Waste Management Project co-sponsored by the Federal Republic of Germany and the Government of Botswana. This project started initially with a preconceived idea of preventing and controlling water pollution through proper identification and planning of waste disposal sites. The project is predicate on pre-determined key factors that are critical to the overall goal conceptualised as *“The reduction of the risks of environmental pollution and waste of natural resources”*. Aside from minimisation of environmental pollution and health risks, the Waste Management philosophy in Botswana considers waste as an economic good where this proves feasible. It identifies waste as a source of raw material whose beneficial use will compliment a conservative use of existing stocks of natural resources, so that future generations could enjoy the rich legacy of the stocks the present generation has reserved for them. Waste Management in Botswana has an actionable Waste Management Strategy, which requires the substantive provision of infrastructure networks to promote collection, storage, transportation, treatment, and disposal.

General

Waste Management developments in Botswana have resulted from a diversity of various directives, incremental approaches, and from the bilateral technical co-operation project with the Federal Republic of Germany. In particular evolution of the waste management sector could be associated with the Legal and Political Prescriptions; Constraints and limitations in resources allocations; Government's Contributions to stimulate service provisions; Private Sector Initiatives; and NCS/GTZ Waste Management Project.

Legal and Political Prescriptions

Chapter 40 of the Laws of Botswana did not only create Local Authority Administrative Structures, but also gave them mandates to provide services in their areas of jurisdiction. The law gave specific powers to these councils to ensure that negative impacts were abated and that protection of the environment and conservation of its natural resources was guaranteed. In particular in exercising his legal prerogative to establish a council, and subject to such conditions as he deemed fit, His excellency the President of Botswana required councils under the stewardship of the Ministry of Local Government, Lands and Housing (MLGLH) to provide services to the constituencies they served. Through such legal directives, Councils were and still are empowered to secure and to promote health, order and good Government of the area for which they are responsible. To execute their statutory responsibilities for the maintenance of health, safety and well being of the inhabitants of their areas of jurisdiction, Councils were authorised to make bye-laws that contributed to or provided approximate cause for "Pristine Environmental Conditions". Therefore, within the context of the Local authority bylaws approved by the Minister of the MLGLH, the prescriptions empowered councils to prevent the "accumulation of waste, to ensure substantive provisions necessary to maintain health and sanitation".

Constraints and Limitations in the Waste Management Sector

The Waste Management Sector like its co-existing environmental disciplines was established based on both Central and Local Governments' ability to pay. Various financial and technical subsidies could not confer a panacea (cure-all) because of the following critical limitations: -

- ☐ Competing interests within all productive sectors in the country's economy;
- ☐ Mandatory economic/financial and human resources ceilings; and

- ❑ Inadequate collections of revenues to recover the cost of services or for further developments within the sector.

Despite these limitations and in order to stimulate waste management sectoral advances, Government introduced specific financial contributions.

Government's Contributions to Stimulate the Waste Management Sector Developments

In conjunction with the Ministry of Finance and Development Planning (MFDP), the MLGLH established, by delegation to Councils, the service delivery programmes in Waste Management achievable through capital and resources subsidies and ensured that accountability through project reviews and verifiable performance indicators within the sector were adequately demonstrated. Waste Management Developments made slow quantum leaps through the fiduciary provisions and affordable financial and economic guarantees in the National Development Plans.

The Sector Performance Within the National Development Plans (NDP) 6 and 7

NDP 6 formulated a waste management intervention strategy that recognised waste management as a fundamentally Government sponsored programme with very little potential investor entrepreneurship contribution. The onus of responsibility became that of Government's Ministries of Local Government, Lands, and Housing, Health, Mineral Resources and Water Affairs, and the Local Authorities. NDP 7 provisions and allocations which were budgeted to affect the waste management sector more meaningfully were predicate to the National Rural Sanitation Programme which addressed in a limited sense and in all the nine national districts procurement of refuse collection vehicles, and the development of Refuse Disposal sites. The urban local authorities benefited from township services subsidies. Funds from the budgetary provisions indicated above are disbursed through the Planning Division of the MLGLH to individual Councils upon effective justification through project memoranda to procure sanitation vehicles and to sponsor construction of waste disposal sites.

Most importantly the MLGLH carried out the following: provided for resources mobilisation, assisted in project designs and implementation, and furnished technical support in waste management programmes. The MLGLH also assisted in the evaluation of new directions and philosophies and in the case of Gaborone City Council the ministry participated in testing the feasibility and physical delivery of services through management by contract (privatisation). The conclusions drawn from this pilot reference will be used to provide other

innovations in our service deliveries. As an author of the National Conservation Strategy that addresses waste management developments, MLGLH is also responsible for ensuring that physical developments made are environment friendly. Out of the above legal administrative structures, there is a discernible trend in partnership among government's ministries and local authorities within which waste management programmes have developed.

Private Sector Initiatives in Waste Management

To ensure that the potential of waste was fully realised, the private sector initiatives attempted to convert waste into an "Economic Good". An example of such conservative programmes is evident in the City of Gaborone where out of investment motives and possibly environmental consciousness some private companies attempted to establish waste resource recovery projects. For instance Collect a Can established a can recovery enterprise; Skip Hire rented out skips, and positioned "Bottle Banks" at strategic places; in schools and next to residential centres to collect bottles. Waste Paper Recovery collected, bailed and transported waste paper to both South Africa and Zimbabwe for reprocessing while Plastic Waste Recyclers collected plastics for conversion into useful by-products. These reuse projects are a positive contribution in the management of wastes but most importantly they demonstrate a burgeoning responsible partnership by industry in waste handling.

Waste Management/Protection of Water Resources Project (Current National Initiatives)

The initial idea to implement a project focusing on the prevention and control of water pollution through proper identification and planning of waste disposal sites came from the Ministry of Mineral Resources and Water Affairs through the Department of Geological Surveys (DGS). The project effectively commenced following the signing of the Botswana – German Technical Cooperation Agreement, in 1992. Furthermore after a more detailed planning had taken place a project appraisal was carried out in Botswana culminating in an Aid Memoir which was prepared, agreed upon, and finally signed on May 2nd, 1991 in Gaborone with the concerned authorities at the bilateral level. The project consists of two phases: the first from April 1993 to March 1996 and the second from April 1996 to March 1999. To ensure sustainability in the development of this project, the agreement recommended employment of counterparts by the Botswana Government. On the Botswana side, the National Conservation Strategy (Co-ordinating) Agency (NCS), and the Department of Geological Survey (DGS) support the project. The responsible partners on the German side are the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) and the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR). NCS

and GTZ are in charge of the overall project implementation whereas DGS and BGR are concentrating on the hydrogeological aspects and the vulnerability mapping.

Aims of the First of the Phase of the NCS/GTZ Waste Management Project

The project identified eight key factors in the first phase, some of these are:

- ☐ The legal and institutional framework;
- ☐ The vulnerability mapping;
- ☐ Establishment of a waste data bank;
- ☐ The research and development on specific waste streams; and
- ☐ State of the art landfill operations.

Sector Performance in Phase One (June 1993-March 1996)

Based on the findings of consultants, Integrated Skills limited, engaged by GTZ an analysis of the current waste laws was carried out in December 1994. Intensive consultations and discussions with all interested parties and a report describing the legal and institutional needs for waste management were prepared. It described the main features of a waste management bill and strongly recommended the establishment of a waste management agency at the central government level and waste management divisions within the local authorities.

Furthermore the report suggested a chronology for introducing the main elements of an environmentally sound waste management in Botswana.

Consequently, a Presidential Cabinet Directive of December 1995 issued the following instructions:

- (a) That the Attorney General drafted the Waste Act.
- (b) That with recommendations from the Ministry of Local Government, Lands and Housing, the Department of Public Service Management strengthened the National Conservation Strategy (Co-ordinating) Agency to enable it to effectively implement the Waste Act currently being drafted.

Effective Waste Management is legislation driven, and legislation is ineffective without enforcement. As a part of the legal and institutional framework, draft technical guidelines for landfill sites were developed and are currently being tested by all stakeholders in waste management for a period of twelve months.

Responses from the interested and affected parties will be consolidated into a final document which would form a national blueprint constituting a permitting process in landfall operations. The cartographic work on the vulnerability map scale 1:1,000,000 is complete and 2500 copies have been printed and distributed for planning purposes. Six vulnerability maps (indicate water resources areas that are fragile to pollution and that require adequate protection) at a scale 1:50,000 with explanatory notes are available and have also been distributed to the respective districts. Data about all major dumpsites/landfills have been collected and will serve as a basis establishing a national waste management data bank. Through another round of intensive contacts with districts the dump sites based on identified need will be upgraded into landfill sites. Three case studies on medical, metal, and oily wastes have been carried out. Physical implementation of the recommendations made will take place in the second phase of the NCS/GTZ Waste Management Project. Other research and development case studies will be carried out on individual waste streams in the second phase.

Decision has been made on the three case studies for landfalls to develop state of the art landfilling operations based on the technical minimum landfill guidelines. These will provide the necessary demonstration and promotion effect on proper landfill designs. The findings of these case studies will be translated into actionable plans in Phase Two. The project also provided for the consultancy to develop teaching materials for Environmental Impact Assessments on landfall sites. The University of Botswana conducted the course in June of 1996.

As part of capacity building among the local authorities, two weeks crash courses for waste managers and landfall operators were administered in April/May 1995 in Kanye and in Molepolole in April 1996 with participants predominantly coming from all districts. The 2nd International Waste Management congress was held in Francistown during the week of 19 - 23 June 1995 under the theme "Waste Management - Pre-Requisite to Sustainable Development". A large portion of the participants came from central and local government, representatives of the House of Chiefs, University of Botswana, parastatal and private companies and non-governmental organisations. There were in addition participants from Zambia, South Africa, Germany, Kenya and consultants on specialised topics made available by GTZ. At the end of the congress the participants came up with twelve resolutions and recommendations, which will influence future programme areas, particularly the national waste management strategies and action plans.

The project carries out public awareness campaigns, develops teaching material and organises seminars and workshops. Through its long term experts from GTZ the project is also involved in ad hoc advice for Councils, the landfall case studies and technical guidelines for disposal of waste by the landfill. In addition to the eight aims mentioned above the project drafted a waste

management strategy/policy for the Government of Botswana, it has currently been reviewed and fine-tuned and will be circulated to government's ministries for comments before adoption and approval.

Waste Management Development

Prospects in Phase Two (April 1996 -March 1999 1999). At the September 1995 Project Planning Workshop attended by representatives from Local Authorities, several key factors were established and these would be implemented within the second phase. It is envisaged that this phase would also comprise recommendations from the Phase One of the project, which we consider crucial if major achievements within the sector are to be realised.

Critical factors were identified that would assist the sector achieve sound management of wastes through an enforceable legislation; intensive public awareness campaigns; resources; conservation and recovery established through waste reduction and recycling incentives. The project's target is to develop strategies and policies that are economically sustainable.

Core Problems

Inadequate waste management in general and the uncontrolled disposal of wastes in particular are considered to be some of the core problems affecting sustainable protection of water resources in Botswana. This is exacerbated by increasing waste generation due to rapid economic development, population growth and changing life style/consumer habits. Wastes include domestic or household waste, industrial waste, hazardous waste, clinical waste, sewage sludge, demolition waste, and excavation waste to name a few. Notably waste generation is the seamy side of our production and consumption of goods.

Without preventive measures and tight controls, high risks of water pollution (ground water as well as surface water) are possible. With the current practice of uncontrolled dumping of wastes the deterioration of drinking water quality may be an unavoidable result, thus constituting a severe threat to public health, the human and the natural environment. These problems have to be seen in the context of a semi-arid country, where ground water resources are scarce and water resource management would become even more difficult.

Other problems resulting from uncontrolled dumping of wastes are that toxic substances could enter the food chain through plants and animals and that insects and rodents breeding on these sites could cause a transfer of infections to people. Furthermore the occurrence of bad odours and smells from the uncontrolled burning of wastes and the ugly visual intrusion on landscape which is created with the present throw away mentality is a nuisance not only to the inhabitants

of Botswana but also affects the tourist industry in the country. Finally the economic effects should not be underestimated because on the one hand waste which is thrown away is 'raw material in the wrong place'. On the other hand it will cost future generations huge amounts of money to clean up an environment which we have damaged through our carelessness.

A Summary of Project Goals - Phase One (1993-1996)

During February 1994 the participants of a ZOPP IV workshop agreed on the **Overall Goal** of the Project to be: "The risks of environmental pollution and waste of natural resources are reduced".

The **Project Goal** for Phase One was formulated as follows: "Waste Management started to be introduced on national level."

The following results were to be achieved:

1. A legal and institutional framework for waste disposal and waste management at the national level should be prepared.
2. The vulnerability of water resources should be identified.
3. The database with regard to environmental issues in the field of water quality, waste generation and current practices of waste management should be improved.
4. Concepts for the reduction, re-use and recycling of certain specific wastes (cans and metal scrap, plastic wastes, waste oil and wastes from health/medical facilities) will be established.
5. Case studies on the identification, planning, operation and closing/after care of landfill sites at three elected locations will be carried out to defame a state of the art for landfilling in Botswana.
6. The qualification of technical staff and planners should be improved.
7. Public awareness with regard to proper waste handling and disposal as well as protection of water resources in general needs to be promoted.
8. *Ad hoc* immediate advice on waste management questions at local level (with specific regard to landfilling) needs to be provided to urban and district councils.

Although this was considered to be a very ambitious project most of the targets were addressed with success during Phase One, especially that all the parties

informed so far have agreed that the waste problem needs urgent attention and the project has come at the right time.

A Summary of Project Goals - Phase Two (1996-1999)

The attendants at the OPP V workshop agreed in September 1995 that for Phase Two, the **Overall Goal** of the project, which is “Risk of environmental pollution and waste of natural resources reduced”, should not be changed.

The **Project Goal** was agreed as: “Central Government Administration, Local Authorities, Politicians, Traditional Leaders, NGOs, Churches, Waste generators, and the Waste Handling Industry establish, execute and actively engage in a sound and effective waste management programme.” Five key results were agreed upon, which were at a later stage revised to produce six key results by splitting result 1 into two independent results, as follows:

1. Set up of Waste Management Division within NCSA as well as waste management units at local level supported.
2. Adequate legal framework at central and local level facilitated.
3. Improvement of political understanding and public awareness in waste management encouraged.
4. Improvement of collection, transport, interim storage, and landfilling supported and facilitated.
5. Reduction, reuse, recycling and treatment of specific wastes encouraged.
6. Economic sustainability of effective waste management facilitated.

Present Status of the Project (Department of Sanitation and Waste Management)

The decision of the Government of Botswana to establish a new Department of Sanitation and Waste Management, which will be exclusively responsible for ‘executing government policy in sanitation and waste management, indicates clearly that Government now assigns adequate priority to sanitation and waste management. This is furthermore expressed by the positive development with respect to the adoption of the waste management strategy, the Waste Management Act and the Landfill Guidelines. Staffing and budgeting, always a contentious issue in the past has turned out better with all the Botswana Counterparts in place. More officers are to be employed in the new Department

and relevant finances planned for waste management under NDP 8. Therefore, institutional and capacity building within the project necessary to achieve sustainable development of the waste management sector is well on track.

Conclusion

There are clear indications that Botswana is making steady but definitive progress in environment friendly waste management programmes. With the implementation of the national aims and objectives spearheaded by the NCS/GTZ Waste Management Project, and with effective national commitments towards environmental protection and conservation, the sector will enjoy continuous growth. For any future waste management strategies to be more meaningful and progressive they should substantively depart from heavy governments subsidies in preference for a more sustainable government, parastatal organisation, local authority, and private enterprise partnership. The future prospects for Waste Management in Botswana will be realised not by singular government's involvement but certainly through the principle of co-operation.

While the project offers a golden chance to reduce environmental pollution, its impact will have been achieved if within its scope and content it could influence common regional approaches that enjoy replicability, that are affordable in character, and that would stand the test of times.

A Catalogue of Project Report Listing

Reports Developed by the Project

Report No.	Title	Author	Date
1	Pollution Protection of Water Resources and Solid Waste Disposal Management - Main Report Mission (GTZ & BGR).	German Project Appraisal	July 1991
2	Pollution Protection of Water Resources and Solid Waste Disposal Management - Annexes, Photo Documentation, Map and Literature.	German Project Appraisal Mission (GTZ & BGR)	July 1991
3	Situation Analysis - Preliminary Report.	Dr. Jacobus P. Venter and Mrs Vidette Engelbrecht	Jan 1994
4	Legal and Organisation Issues.	Nicholas Crick and Richard	

		Hawkins	Dec 1994
4A	Legal and Organisation Issues (Appendices).	Nicholas Crick and Richard Hawkins	Dec 1994
5	Landfill Case Study No. 2 - Pilane Waste disposal site upgrading.	Mr. David Hojem GTZ (German Technical Co-operation)	Mar 1995
6	Recycling Study on Metal Wastes Minutes of Interviews.	Dr. Ing. Heino Vest	June 1995
6A	Recycling Study on Metal Waste.	Dr. Ing. Heino Vest	July 1995
7	Clinical Waste - Final Report.	Nicholas Crick and Derek Johnson (Integrated Skills Ltd)	July 1995
7A	Clinical Waste Management - Implementing the Code of Practice - Training Manual.	Nicholas Crick and Derek Johnson	July 1995
8	Report on the Project Progress Review	German Review Team Mr. Menche, Mr. Mutius and Mr Oeltzschner	Sep 1995
9	Landfill Case Study No. 3 - Maun Waste Disposal Site Closure & Rehabilitation.	Mr. David Hojem GTZ (German Technical Co-operation)	Sept 1995
10	Management of Oil Containing Wastes	JHW du Toit, Toicon cc and GWP de Mattos Lombard & Associates	Oct 1995
1A	Management of Oil Containing Waste - Appendices.	JHW du Toit, Toicon cc and	

		GWP de Mattos Lombard & Associates	Oct 1995
11	Environmental Impact Assessment for Sanitary Landfill in Botswana - An Introduction and Case Studies.	NCSA/GTZ and the University of Botswana	1995
11A	Environmental Impact Assessment for Sanitary Landfill in Botswana - An Introduction and Case Studies.	NCSA/GTZ and the University of Botswana	
12	Sanitary Landfall Guidelines (Draft).	Nicholas Crick (Integrated Skills Ltd.) and Jarrod Ball, Jarrod Ball & Associates	Dec 1995
13	Landfill Case Study No. 1 - Selection and Development of a new Landfill Site Ghanzi/Gantsi.	Mr. David Hojem GTZ (German Technical Co-operation)	Jan 1996
14	Organisational and Human Resources Development for Waste Management in Local Authorities.	The National Conservation (Co-ordination) Agency	Aug 1996
15	Botswana's Strategy for Waste Management (Draft).	NCSA/GTZ Waste Management	Jun 1997
16	Collection of Industrial Waste Information - Final Report.	The National Conservation Strategy (Co-ordination Agency & GTZ - German Technical Co-operation)	Dec 1996
17	Risk Assessment and Environmental Impact Assessment for burning small quantities of household waste at villages in Botswana.	NCSA/GTZ Waste Management Project	Mar 1997

18	Implementing Metal Waste Recycling.	Dr Ing. Heino Vest	Aug 1997
19	Development of Guidelines for the Disposal of Large Quantities of Animal Carcasses.	Ecosurv (Pty) Ltd. Mr D. Parry (Team Leader)	May 1997
20	Management Information Systems - Final Year Project.	Samuel Serero (UB)	Apr 1997
21	Guidelines for the Disposal of Waste By Landfill.	David J. Hojem, GTZ/NCSA	

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30	Application of Appropriate Technologies in Waste Management in Developing Countries - Brighton Kaonga	379
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33	Waste Management Services in Botswana: Evolution of Problems, Perspectives and Responses - V T C Matsoga	433
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CHAPTER 30

THE APPLICATION OF APPROPRIATE TECHNOLOGIES IN WASTE MANAGEMENT IN DEVELOPING COUNTRIES

Brighton Kaonga

Rural Industries Innovation Centre (RIIC)

Private Bag 11

Kanye, Botswana

Fax: 267-340642aborone E-mail: riic-ings@info.bw

The Application of Appropriate Technologies in Waste Management in Developing Countries

Introduction

Waste characterisation data specific to African countries and cities are not generally available, though some regional evaluations have been made. Additionally, the income level of the generators has been shown to be correlated with the generation rate and composition of the *municipal solid waste* (MSW) stream. This correlation has been established in case studies of cities in OECD countries and on the basis of GNP for countries as a whole. Such regional and global-level statistics may be the most reliable bases available for inferences about the characteristics of the MSW stream in Africa. *The limited available data suggest that the MSW stream in the typical African City at point of disposal is high in putrescible organic content. However, it is low in percentage of commercially recyclable components and too low in heating value for energy recovery by incineration* (UNEP International Environmental Technology Centre, 1998).

For the most part in Africa, services are not available for the separate handling of special wastes such as household hazardous waste (HHW); paints, solvents, consumer batteries, etc.), construction and demolition debris (CDD), medical and infectious waste (MIW), tyres, sewage sludge, or chemical and pharmaceutical wastes. The predominant practice is to collect these items along with the rest of the waste stream and co-dispose of them at the same open dumps used for regular MSW.

Until the late 1980s, municipal solid waste management (MSWM) policies and programs in most African cities were formulated and implemented by government agencies without significant public participation. Political and social changes across the continent, including the rise of NGOs, have fostered an increased awareness of environmental issues among the public. Urban populations have become more involved in the issues surrounding MSW. Resistance to MSW incinerators in countries like Cote d'Ivoire, Senegal, and South Africa reflects an emerging involvement of the public in the debate and policy formation process of MSWM.

The key to changing MSWM practice at the consumer level is to make the distinction between public awareness and public education. Public agencies engage in this education primarily through initiatives based in the departments of health and education. Community service organisations, in collaboration with the health department and international health organisations such as the World Health Organisation conduct training seminars on sanitation.

if not properly handled.

Safety Aspects

For any organisation or laboratory institution, the safety obligations start with institutional responsibilities. Maintenance management and safety management are related (Ekosse and Nkoma, 1995a) and Laboratory Waste Management is directly linked to Laboratory Safety Management. There should be a safety policy which must be adopted and implemented. During the short courses conducted in 1994 and 1995 mentioned at the beginning of this paper, participants expressed ignorance of the existence of any institutional safety policies in their laboratories. One of the reasons to account for some of the problems encountered in the execution of an institutional safety policy in most LDCs is having Directors and Managers who are not professionally knowledgeable in Science Laboratory Technology.

The Laboratory Supervisor plays a pivotal role in the implementation of institutional safety policies. He checks all safety equipment and gadgets on a very regular basis to make sure there is no malfunctioning. Individual workers should be informed regarding the hazardous nature of compounds they handle daily at work. Safety drills should be organised by management for workers periodically. Workers must dress to conform to the rules and norms of the profession. It is the corporate responsibility of each laboratory worker to make sure that laboratory safety standards are not compromised, even when it comes to laboratory waste disposal.

Educational Aspects

It is noted that in most LDCs, while Directors and Heads of Departments are academically qualified, most of the laboratory personnel are not fully trained to effectively handle their jobs. In a recent study carried out on the compilation of an inventory of laboratory facilities for the study of environmental resources in Botswana (Ekosse and Khathola, 1997), it was pointed out that most of the laboratory workers either had higher degrees or low technical qualifications. A need was identified to train more laboratory personnel with appropriate technical and specialised qualifications. This is the class of workers able to efficiently handle Laboratory Waste on a daily basis.

Information and research on Laboratory Waste Management has not been encouraging in developing countries. This may apparently be associated to the fact that there are very few training institutions that run programmes in Science Laboratory Technology. there is a crucial demand for regional schools to be set up in Africa in Science Laboratory Technology covering the Environmental

quantity of waste generation. All types and classes of waste are produced in these laboratories. The production of a broad spectrum of laboratory waste is associated with all the environmental, geochemical, health and socio-economic hazards and implications.

Most laboratories separate their waste into different categories but do not dispose of them. It is economical to hire a waste disposal company to dispose of the waste. Because of readily available funds and frequency at which experiments are conducted, National Waste Disposal Companies exist with specialised equipment and trained manpower to handle and dispose of laboratory waste.

Less Developed Countries

Laboratories in LDCs generate less quality and quantity of waste. Most of the waste generated in these laboratories are disposed off by the laboratory staff. Because of lack of national legislation and regulations in LDCs, it is not certain that the laboratory waste are properly disposed off. Other factors which may affect the disposal of laboratory waste in LDCs are lack of trained and committed personnel, lack of funds and professional negligence.

Environmental Aspects

Conventional methods used for the disposal of waste in general are also applicable to the disposal of laboratory waste. In the past, the disposal of laboratory waste was not a concern because there were few laboratories and society was ignorant of the hazards associated with the waste. Many harmful substances have penetrated into different environments, endangering human health and threatening the ecosystem (Norwebb, 1995). Surface and groundwater have been contaminated, irritating gases have been emitted and vegetation has been discoloured as a result of poor waste management. In most cases, the effects of inappropriate waste disposal are only detected after a long time.

Waste disposal sites located at proximity to urban and residential centres have posed as potential dangers to explosions, fires, and contamination of aquifers. There have been reports that point to the relationship of waste disposal and health effects.

Owing to the environmental and health risks associated with inappropriate waste disposal, there is need for its production to be reduced as much as possible. Laboratory waste could be recycled. Hydrocarbonated waste can be recycled by fractional distillation. Depending on the type of waste, stabilisation, detoxification and neutralisation techniques could be used to reduce its hazard to the environment. Storage in abandoned shafts and salt domes can be harmful

Materials Recovery - Waste Reuse

*There are few formal systems of materials recovery through public agencies or the private sector in Africa. Instead, **materials recovery**, including *source separation* and *recycling*, is largely the domain of the informal sector. The activity is focused on components of economic and/or social value and occurs at several levels.*

*At the **household level in low-income peri-urban areas**, *resource recovery begins with the reuse of plastic bags, bottles, paper, cardboard, and cans for domestic purposes.* The rate of reuse in this instance is high, and these materials enter the waste stream only when they are no longer fit for domestic use.*

*At the **household level in high-income areas**, domestic servants and/or wardens carry out recovery. Rather than reusing the materials directly, they sell their bottles, plastics, cardboard, and paper to middlemen or commercial centres that pay for these materials. Glass bottles are largely returned to their point of sale for direct reuse by the beverage industry. A deposit system has maintained a high return rate continent-wide. In the majority of cities, the glass content of the MSW stream would not be sufficient to support a glass recycling industry. Instead, the bottles not used for beverages are diverted from the waste stream and used as containers in the home. Other glass items are discarded with the rest of the MSW stream.*

Materials Recovery - Waste Recycling

Where there is a market, plastics are recycled by waste pickers, some of whom have modular pelletizers to process the material prior to sale. The material is then sold to local plastic product manufacturers. These plants use granulated or pelletized virgin plastics for the manufacture of packaging material and extrudable utensils and furniture.

Waste pickers with rag-pulling equipment shred, clean, and re-knit this material as all-purpose utility cloths for resale. In South Africa a deposit system is used to encourage the return of bottles and tin and aluminium cans. In addition, specially marked receptacles are placed at greens depots for the drop off of bottles and cans. The country has a sizeable tin mining and processing industry, with a demand for the recycled material. Aluminium is processed for use in beverage containers.

Materials Recovery - Overview

In summary, the informal recovery and reuse of materials from the waste

stream occurs at several levels in Africa. At the **household level** items are reused before entering the waste stream, thereby extending their useful life. Waste pickers also recover materials for personal and commercial purposes. The extent of **commercial recycling** of paper, metals, glass, and plastic depends on the presence of industrial or other end uses for these materials. While such industries may be found in some primary cities, they are largely absent in secondary cities and in rural areas. Even in those cases where they are found, they do not consistently stimulate recycling in their host cities. With few official statistics on MSW generation and recycling to point to continent-wide, it is not possible to generalise about an overall rate of waste reduction or materials recovery in Africa. As African cities move to upgrade their MSWM systems, obtaining these data will be vital to their design of well integrated systems.

Administration of MSWM Systems

Administration of MSWM systems takes many different organisational forms across the continent. However, the institutional arrangements are fairly consistent across countries. Generally, administration is relayed through **three layers of responsibility**.

- ❑ At the highest level is the Ministry of Environment or its equivalent. In some countries responsibility for MSWM rests with the Ministry of Health or the Ministry of Planning and Development. The ministry is generally responsible for overseeing MSWM across the country. It controls the allocations for MSW capital investments by city municipal waste authorities. In many cases this ministry is charged with setting standards for MSWM based on laws enacted by the legislature. It is also through this ministry that international co-operation in MSWM is effected.

Often, the central government ministry, such as the Ministry of Environment, is charged with other responsibilities like tourism, wildlife conservation, and land and/or water resources management. These responsibilities generally carry a higher national priority than MSWM, since they often directly generate income. When combined with limited staff and budget constraints, MSWM may not receive due attention or financial allocation from the ministerial level. Besides the ministries, other national environmental agencies share oversight for MSWM. The Environmental Council of Zambia is one such example.

- ❑ Most major cities in Africa have an established **municipal waste collection system**. Collection is carried out by human and animal drawn carts (wheelbarrows, pushcarts), open back trucks, compactor trucks, and trailers. Collection rates across the continent range from 20-80% with a

median range of 40-50% (UNEP International Environmental Technology Centre 1998). In cities across West Africa, vehicle immobilisation rates reach as high as 70%, reducing the rate of collection. Where collection is performed by non-mechanical means, the volume of material to be collected often exceeds the capacity of the collection system. Community groups in some areas not served directly by municipal vehicles carry out precollection. For example, in Cotonou, Benin, such a group is authorised to pre-collect the waste and deposit it in communal bins for later removal by the municipality.

In most cities the municipality provides collection. Private operators also provide service on a fee basis to households and commercial establishments. In Cairo, the Zabbaleen is a group that has traditionally specialised in MSW collection and now operates as a co-operative to perform this service with authorisation from the municipal authority. However, though such co-operatives might do much to improve municipal sanitation, they are not common in other African cities. Since the mid-1970s international aid has promoted initiatives to improve the coverage of MSW collection services in Africa. These efforts have focused primarily on vehicular collections in the central city. In some West African cities, such as Dakar and Cotonou, local initiatives have focused on service to formerly neglected peri-urban areas. The lack of reliable collection service undoubtedly takes a toll on the public health and aesthetics of African cities. As the urban share of the population grows on the continent this problem is likely to increase. Collection is a key link in the chain of MSWM from the point of generation to ultimate disposal. In any initiative to upgrade waste management service, sustainable, contextually appropriate collection should be a major focus of attention.

- ❑ Various academic departments at universities across Africa provide training in the engineering principles of MSWM. In addition, most countries have sufficient resident personnel to develop and manage effective MSWM systems that are appropriate for local conditions and resources. These can be enhanced as the pool of human and other resources grows with time. However, the evolution of MSWM systems requires an enabling policy and administrative environment to be successful. Thus, in connection with MSWM in Africa, training and human resource development are subordinate issues to institutional and organisational change and to appropriate infrastructure development.

Training and human resource development generally focuses on the training of process and operations personnel. For example, drivers may be trained to operate a new compactor truck or other piece of equipment donated by an international aid agency. However, to be sustainable, such education would need to be supplemented by training of support staff in the maintenance and repair of this equipment. Landfill staff, where available, may be trained in the daily operations of spreading and covering the lifts. However, equipment

failures or the practice of open waste picking may quickly render such training ineffective. NGOs active in MSWM train waste handlers from the informal sector in the safe handling of MSW for pre-collection, sorting for recycling, and composting. The Cape Recycling Network of South Africa is a good example of an NGO involved in MSW training and awareness for members of community organisations. Among the issues addressed by the South Africa Municipal Workers Union (SAMWU) are safety and health issues affecting municipal waste handlers.

The Department of Civil Engineering at the University of Lagos in Nigeria provides training in MSWM to undergraduates. The Biology Department of Bunda College of Agriculture trains students and community groups in the practice of composting. Several other national universities across Africa provide curricular training to undergraduates in MSW-related fields. The Environmental Council of Zambia promotes periodic public information campaigns on the safe handling of MSW. The health department also trains sanitation workers responsible for monitoring sanitary conditions at the landfill. Other health ministries across Africa also provide similar training for municipal health workers on the MSW detail. In addition, the sanitation or public works departments of major municipal governments often provide some period of probationary training for their new workers. This includes MSW collection truck crews as well as manual and supervisory staff at the landfill.

Financing Options

In African countries, the central government generally finances MSWM and other municipal activities through taxes collected by the Treasury. Even municipal property taxes and direct taxes on household refuse collection flow to the coffers of the central government. These funds are then allocated across the different central government ministries and to the municipalities. MSWM is then funded by allocations from the responsible ministry for capital projects and special projects (such as public education) and by municipal allocations for operation and maintenance.

Under this system, MSWM is just one of many ministerial and municipal responsibilities. It does not accommodate the actual budget required for the MSWM program, projects, and operations. User fees are based on a flat rate for collection service to households and commercial establishments. Where this service is provided by the private sector it is likely that the fees yield full cost recovery plus a profit for the service provider. In other cases, where the municipality charges a user fee, full cost recovery may not be realised and the service is subsidised by funds from other sources. Examples where municipal user fees are used include Accra; Conakry, Guinea; and some suburbs of cities in South Africa. The municipalities may retain these revenues specifically for

their MSWM activities, or the funds go into the general municipal pool. Special taxes are also used to raise revenue for MSWM services. In Dakar an MSW collection tax is imposed by the central government and is collected by the Treasury. In Bamako a cleansing tax based on property value is levied and direct user fees are also employed in some areas. Direct user charges also prevail where pre-collection services are provided by community organisations. These revenues cover part or all of the costs for community collections though they may not extend to covering the cost of emptying the communal receptacles and disposing of their contents. These latter costs are borne by the municipality. Direct municipal charges appear to be an emerging instrument for cost recovery in African cities. However the practice is not yet widespread and in general, residents pay via indirect local taxes.

In summary, financing options include taxes, user fees, bank financing (for private service providers), and international aid. The central government is the main mechanism by which these options are exploited. The Treasury generally controls the collection of taxes and the flow of funds to municipalities. Direct user fees collected and retained by municipalities are a relatively new instrument for cost recovery in several African cities. These generally provide partial recovery of the MSWM service costs. Private service providers also apply direct user charges. It is likely that these cover full costs of the service, which primarily involves collection.

Municipal Waste Landfills

The overwhelming majority of landfills in Africa are open dumps. These facilities are generally located at the perimeter of major urban centres in open lots, wetland areas, or next to surface water sources. Though many municipalities have statutory requirements for the construction and maintenance of landfills these are generally not enforced. In most instances the landfills are owned and operated by the same public agency that is charged with enforcing the standards. Often a lack of financial and human resources, coupled with absent enabling policies, limit the extent to which landfills can be built, operated, and maintained at minimum standards for sanitary practice. Thus, landfills are generally sited based on considerations of access to collection vehicles rather than hydrological or public health considerations. This practice ranges from cities in the more arid regions of the North such as Algeria, Libya, and Sudan to those in higher rainfall central countries such as Cameroon and The Democratic Republic of the Congo (formerly Zaire). The environmental and health consequences for water sources at risk are more significant for the latter cities than the former.

At existing landfills management operations are minimal. Most of these facilities are unlined and unfenced. Operating practice generally does not include compaction or the application of daily cover. This may reflect the

absence of appropriate equipment or other resources to carry out these practices. Additionally, large numbers of waste pickers may scour the landfills for materials of economic or personal value. The returns from the sale of these materials go to the waste pickers, and not to the agency operating the facility.

Over the past five years some countries, including Egypt and South Africa, have considered policy changes to promote upgraded landfills for their major cities. These facilities would be classified according to the type of waste they receive, their manner of construction, and their operating procedure. Tunisia has shown leadership in developing a nation-wide sanitary landfill program. New guidelines for the construction and operation of landfills were issued in South Africa in 1995. The Environmental Council of Zambia also considers linking improved landfilling to upgraded MSW collection services in its 1995 solid waste plan, (UNEP International Environmental Technology Centre 1998).

Ocean Dumping of Municipal Solid Waste

Ocean dumping of MSW is banned or restricted by law in most of Africa. This is largely a consequence of restrictions on ocean dumping initially related to hazardous waste under the Lome IV and Bamako Conventions, as well as the London Dumping Convention of 1972. Even though the practice is largely prohibited across Africa, it still occurs to a significant extent in larger coastal cities. Ocean dumping of sewage sludge beyond the 12-mile limit is still practised. However, in most of coastal West Africa as well as in South Africa, policy changes are under way to phase out this practice (UNEP International Environmental Technology Centre 1998).

In summary, landfills in Africa are primarily open dumps without leachate or gas recovery systems. Several are located in ecologically or hydrologically sensitive areas. The landfills are generally operated below the standards of sanitary practice. Waste pickers remove materials of economic value for recycling without a fee to the facility owner and operator.

Operation and maintenance costs are provided from municipal budget allocations and often do not cover the full amount needed. The result is substandard and unsafe facilities, which pose public health risks and aesthetic burdens to the citizens, they are meant to serve. Though the standards of modern sanitary landfills with leachate and gas recovery may be too expensive for most African cities today and for municipalities in OECD countries, sound practice in current operations and in the design and siting of new facilities can reduce the risks posed by existing facilities.

Composting of Municipal Solid Waste

In the suburbs of larger South African cities such as Durban, there are community composting centres. Residents drop off their garden waste and it is composted and resold for household sized gardens. In peri-urban areas throughout Africa, NGOs, community based organisations, and economic interest enterprises also promote composting of MSW. These projects are generally highly labour-intensive with a low capital investment. In Brazzaville (Congo) peri-urban farmers practice small-scale composting, applying the composite to their fields. There are operating composting systems in Benin and Cameroon.

Several NGOs such as the Biomass Users Network (BUN) in Zimbabwe also promote anaerobic digestion and the recovery of methane. However, these systems primarily target rural, agricultural areas and focus on the use of animal wastes rather than MSW. Overall, even though the organic content of the MSW in the typical African city may exceed 70% (wet basis), centralised composting, anaerobic digestion, and gas recovery are not significant components of African MSWM practice. Further investigation of their market potential may prove this to be an overlooked opportunity.

Back-yard Composting is limited. Some NGOs promote the practice in Benin, Cameroon, Egypt, Ghana, Kenya, Nigeria, South Africa, and Zimbabwe but the practice does not have a significant impact on MSWM at the city level. This may be a large forgone opportunity if the typical African waste stream is high in organic material with potentially high yields of compost.

Incineration of Municipal Solid Waste

Incineration and Waste-to-Energy (WTE) remain little-used options for MSWM in Africa. One energy recovery plant was recently constructed in Tanzania with foreign assistance. If successful in the long run, this experience would show how safe operations at such a facility can be sustained with local resources. Local capacity to sustain safe and efficient operations at such facilities is a key consideration in weighing the appropriateness of this technology for African cities. These considerations include local technical capacity to maintain and service the facility, the availability of basic spare parts, the scheduled replacement of pollution control equipment, and the effective implementation of a monitoring program to protect public health from plant emissions. The Senegalese have conducted research into refuse derived fuel (RDF). However, implementation of this system faces the same considerations listed above for incinerator technology in general. The high cost of preprocessing RDF poses an additional obstacle to its safe and cost effective implementation in Africa.

High capital and operating costs make incineration and WTE inaccessible

technologies for most African cities. Another limiting factor is the lack of infrastructure to support this technology. This includes human and mechanical resources as well as institutional controls. Furthermore, incineration in Africa would be infeasible if the waste stream is indeed 70% (wet basis) putrescible organic content. Under these conditions, incineration is likely to be an energy-consuming rather than energy-producing option. Characterisation of the ~MSW stream would first be necessary to establish the feasibility of incineration and WTE from MSW in Africa. To date, such city-specific information is largely unavailable for African cities.

In summary, incineration and WTE presently do not play significant roles in MSWM in Africa. High costs relative to other MSWM options, a limited infrastructure of human, mechanical and institutional resources, and the composition of the waste stream itself, suggest that incineration is an inappropriate technology for Africa now and for the foreseeable future.

Technologies in Waste Management – The RIIC Experience

Rural Industries Innovation Centre (RIIC), based in Kanye in Botswana, is involved in several technologies for *waste collection and management*. These are:

- ☐ Ventilated Pit Latrine Technology;
- ☐ Animal Proof Bin Technology;
- ☐ Can Crusher Technology;
- ☐ Incinerator Technology; and
- ☐ Constructed Wetland Technology.

In this paper, only three technologies are discussed. These are the Incinerator, the Medium Can Crusher, and the Constructed Wetlands.

The Incinerator

The RIIC designed Incinerator has evolved as a result of environmental risks caused by problematic disposal of medical waste in Botswana. The small scale - incinerator is basically a furnace designed to destroy metallic and other medical refuse for safe disposal.

The main objective of the test was to assess the performance of the small scale Incinerator as a means to destroy the waste material (mostly toxic medical waste) to aid in their safe disposal.

Table 30.1: Paraphernaliae in the RIIC Incinerator (Equipment, Fuel and Refuse)

Apparatus	Fuel	Refuse
Airflow Meter	Coal	Sharp Contents including:
Electronic Balance		Needles
Tachometer		Surgical Knives
Stopwatch		Drug Containers
Single Phase Motor		Cotton Wool
Termocouple		
Small Scale Incinerator		

The volume of the incinerator provided a limitation on the amount of refuse added per charge. The incinerator was shut to allow the contents to bum out with continuous blowing of air.

A single phase motor powered from an AC mains supply was used to drive the blower-attained air supply in the incinerator. The speeds of the motor and the blower were recorded. Also measured were the output airflow in metres per second from the blower and the airflow into the incinerator through each of the four inlet holes. The airflow as measured above was then converted to the required parameter of airflow rate in cubic metres per minute by multiplying by the cross sectional areas of the ducts.

Temperatures were measured using a thermocouple at 5 different points of the incinerator after burning for a period of 1.5 hours:

- ☐ Inside top of the incinerator;
- ☐ Inside centre of the incinerator;
- ☐ Inside bottom of the incinerator;
- ☐ Inside chimney; and
- ☐ A zone of 0.05 m around the incinerator

Results indicated the following findings:

- ☐ Motor speed - 2878 rpm.
- ☐ Blower speed - 2921 rpm.
- ☐ Blower Output Flow rate - 16.55 cubic metres per minute.

(*Note:* This is the output flow from the blower when it is not connected to the air line system into the incinerator).

Table 30.2: Flow rate through each of the Inlet Holes into the Incinerator.
[Source: Rural Industries Innovation Centre (RIIC), 1998]

Hole Number	Air flow rate (metres cubed per min)
1	0.064
2	0.067
3	0.061
4	0.058

The results above indicate that the air flow rate into the incinerator was far much less than the output rate of the blower when it is not connected to the airline, that is, when blowing air into the atmosphere.

This is attributed probably to the airline layout that includes very sharp pipe bends where the air has to make sudden changes in direction. This creates high back pressure against the flow and thus result in very low airflow along the air supply line into the incinerator.

Although the airflow into the incinerator was deemed adequate for its desired purposes, the high back pressure against the airflow along the duct indicate that the efficiency of the air supply system is very poor and thus need to be addressed.

The need for continuous blowing to maintain the incinerator temperatures at the required level for refuse destroyal was evident since at any point the blower was turned off the temperatures dropped drastically, especially at the incinerator Bottom.

Table 30.3: Maximum Temperatures Recorded

Incinerator point	Temperature (deC)
Bottom of Incinerator.	1318
Centre Of Incinerator.	1201
Top Of Incinerator.	107
A zone 0.05m around incinerator.	107
At chimney (inside).	989

Total weight of refuse destroyed per charge - 3.54 kg

Time taken to completely destroy the refuse - 1.5 hrs

Thus refuse destruction - 2.36 kg/hr

Amount of coal used per charge - 36 kg

The calorific value of the coal used - 25 MJ/kg

The design objectives of the small scale incinerator are very viable as indicated by the satisfaction expressed by the nursing community. The test results have indicated that the incinerator is capable of destroying the refuse into harmless waste that can easily be disposed off, thus satisfying its prime objective.

Constructed Wetlands

Treatment of Wastewater in Constructed Wetland Systems

Constructed wetlands in Botswana have joined already existing wastewater treatment systems such as septic tanks-soak away, stabilisation ponds and the recently introduced activated sludge. These systems have been adopted to promote recycling of water.

Wastewater consists of *soluble and insoluble material*. *Treatment therefore*

consists of sedimentation and filtration by the soil (filter medium), absorption (uptake by plants, thereby reducing conductivity), and by biodegradation by bacterial (reduction of biochemical oxygen demand - BOD)

As wastewater percolates through soil, it experiences filtration process resulting into clarity from turbidity. Bacteria (anaerobic, facultative, and aerobic) feed on the waste for their energy, releasing by-products that either escapes as gas or dissolve in the water. The soil media as water flows along filters the insoluble products. The plants take up the soluble substances in the system. Soil media (mainly sand) traps the insoluble substances and the bacteria start acting upon them. Simpler compounds are produced which include nitrates, phosphates, carbon dioxide, hydrogen sulphide and so on, during biodegradation. The plants thrive on carbon dioxide, nitrates, and phosphates. In the process of taking up nutrients, they also take up other dissolved substances which may include pathogens. Plants release oxygen into the wastewater through their root hairs during biomass growth. The released oxygen is eventually utilised by the aerobic and facultative bacteria. Ultimately, wastewater is purified to a great extent.

Use of Constructed Wetland Systems

The methodology of constructed wetlands, based on constructed basins planted with wetland species, was pioneered by Dr. K. Seidel in the 1950's [Rossiter and Crawford, 1984) as reported by Gearheart, 1992][1]. These systems can either be Surface Flow (SF) or Subsurface Flow (SSF). The SF system entails growth of rooted emergent plants such as reeds and bulrushes in a shallow basin with the passage of wastewater across the surface of the wetland. The SSF system on the other hand involves growth of rooted emergent plants such as reeds and bulrushes in gravel as a growing medium and wastewater flows through the medium below the surface.

Constructed wetlands are cost effective methods for wastewater treatment and have been and continue to be used in several countries. In California for example, the city of Arcata have been involved in the constructed wetlands for 10 years (Gearheart, 1992)[1]. Gearheart further reported that the in the first five years (1980 -1986), the Arcata city worked on an experimental system of size 6 x 66 metre system. This was followed by a full scale system of 2.8 hectares by 12 hectares successfully in the next five years. The United states have used constructed wetland systems for more than 50 years [(Hammer and Kadlec, 1983) as reported by Gearheart, 1992][1], United Kingdom have used the system for over 100 years (Cooper and Boon, 1985)[2]. Canada [(Nichols, 1983) as reported by Gearheart, 1992][1], the Netherlands (De Jong and Koridon, 1985)[3], South Africa (Haas and Borain, 1995)[4] to mention but a few are active in the constructed wetlands systems.

Purification Efficiency of Constructed Wetlands

Efficiency of constructed wetlands or reed beds as they are called sometimes is normally referred to the Biological Chemical Demand (BOD), Chemical Oxygen demand (COD) and the elimination of the nutrients as represented by total nitrogen (N_{tot}) and total phosphorous (P_{tot}). The removal efficiency of the above mentioned parameters can fall within 72% and 99% with respect to BOD, and between 61 to 99% with respect to COD (Netter, 1992)[5]. N_{tot} and P_{tot} on the other hand vary between 5 and almost 100%. Faecal Coliform (FC) removal mechanism is by adsorption, ingestion, temperature, flocculation, sedimentation and denaturing (Gearheart, 1992)[1]. Removal of FC is normally in the range of 99% or more.

The Botswana Experience

The constructed wetland for Kanye Prisons in Kanye is taken as a case study. Construction of this 10 metre wide by 60 metre long project started in February, 1997 and was completed in August, 1997. Some modifications were carried out in the period September to November, 1997.

The Kanye constructed wetland was closely monitored for its performance and efficiency. Detailed monitoring began early January, 1998. Physical monitoring included observing the effect of heavy rainfall on the operation of the reed bed and rate of clogging of the pre-filter section as this would determine the frequency of maintenance.

Results and Analyses

All the analyses were done at the Rural Industries Innovation Centre (RIIC) laboratory. Other laboratories such as Wellfields in Gaborone, and the Department of Water Affairs Laboratory were requested to participate in the analysis of some parameters like BOD which RIIC had insufficient capacity to carry out. The other reason for approaching these laboratories was purely for result comparisons.

Physical Monitoring

This physical monitoring aspect included observations of the *rate of clogging of the pre-filter system*. Constructed wetlands have the advantage of almost no maintenance. This applies to a wetland that does not incorporate a pump, which would be the only prime mover. In the Kanye constructed wetland case study, it was observed that it took six months after the system began operating before the pre-filter clogged up. Maintenance therefore entailed removal of

Table 30.4: Chemical Performance Data (1998) of the Kanye Prisons Constructed Wetland

* Indicates that no measurements were taken.

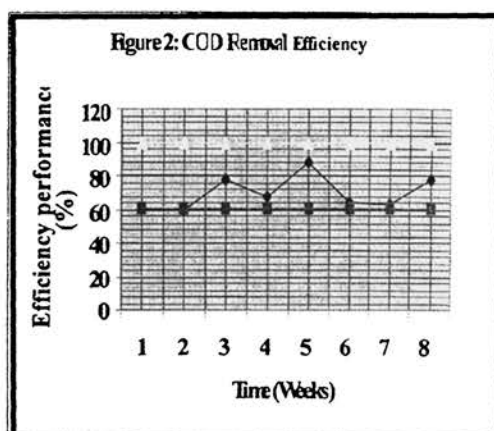
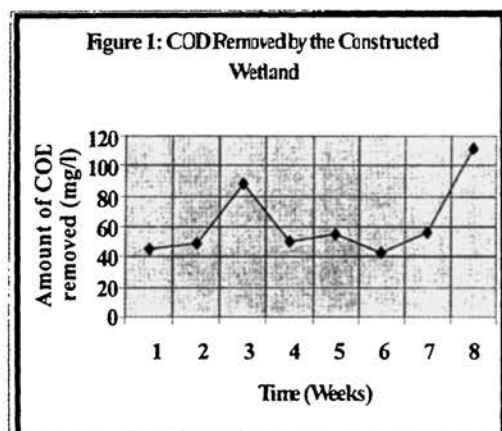


FIGURE 1 shows the COD amounts removed by the system. FIGURE 2 shows the efficiency of the system. It is obvious from the FIGURE 2 that the range of the system efficiency lies between

60% -88%. The straight lines at 61% and at 99% refers to efficiency of systems to remove COD as reported by Netter (1992)[5]. It is worth noting that the influent COD changes from time to time.

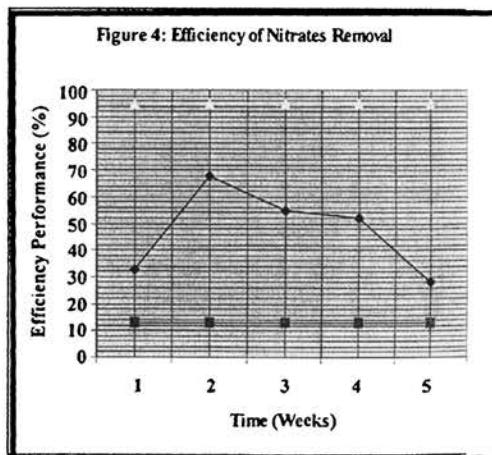
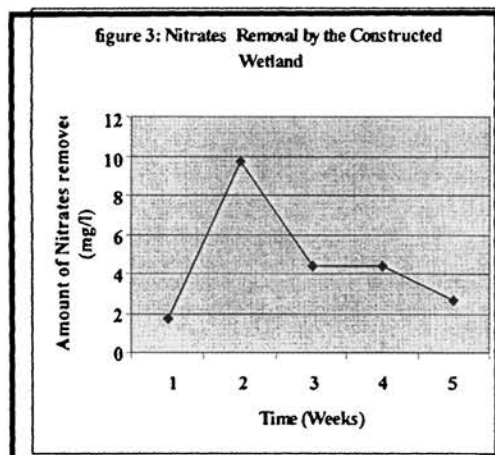


FIGURE 3 and Figure 4 show how much nitrates the system is able to remove and the efficiency respectively. The system was able to remove nitrates between 20 % - 70 %. R. A. Gearheart

(1992)[1] reports a range of 13 % - 95 % removal.

Figure 5: Phosphate Removed by the Constructed Wetland

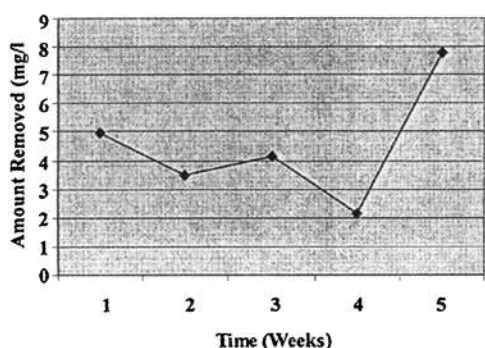
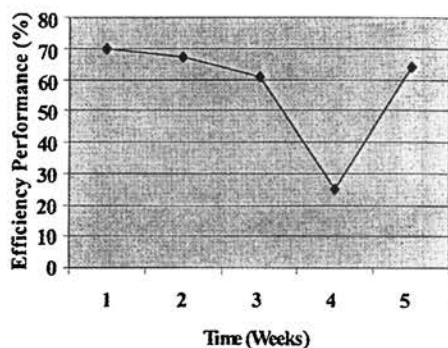


Figure 6: Efficiency of Phosphate Removal by the Constructed Wetland



The phosphorous and nitrogen in wastewater are of water quality significance in relation to potential enrichment of receiving waters in terms of nutrients. From the FIGURE 6, it can be seen that constructed wetlands can remove a substantial amount of phosphorous, ranging between 60% - 70 %.

Metals

From TABLE 4 above, it can be noted that the reed bed played a role in the reduction of metals like iron, copper, nickel, and sodium. It was surprising however that instead of reducing, the manganese actually increased. No explanation can be offered at this stage.

pH

pH of the system remained within the range of 7.0 - 7.9. The treated wastewater passing through the constructed wetland is so clear that there is not much difference with domestic tap water. The turbidity values in TABLE 4 speak for themselves.

Pathogenic bacterial removal

Wetlands have been shown to effectively remove faecal coliform to 99% levels (Gearheart et al., 1985; Gersberg et al., 1984). TABLE 5 below show that the Kanye constructed wetland was able to remove faecal coliform to same levels of 99%, faecal streptococci 98%, and total cloakrooms from 90% upwards.

gravel stones and washing them before returning them. Noteworthy is the fact that the prisons were not desludging the septic tanks and consequently most sludge found its way into the pre-filter system.

Discussion

Results presented above indicate that the Kanye Prisons Constructed Wetland is presently working efficiently. Efficiency refers to the degree of removal of COD, BOD, pathogens, nitrogen and phosphorous. This was satisfactorily achieved.

A point worth stressing is the fact that emphasis was placed on a low impact engineering approach, meaning that unnecessary expenses were avoided as much as possible. Natural processes like gravity flow were taken advantage of thereby excluding pumps in the system. The design concept was such that the reed bed fit naturally into the landscape following the topography.

Conclusion

Comparison of the data collected from the analyses show that the Kanye Prisons Constructed Wetland have achieved the guidelines of water for irrigation purposes as laid down by the Department of Water Affairs of Botswana. The guidelines state that water for irrigation which originates from domestic wastewater should have faecal coliform content of 1000 CFU/100ml for cooked vegetables, and the BOD should be 35mg/l. Values obtained through the reed bed were faecal coliform 125 CFU/100ml and BOD 24mg/l.

The Benefits of Wastewater Treatment

The benefits of wastewater treatment include the following:

- ☐ Protection of public health from waterborne disease;
- ☐ Protection of the natural environment and the wildlife that depend;
- ☐ Protection of water resources; and
- ☐ Removal of toxic and hazardous materials that might accumulate in the environment.

Treated wastewater could be used for a variety of purposes, including recreation. Small hydroelectric power generation can be interesting to investigate especially looking at the vast amounts of wastewater generated.

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CHAPTER 31

TRANSNATIONAL MOVEMENT OF HAZARDOUS WASTE IN DEVELOPING COUNTRIES

Prof F A O Otieno
Department of Civil Engineering,
University of Durban-Westville
Private Bag X54001,
Durban 4000 South Africa

**Phone: +27 31 204 4572/4 749 Fax: +27 31 204
4291/4755**
E-mail: otieno@ pixie.udw.ac.za

Transnational Movement of Waste in Developing Countries

Introduction

The World Health Organisation (WHO) defines waste as follows:

“Something which the owner no longer wants at a given place and time and which has no current perceived market value.”

- Suess et. al., 1983.

Because waste is by definition of little or no perceived value to the entity generating it, there is little financial incentive to handle it in a careful and secure manner and, on the whole, there is an inbuilt temptation to relinquish responsibility for it at the earliest opportunity. There are several problems associated with poor disposal techniques and fly tipping and litter are examples of what can happen when waste is disposed of without proper care and without a suitable framework of regulation and enforcement. Movement of hazardous wastes across national boundaries and, certainly, from the developed countries to the developing countries is on the increase.

The international community, the African countries and regional initiatives aimed at the regulation and control of illegal movement of hazardous wastes have been attempted.

Sound management of hazardous waste activities, including transnational movement, is essential for any civilised society. Ideally, it should be viewed as a complete unit with integrated control at all levels of the problem. Such management is even more critical in developing countries where legislation to control the menaces from careless disposal are lacking.

Transportation and Storage of Hazardous Wastes

The public has become increasingly aware of environmental and health damage that can result from accidents involving the transportation of hazardous wastes. At the same time many officials are aware that they do not fully understand the complexity of the risks to public safety posed by transportation of hazardous materials. Moreover, there is a pervasive feeling that existing programmes aimed at minimising transport risks do not take into account special local circumstances and are increasingly asking for international help in establishing regulatory, enforcement and emergency response programs that meet their specific needs.

For example, the federal regulatory system governing the transportation of hazardous materials in the US was developed over the twentieth century with substantial industry involvement. The existing regulations promulgated by the US Department of Transportation (DOT), Environmental Protection Agency (EPA), and other federal agencies are extensive. They cover all aspects of the transportation of hazardous wastes: *classification of the wastes, engineering specifications for containers, communication requirements such as container and vehicle labelling, handling and operating requirements for each mode of transport, safety requirements for shippers and carriers, worker safety, and environmental protection.* This type of arrangement is seriously lacking in most developing countries, certainly on the African continent.

The Consolidation of Regulations Governing the Transportation of Hazardous Wastes

Because the US is presently the largest producer of hazardous wastes in the world (see Table 27.1), we will use the existing regulations in the US to try and illustrate the dangers of hazardous wastes movement. Furthermore, although hazardous wastes are transported across boundaries in developing countries, very little is documented about such movement as on many occasions, this is done illegally by business people who seek to exploit stringent environmental regulations in developed countries to dump such wastes in developing countries.

Table 31.1: Volume of Hazardous Wastes Generated
(million tonnes per year) 1988

Country	Volume of Waste (million tonnes per year)
United States	275
OECD Europe	30
Eastern Europe	25
Rest of the World	20

Persistent administrative and organisational difficulties in the early 1970s led the DOT to seek the passage of legislation to consolidate regulatory authority over hazardous materials. Little was done until 1973, when a cargo jet carrying several tons of hazardous materials crashed. The inquiry into the accident showed that there was a *general lack of compliance with existing requirements because of the complexity of the rules, fragmentation of federal surveillance and enforcement authorities, and lack of industry familiarity with the regulations at working level.*

In 1975, the Hazardous Materials Transportation Act (HMTA) of the US was passed. The intent of the law was to improve regulatory and of transportation broad authority to set regulations applicable to all aspects of the transportation of hazardous materials. Such an arrangement needs to be formalised for most developing countries if they are expected to cope with this increasing menace.

Countries need to *list the classification* for hazardous materials that should be subject to international transportation regulation. These regulations should focus on materials likely to cause immediate injury to carrier personnel and the public if they are unexpectedly released during transport. Such regulations should further *define the label, packaging, and carrier requirements* for specific hazardous chemicals. *This should be based on serious threats to human health but not necessarily to the environment.*

It is estimated that 264 million metric tons of hazardous materials are generated each year in the United States. Of these, 96 percent are disposed of on site. Most of the waste shipped off site for disposal or treatment is transported by truck over distances less than 100 miles. In 1981, the EPA estimated that over 14 000 generators produced hazardous wastes, and that there were 12 367 transporters of such materials. In 1984, legislation was passed that extended the scope of existing regulations to include small quantity generators of hazardous wastes. Because most small quantity generators ship their waste to offsite facilities, the number of shipments regulated has increased.

The transportation of hazardous wastes should be governed by establishing certain standards for transporters of hazardous materials and to co-ordinate regulatory activities with responsible government departments in each country. This should cover among other things the following:

- ☐ Identification, listing, and labelling;
- ☐ Record keeping;
- ☐ Generators, transporters, and owners and operators of treatment and disposal facilities;
- ☐ Permit requirements for all facilities involved in the production and transportation of hazardous materials; and
- ☐ Tracking of the movement of hazardous wastes.

Countries should administer and enforce their own hazardous waste programs if their regulations are consistent with and at least as stringent as internationally accepted and acceded to programmes and regulations.

Definition of Generators (Shippers) and Transporters (Carriers)

A **shipper of hazardous wastes** is considered to be an entity that performs any of the functions listed in 49 Code of Federal Regulations, Parts 172 and 173 such as labelling or packaging.

In the US, the EPA calls an entity fitting the DOT description of a shipper a waste “**generator**” defined as *any person, by site, whose act first causes a hazardous waste to become subject to regulation*. For example, any person who removes hazardous sludge and residues in vehicles or vessels that have carried products or raw materials or who hires another party to remove and dispose of sludge and residues, or who takes a vehicle or vessel to a central facility for cleaning, fall under the category of waste generator. The EPA regards *all parties involved in the transportation of hazardous waste as generators and believes they can be held jointly and severely liable if regulations are violated*. An international protocol could be arrived at which would regulate this internationally.

Under DOT regulations, a **carrier** *is also considered a generator if the carrier imports hazardous wastes into the United States, mixes hazardous wastes with different DOT descriptions, or is responsible for discharge or spill of hazardous wastes or commercial chemical products occurring during transport*. In the latter cases, the transport generator is responsible for cleanup of the discharge or spill of hazardous wastes or commercial chemical products occurring during transport. In the latter cases, the transporter-generator is responsible for cleanup of the discharge or spill as well as any resulting pollution, such as the contaminated soil or water. *This scenario is critically lacking in most developing countries and may be responsible for many of the incidences that have been reported regarding dumping of hazardous wastes from developed countries*.

If a generator or transporter accumulates hazardous wastes for more than 90 days, an RCRA storage facility permit must be obtained. However, if a transport vehicle, vessel, tank, or container is used for neutralising corrosive wastes, a facility permit is not required. Transfer facilities that store manifested shipments of hazardous wastes for 10 days or less are not required to obtain a permit. There are incidences where large volumes of hazardous wastes are stored for years in developing countries and very little precautions are taken to ensure that they are safely stored or looked after. The potential for accidents is great and should not be underestimated.

Regulations Governing Generators of Hazardous Wastes

Generators of hazardous wastes should be responsible for complying with all legislation regulating the transportation of hazardous materials as well as regulations promulgated internationally specifically covering hazardous wastes. These regulations cover three major areas: *preparation for transport*, including identification, notification, and packaging; *compliance with manifest requirements*; and *record keeping and reporting*. Details exist of how each hazardous waste type should be handled to comply with such requirements (Wentz, 1989).

Most pre-transport requirements apply to all hazardous materials. They include identifying and classifying wastes determining whether the wastes are prohibited from certain modes of transport or whether special shipping requirements must be met; and complying with all packaging, marking, labelling, and placarding requirements. Looking at DOT regulations as they pertain to hazardous wastes and the relevant EPA requirements sees an indication of how this works.

EPA Identification and Notification

Generators of waste must first determine whether their wastes are hazardous according to EPA criteria. A waste is considered hazardous if it satisfies all of the following conditions:

- ☐ It is a *solid waste* as defined by the EPA;
- ☐ It is listed as a hazardous waste by the EPA or is a mixture that contains a listed waste or exhibits one of the four EPA characteristics of a hazardous waste - *ignitability, reactivity, corrosivity, or toxicity characteristic*;
- ☐ It is *not explicitly excluded from regulation*.

Once it has been established that a waste is hazardous, generators are required to obtain an EPA identification number by submitting an EPA Form 8700 -12 to the agency. Generators are also responsible for seeing that any entities that will eventually handle the waste (e g: transporters or owner-operators of treatment, storage, or disposal facilities) have EPA identification numbers. This is to ensure that all activities related to this industry are done in a professional manner, and accountability exists.

In addition, the EPA requires generators to mark all containers of hazardous wastes with a capacity of 110 gallons or less with a statement indicating that federal law prohibits improper disposal of such wastes.

Generators of hazardous wastes that produce less than 100 kg of hazardous

waste per month are conditionally exempt from full EPA regulation, such as certain record keeping requirements.

DOT Identification and Classification

In the DOT system of classification, hazardous wastes are any material so classified by EPA under 40 CAR 262. It is important to classify hazardous waste correctly according to this system, because regulations covering hazard communication and packaging of hazardous material and waste correspond to the class of the hazard.

First, it must be determined whether a hazardous waste is listed in the DOT Hazardous Materials Table in 49 Code of Federal Regulations. 172.101. If it is not, the EPA characteristics or EPA lists of the waste must be identified. The proper shipping name for a hazardous waste includes the word waste preceding the 49 CAR 172.101 material name (eg: waste toluene or waste sodium hydroxide).

All generators and carriers of hazardous waste including small quantity generators, must comply with appropriate DOT regulations covering marking, labelling, and placarding. These “hazard communications” furnish essential information about the cargo that can be used by the emergency response personnel should an accident occur.

The DOT requires shippers (generators) to mark all the packages with a capacity of 110 gallons or less with a proper shipping name, including a United Nations or North American (UN/NA) identification number (see Wentz, 1989). This is done so the contents of a package can be identified if it is separated from its shipping papers. Requirements for intermodal portable tanks, highway cargo tanks, and rail tank cars specify that the UN/NA number be displayed on a placard or an orange rectangular panel. There is a number for all hazardous waste in the “Hazardous waste n.o.s.” (Not otherwise specified) category - NA 3082 (liquids) and NA 3077 (solids).

Labels are symbolic representations of the hazards associated with a material. Labels are required for most packages containing hazardous materials and must be printed on or affixed to a spot near the marked shipping name. Like labels, placards are symbolic representations of the hazards of a given cargo. They are placed on the ends and sides of motor vehicles, railcars, and freight containers. Placards are particularly important in case of accident because they are highly visible.

Packaging

The DOT regulations that pertain to the packaging of all hazardous materials are discussed below. Because of their usefulness in trans-boundary movement of hazardous wastes, they should be used where possible in third world countries. Two special rules that apply to hazardous wastes are:

- ☐ An open-end drum, rather than a closed-head drum, may be used for wastes containing solids or semi solids; and
- ☐ Hazardous wastes may be shipped in used packaging that has not been reconditioned but is in good condition.

Manifest Requirements

The manifest system was established by RCRA to ensure that hazardous wastes designated for delivery to offsite treatment, storage and disposal (TSD) facilities actually reach their destination. Hazardous waste management in the United States covers hazardous wastes from cradle to grave. A **manifest** is a *form that contains information about the specific hazardous waste and accompanies a shipment from generation point to ultimate destination*. Like DOT shipping papers, manifests provide information about the nature of the shipment than can be used by emergency response personnel when accidents or incidents occur. The only significant difference between a manifest and a DOT shipping paper is that a manifest lists the EPA identification numbers of the generator, transporter, and designated facility. The DOT regulations specify that an EPA manifest may be used in place of a DOT shipping paper.

Generators are responsible for originating and signing manifest forms. They must also obtain the signature of the transporter, retain one copy of the form for their records, and give the remaining copies to the transporter.

Record Keeping and Recording

Generators are required by the EPA to keep a copy of each signed manifest for 3 years whether or not a signed copy is returned to the generator by the designated TSD facility. Records of all test results, waste analyses, and so on as well as copies of all reports submitted to the EPA must also be kept for at least 3 years.

Biennial reports must be submitted to the EPA by all generators who ship their wastes offsite. The report describes all shipments initiated by the generator during a given time period. In addition, if a generator does not receive a signed copy of a manifest from the designated TSD facility within 45 days of

the date the waste was accepted by the initial transporter, an exception record must be filed with the EPA. Exception reports help the EPA determine whether a waste has been properly disposed of. This kind of arrangement in the movement of hazardous wastes would ensure that trans-national movement of hazardous wastes adhered to accepted principles of managing such wastes.

Regulations Governing Transportation of Hazardous Wastes

Both the EPA and DOT also regulate transporters of hazardous wastes. The relations applicable to transporters include notification requirements, manifest requirements, rules governing record keeping, and cleanup regulations. Some states have developed their own permit and registration programs for transporters of hazardous wastes. This system of regulating transporters of hazardous wastes would also be useful if applied in trans-boundary movement of hazardous wastes.

Notification to Transport

All transporters of hazardous wastes are required to obtain an EPA identification number and to follow DOT regulations governing hazard communication. The DOT regulations prohibit all transporters from accepting hazardous materials that have not been properly identified, packaged, marked and labelled. Special requirements for leaking containers have been established by the DOT for each mode of Transport.

Generators are responsible for following DOT and EPA pre transport requirements. If a generator has not affixed the appropriate placard to a shipment, it must supply the transporter with the necessary placard and the transporter must affix it. Generators are responsible for placarding railcars, highway Varga tanks, intermodal tanks, and certain freight containers.

Manifest Requirements

The EPA regulations prohibit transporters from accepting hazardous waste shipments from a generator without a manifest. Transporters that accept manifested hazardous wastes are required to sign manifest, return a signed copy of the manifest to the generator, and ensure that the manifest accompanies the waste to its destination. When the shipment is delivered to the next transporter or designated facility, the initiating transporter must obtain a signature from the accepting transporter or the operator of the facility. A transporter is responsible for a hazardous waste shipment until the manifest is signed by a receiving

facility. If a hazardous waste shipment cannot be delivered to the designated facility the transporter must ask the generator for further instructions. Special requirements for bulk shipments by water and rail have been established.

Record Keeping

Transporters must keep a copy of each signed manifest or shipping papers used in place of manifests for bulk shipments for 3 years. This applies for shipments of hazardous wastes outside the United States, and would apply within developing countries as well.

Discharge and Clean-Up

A **discharge of hazardous waste** is defined as “*the accidental or intentional spilling, leaking, pumping, pouring, emitting, emptying, or dumping of hazardous wastes into or on any land of water*”. The EPA regulations require all transporters to take immediate action in the event of a discharge. Such action may include notifying local authorities or initiating interim measures such as diking an area to contain the wastes. The DOT immediate notification requirements for incidents involving hazardous materials are applicable to discharges of hazardous wastes. Notice is given by calling the National Response Centre, which is operated by the US Coast Guard. Both the EPA and DOT include provisions in their regulations authorising federal, state, or local government officials to permit the immediate removal of hazardous wastes by transporters who do not have EPA identification numbers and are without a manifest. The EPA has also exempted all persons involved in treatment or containment activities taken during an immediate response to the discharge of hazardous wastes on materials from requirements governing facility permits. After the emergency, all normal regulations for formal disposition of the wastes must be followed. The EPA has established a procedure for rapidly issuing identification numbers to emergency response personnel and to shippers or carriers who need to transport hazardous wastes following an unanticipated release. A provisional identification number may be obtained by telephoning the appropriate EPA regional office.

The EPA regulations require that transporters clean up all discharges that occur during transport and take any actions required by government officials for mitigating the effect of the discharge on human health or the environment. The DOT regulations do not contain a comparable provision for other hazardous materials.

Finally, DOT requirements for written incident of accident reports must be met. For discharges of hazardous wastes, transporters are required to attach a copy

of the manifest to the DOT reporting form and provide an estimate of the quantity of wastes removed from the scene. The name and address of the facility to which the wastes were taken, and the manner of disposition of any wastes that were not transported elsewhere.

Conclusions and Recommendations for Managing Trans-National Movement of Hazardous Wastes in Developing Countries

An increasing amount of hazardous waste is affecting human health and the environment, but *many developing countries do not have the expertise to manage the hazardous waste problem.* Governments often lack information about how much and what types of pollution are released, and what risk they pose to people and the environment.

All national environment protection plans should include targets for hazardous waste reduction. Programmes are needed to identify wastes and their potential effects, and to minimise them and treat them safely. They should be based on the “polluter pays” principle.

The priority should be to change industrial processes, and this includes setting targets for reducing the amount of hazardous waste produced per unit of manufacture. Governments should work with industry on campaigns to minimise hazardous wastes and on the reduction of other emissions. Industries have a critical role to play, and should promote cleaner production methods on a wide scale and ensure that their hazardous waste standards are not weaker in one country than in another. In this way, unnecessary trans-national movement of hazardous wastes will be minimised.

In an effort to curb this menace which if not checked will continue to cause suffering to millions of people in third world countries, it is suggested that certain steps and actions by governments and the international community be taken:

- ☐ Governments should immediately identify contaminated waste-disposal sites and populations at high risk, and take the necessary remedial measures, including cleaning up the sites.
- ☐ Governments should require and assist in the innovation by industry of cleaner production methods and of preventive and recycling technologies.
- ☐ Governments should encourage the phasing out of the processes that produce high risks because of hazardous waste.

- ❑ Governments should conduct environmental audits of existing industries to improve hazardous waste management.
- ❑ Governments should hold promulgate regulations that hold waste “generators” responsible for the environmentally sound disposal of the hazardous wastes they generate.
- ❑ Governments should establish public information programs and ensure that training programs are provided for industry and government workers on hazardous-waste issues, especially waste minimisation.
- ❑ Governments should promote the establishment of treatment centres for hazardous wastes, either at a national or regional level. Industry should treat, recycle, re-use and dispose of wastes at or close to the site where they are.
- ❑ Developed countries should promote the transfer of environmentally sound technologies and know-how on clean technologies and low-waste production methods to developing countries.

In an effort by the international community to address the movement of hazardous waste, the General Assembly of the United Nations made this pronouncement:

“In Section 1 of Resolution 44/2226 of 22 December 1989, the General Assembly requested each regional commission, within existing resources, to contribute to the prevention of the illegal traffic in toxic and dangerous products and its environmental and health implications. The Assembly also requested the regional commissions to interact among themselves and co-operate with the United Nations Environment Programme (UNEP), with a view to maintaining efficient and co-ordinated monitoring and assessment of the illegal traffic in toxic and dangerous products and wastes.”

It should also be recognised that part of the international movement of hazardous waste involves illegal shipments, often to developing countries. Governments should ban the export of hazardous wastes to countries that are not equipped to deal with those wastes in an environmentally sound way. They should see that hazardous waste shipments destined for recovery are handled by environmentally and economically sound recycling systems. Countries should create an alert system to detect illegal traffic in hazardous wastes.

Furthermore, it is important that the root cause of this problem is addressed. A good starting point would be to require that National Environmental Protection Plans include targets for hazardous waste reduction. This would ensure that there is nominal hazardous wastes produced and hence to deal with.

Overall Objectives of Most Countries in the Management of Hazardous Wastes

Within the framework of integrated life-cycle management, the overall objective should be to prevent, to the extent possible and minimise, the generation of hazardous wastes, as well as to manage those wastes in such a way that they do not cause harm to health and the environment.

Overall targets and Recommendations may be stated as follows:

- ❑ Minimising the generation of hazardous wastes as part of an overall integrated cleaner production approach; reducing trans-boundary movements of hazardous wastes; consistent with the environmentally sound and efficient management of those wastes, and ensuring that environmentally sound and efficient management of those assets and hazardous waste management options are pursued to the maximum extent possible. The transboundary movements that take place should be on environmental and economic grounds and based upon agreements between the States concerned;
- ❑ Ratification of the Basel Convention on the Control of Trans boundary Movements of Hazardous Wastes and their disposal and the expeditious elaboration of related protocols, such as the protocol on liability and compensation, mechanisms and guidelines to facilitate the implementation of the Basel Convention;
- ❑ Ratification and full implementation by the countries concerned of the Bamako Convention on the Ban on the Import into Africa and the Control of Transboundary movement of Hazardous Wastes within Africa and the expeditious elaboration of a protocol on liability and compensation:
- ❑ Elimination of the export of hazardous wastes to countries that, individually or through international agreements, prohibits the import of such wastes, such as, the contracting parties to the Bamako Convention, the Fourth Lome Convention or other relevant conventions, where such prohibition is provided for.

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CHAPTER 32

TRANSBOUNDARY MOVEMENT OF HAZARDOUS WASTE

Georges Ekosse

**Geology Department
University of Botswana
Private Bag 0022
Gaborone, Botswana**

**Phone: 267-3552524 Fax: 267-356591
E-mail: ekosseg@noka.ub.bw**

Transboundary Movement of Hazardous Waste

Introduction

This chapter discusses the different categories of hazardous wastes generated all over the world from a variety of industrial, agricultural, research and development processes, and from science and technology and military operations. It also considers the ways in which these materials cross political, social, cultural, environmental and geological boundaries. Legal and legislative aspects in the movement of hazardous wastes is incorporated in the paper.

The political, health, environmental and geochemical implications of transboundary movement of hazardous wastes is discussed and some ways of monitoring and controlling the migration and production of hazardous wastes are suggested. Particular reference is made for the storage, handling and disposal of hazardous wastes generated in laboratories.

Short-term and long-term measures to reduce and/or prevent the production and movement of hazardous waste materials are recommended. The roles to be played by government and inter-governmental agencies and non-governmental organisations (NGOs) in controlling and regulating the movement, reduction and production of hazardous wastes are highlighted. Training programmes for developing and industrialised nations are also suggested.

Generic Sources of Hazardous Waste

During the last few years, *there has been an ever increasing awareness on the problems of pollution and the need for environmental management of hazards and of pollution* (Silver and DeFries, 1990). The problems of pollution do vary greatly from one part of the globe to the other (Nkoma, 1995). It is very difficult to accurately determine the total quantity of hazardous wastes produced in the world. Specifically, it is accepted that the more developed countries (MDCs) generate more hazardous waste than the less developed countries (LDCs). The Environmental Protection Agency (EPA), United States of America (USA), estimates an annual production of 264 million tons of hazardous wastes in the US but the American Chemical Society (ACS) thinks the figure is grossly underestimated (Miller, 1992).

With the rapid advancement of technology, hazardous wastes are generated from a variety of industrial processes. Solid, liquid and gaseous hazardous wastes are derived from solvent usage operations (surface coating operations, dry cleaning, solvent decreasing, waste solvent reclaiming, graphic arts),

metallurgical industries (primary, secondary and miscellaneous metal production operations), synthetic organic chemical manufacturing industries (primary and secondary zinc, aluminium, copper processing, lead products, primary and secondary cells, steel foundries and copper smelting), chemical products industry (carbon black, synthetic fibres, synthetic rubber and plastics which are used in further manufacture), mineral products industry (cement production, coal beneficiation and conversion, glass and glass fibre manufacture, phosphate rock and taconite processing), wood products industry (conversion of logs to pulp, pulpboard, plywood, or related wood products), petroleum related industries (oil, gas and petrochemicals), and combustion sources.

The use of pesticides, herbicides and insecticides that are detrimental to the environment cannot be overemphasised. The testing of nuclear and chemical weapons also generate hazardous wastes of considerable proportions. Other factors which affect the production of hazardous wastes include ignorance, poverty, agriculture, poor planning and financial constraints.

Definition of Hazardous Waste

The EPA defines a **hazardous waste** as *any discarded chemical that can cause harm because it is flammable, unstable, corrosive or toxic* (Miller, 1992). This definition according to Miller, which is considered by environmentalists as a form of linguistic detoxication, is very narrow. Radioactive and municipal wastes are not included in the definition.

In an attempt to understand what a hazardous waste is, it makes more sense to clarify what a hazard portends. *A hazard is considered as a risk source capable of causing injury, disease, economic loss and environmental harm that may lead to the loss of plant and animal life.* Consequently, hazards could be classified according to their forms and environmental associations. Ten classes of hazards may be identified as follows:

- ❑ **Political hazards** result from political disputes leading to civil and international wars.
- ❑ **Cultural hazards** result from traditional practice such as ritual sacrifices in which animals are sacrificed and allowed to putrefy thereby releasing toxic gases into the atmosphere.
- ❑ **Social hazards** result from working and living conditions, smoking, drugs, drinking, criminal assault, poverty and unsafe sex leading to a variety of epidemiological diseases, sicknesses and deaths.
- ❑ **Industrial and municipal hazards** result from chemical wastes,

noise from machinery and accidents at work. Domestic and hospital wastes are also considered in this category. The consequences include burns, suffocation and asphyxiation, loss of hearing, loss of sight and deaths.

- ❑ **Electrical hazards** result from overhead powerlines, buried cables and electrical equipment that may pose a danger of electrocution or electric shock.
- ❑ **Safety hazards** result from the use of personal protective equipment (PPE) and heavy machinery increasing the risk of accidents by impairing the workers' hearing, vision and agility.
- ❑ **Biological and health hazards** result from widespread distribution of pollen dust and parasites, disease causing bacteria and viruses leading to transmissible diseases that are generally fatal.
- ❑ **Physical and geomorphological hazards** result from ionisation radiation, fires, floods, droughts, tornadoes, hurricanes and landslides. The consequences include loss of mass lives and property.
- ❑ **Geological hazards** result from karstification of terrains, degasification of lakes and maars, earthquakes and volcanic eruptions. In 1986, Lake Nyos and all animal life within a radius of 3km "died". A recent earthquake which occurred in Iran in May, 1997 left more than 3000 people dead and about 10 villages destroyed beyond recognition.
- ❑ **Chemical hazards** result from the use of hazardous substances, carcinogens, mutagens and teratogens. Their effects are very disastrous.

Classification of Hazardous Substances

Hazardous wastes could be classified according to their *chemical and/or physical characteristics* (acids, organic solvents), the *source of contamination* (organic sludges, washwaters), *constituents* (plastics, textiles) and *special wastes* (polychlorinated biphenyls, contaminated soils, soil spills) (Norwebb, 1995). All the wastes generated are characterised by chemical constitutions, irrespective of the state of matter (solid, liquid, gas and plasma) in which they exist. The EPA (1989) allows waste substances which are explosive, corrosive, flammable, ignitable, reactive or toxic to be considered as hazardous. A classification of hazardous wastes is discussed below, based on their chemical forms.

- ❑ **Explosives and unstable chemical substances** are hazardous substances such as pictrates and azides that can explode as a result of

heat, flame, shock or friction. Auto-ignitables could also be considered as unstable.

- ❑ **Flammables** are hazardous materials that include combustible liquids, flammable solids, flammable gases, hydrocarbons and solvents with low flash points that ignite very easily.
- ❑ **Corrosive and irritant substances** include concentrated inorganic acid and bases that have the ability to damage or destroy material and living tissue by direct chemical action.
- ❑ **Toxic substances** include mercuric compounds, carcinogenic, teratogenic and mutagenic substances. They are poisonous and can access living beings through the skin, eyes, ingestion and inhalation.
- ❑ **Reactive chemicals** such as Ammonia are those that if contaminated, can cause burns, poisoning, fire.
- ❑ **Radioactive substances** include Uranium and Thorium. They affect the reproductive systems of living organisms and could cause mutations in living cells.
- ❑ **Cryogenic substances** include liquid Nitrogen and Oxygen. They must be handled at extremely low temperatures. They have the tendency of destroying life, and increasing the chances of fire outbursts.

Boundaries

In order to understand the movement of hazardous wastes across boundaries, there is need to define what a boundary constitutes and what types of boundaries exist in practice.

Definition

The dictionary defines a **boundary** as *something that indicates the farthest limit, as of an area, border* (Collins English Dictionary 1992). In mathematics, boundaries are characterised by upper and lower limits, within which elements with like identity are delineated.

Types of Boundaries

There are several types of boundaries existing in nature: spiritual, cultural,

social, political, economic, professional, chemical, geological, and environmental, to mention a few.

(a) *Political Boundaries*

These are boundaries which define national, regional and continental territories.

(b) *Environmental Boundaries*

These are boundaries that define a given environmental system. There are many environmental systems and subsystems. The earth could be divided into atmospheric, lithospheric and hydrospheric systems. Some examples of subsystems of the hydrosphere will include *lacustrine, marine, and riverine*.

(c) *Geological Boundaries*

These are boundaries that define rock types (igneous, metamorphic and sedimentary rocks) occurring within a given geological formation. In the movement of hazardous wastes, sedimentary rocks such as sandstones and carbonates serve as reservoirs and are important because they are used as sealants in controlling and regulating the flow of hazardous materials from within the confinement zone.

Significance of Matter on the Boundary Concept

Matter exists in solid, liquid, gas and plasma states. These states could also be considered as boundaries of different forms of matter. Matter can be converted from one form to another. However, if matter of one state penetrates the zone of another, then it could be said to have crossed its boundary.

Although hazardous wastes exist in solid state, they mostly occur in liquid or gaseous states (Table 32.1), the liquid and gaseous forms are more mobile than the solid form of matter. While solids are good absorbers of liquid, liquids are also good absorbers of gases.

Table 32.1: Most Frequent State in which Hazardous Substances Occur in Nature

Serial Number	Class of Substance	Common State
1	Explosives	Liquid (mostly), Solid, Gas
2	Flammables	Liquid, Gas
3	Corrosives	Liquid
4	Toxic	Liquid (mostly), Solid, Gas
5	Reactive	Liquid
6	Radioactive	Solid, Liquid
7	Cryogenic	Liquid, Solid

Movement

Hazardous wastes can be displaced in any of the following ways: *artificial displacement, natural displacement and auto displacement.*

Artificial Displacement

Man being the primary generator of hazardous wastes is also the main agent displacing (moving) the wastes to risk-free or near risk-free environments. Before hazardous wastes are displaced from one location to another, they are decontaminated. The EPA has reference documents that deal with the treatment and disposal of hazardous wastes.

There is evidence of growing illegal shipments of hazardous wastes across international borders. Waste disposal companies in Most Developed Countries (MDC) rid their debris to Least Developed Countries (LDCs) where government officials who are poorly paid find it difficult to resist bribes (Miller, 1992). There are companies in the MDCs that specialise in the disposal of hazardous wastes. Most of the hazardous wastes generated in the MDCs and especially the United States are being disposed in LDC countries such as Mexico, the Caribbean countries (Miller, 1992) and Nigeria.

Natural Displacement

Nature plays a significant role in the displacement of hazardous wastes. Living organisms such as seabirds and seals that are contaminated with oil spills and other toxic substances play the role of pollutant carriers as they displace themselves.

Auto Displacement

Most wastes resulting from natural hazards, such as the upwelling of Lake Nyos in The Cameroon in 1986 resulting in carbon Dioxide degasification, displace themselves intra- and inter- environmentally.

Implications

There are a number of implications that arise in the handling and disposal of hazardous wastes. Among these implications, the political, health, environment and geochemical implications are addressed below.

Political Implications

There are more than 500 000 shipments of hazardous waste material each year in the US, of which 14 000 people displaced (Miller, 1992).

These acts have instigated concerned individuals to strongly *condemn waste sites locations, incinerators, landfills or treatment plants that are close to human habitation*. Other MDCs also produce a lot of hazardous wastes.

The story of the **Koko Toxic Wastes** exported from Europe to Nigeria is worth mentioning. It should be recalled that many drums of toxic wastes were exported from Europe to Nigeria in the late Eighties. The wastes were dumped at the backyard of a compound in a village located along the the Delta of River Niger. Several months later, the contents had eaten up the drums and spilled to the land, thereby creating very serious environmental pollution problems. Many people lost their lives and the health of several others grossly affected.

In Europe, the surface winds transport acid-producing chemicals to other countries. Countries like Sweden, Swtzerland, Austria, the Netherlands and Finland receive a lot of acid producing chemicals from other heavily industrialised countries such as Britain, France, Germany and Italy.

Most of the hazardous wastes produced by MDCs are dumped in LDCs. The MDCs use their economic and political powers to encourage the illegal trade. The illegal trade in disposing hazardous wastes is a multi-million dollar business venture. However, there is need for dissemination of information for education of the masses.

Health Implications

A lot of hazardous waste materials are considered to affect the health of human beings if not properly handled. A selected few cases of health implications are discussed.

Case cluster, case control and cohort studies to confirm whether substances are carcinogens, suspected carcinogens and questionable carcinogens carried out by epidemiologists and related health research personnel give a long list of runs from acetomethoxane which releases acrid smokes and fumes to zirconium sodium lactate that causes bronchiolar abscesses.

Low levels of lead in the bloodstream of children can damage the brains and central nervous system (CNS), affect the ability of Iron, Calcium and vitamin D absorption in the body, and also causes high blood pressure, partial loss of hearing, hyperactivity, irritability and behaviour problems. More than 16 000 children in the US die as a result of Lead poisoning (Miller, 1992). The Lead is picked from paints, drinking water, tetra ethyl lead fuel. Contaminated groundwater, food grown on contaminated soils, imported lead-containing glassware, ceramicware, precelin, and the burning of certain types of paers in wood stoves and fireplaces.

The **Second World War** left more than 41 million people dead (Weapons and Military Technology, 1991). The after-effects of the Atomic Bombs dropped on Hiroshima on 06 August 1945, and on Nagasaki on 09 August 1945, which killed about 3000 000 people, are still being felt today. Most deaths were the result of exposure to high levels of ionising radiation from neutrons emitted by chain reactions and by radioactive isotopes. Japanese children have been born deformed with less developed body systems. The military arsenals of the world possess explosive power which is equated to 952 000 Hiroshima-type bombs or 3 333 times all the explosives detonated during the Second World War (Miller, 1992).

The **Chernobyl Nuclear Reactor Disaster** which occurred in The Ukraine, then part of the USSR on 26 april 1986, is perhaps the most hit health problem of modern times. The **Explosion Reactor Four** at the Power Station released Caesium-137, Strontium-90, Plutonium-239, Plutonium-240 (Encyclopaedia of Russia, 1995) into the atmosphere and waters of The Ukraine, causing very

high air, land and water pollution levels compounded by pervasive radioactivity. More than 1.5 million were affected at the time with 10% irradiated by Iodine-131. Almost all the 700 000 workers sent to clean up the mess have increased illnesses and more than 250 000 of them dead. There are increasing cases of birth deformities, maternal and infant mortalities, and decline in life expectancy of adult males. Other parts of Eastern Europe is affected and the effects will continue to increase for the next 50 years at least.

Environmental Implications

Environmental implications that arise from transboundary movement of hazardous wastes include *Ozone Depletion, Acid Deposition and Oil Spillage*. The Ozone crisis is a sudden global emergency that must be critically addressed and each year, Ozone Depletion in the stratosphere seems to get worse. although the use of chlorofluorocarbons (CFCs), carbon tetrachloride, halons and 1,1,1-trichloroethane are on ban lists, their irreversible effects on the ozone layer is today very little. The MDCs account for about 85% of CFC production. The consequences of ozone depletion is similar to the AIDS virus (Miller, 1992). Other effects of ozone depletion include skin cancer, blindness, decrease in crop yield, reduction in growth of phytoplankton, economic loss resulting from the degradation of paints, plastics and polymer materials. There is increased global warming (Greenhouse Effect), and an increased and unpredictable global climate with increasing depletion of the gas.

Acid Deposition is a global problem and in the United States. It has an estimated damage of 10 billion dollars annually. Sulphur and Nitrogen gases and their acids resulting from the burning of coals and oils accumulate as acidic precipitates on the earth's surface. Effects of acid rain can be seen on statues and monuments. Buildings, metals and car finishes are damaged. Fish, aquatic plants and animals and micro-organisms in lakes, ponds, lagoons and streams are killed. Trees are weakened and killed and vegetable growth stunted. Toxic metals are leached from water pipes and conduits into drinking water. It provokes human respiratory diseases and leads to mature death.

During the Persian Gulf War, oil was released as an act of environmental terrorism. Oil slicks have been found to affect coastal and marine environments. Birds, sea otters, seals, whales, fish and many other organisms have been found coated with hydrocarbons. Such coatings affect the animal life and many of them die.

Geotechnical Implications

A number of geotechnical phenomena result from hazardous wastes generation and disposal: *subsurface water pollution, secondary porosity, accelerated*

karstification and false geochemical anomaly.

Deep-well injection, surface impoundments and landfills are some of the ways of disposing of hazardous waste materials. Waste spillage and leakage leach into groundwater. The corrosion of well pipe casings causes wastes to escape and contaminate subsurface waters through aquifers. Liners of hazardous waste landfills eventually leak. Storms and hurricanes could cause overflows. Volatiles evaporate into the atmosphere and are naturally recycled as surface and subsurface water contamination.

Secondary porosity is most common with sandstones, feldspathic arenites (arkoses) and conglomerates but could also affect carbonate minerals. The infiltration of hydrocarbonated wastes could lead to secondary porosity. Zuhair (1981) reported that secondary porosity is the result of dissolution of carbonate minerals, feldspars, and rock fragments and pellets. Detailed core description data on the visual redox boundaries and hydrostratigraphy constitute the foundation for geochemical investigations of contaminant migration from waste dumps (Bimal *et al*, 1989).

Acidic hazardous wastes could dissolve carbonates (limestones) and cause an accelerated karstification of terrains. Hydrocarbonated wastes have infiltrated certain strata giving false geochemical anomalies, and some prospecting companies have erroneously thought of discovering ore bodies and oil deposits.

Monitoring and Controlling

It is ascertained that source prevention and recycling are preferred over treatment and disposal of hazardous wastes. Institutions such as the National Academy of Sciences (NAS) in the US and environmentalists have suggested a waste prevention and waste reduction approach, gives the following options: *no production, recycle, detoxify, burn and hide.*

It is postulated that manufacturing institutions should manipulate processes to eliminate the production of hazardous waste. Governments of countries are encouraging manufacturing companies not to be involved in processes that produce hazardous wastes. It should be noted that alternative production technology is expensive and on-going research is yet to produce 100% finish products with little or no hazardous wastes occurring at any of the fabrication stages.

The EPA has estimated that with current technology, about 30% of hazardous wastes produced in the US can be recycled (Miller, 1992)., but unfortunately only 5% are presently being recycled, although most hazardous wastes can be converted to less hazardous substances through incineration, thermal, chemical

and physical processes.

Government officials are encouraged to visit disposal sites and carry out an on-the-spot assessment. Systematic sampling and laboratory analysis of groundwater for the organic and inorganic constituents currently regulated by EPA for unstable geochemical parameters such as pH, Eh, redox couples, alkalinity, specific conductance, temperature, major, minor and trace elements including contaminants are used to check investigations on contaminant migration in the aquifers below tailings dumps due to hazardous wastes disposal.

Legal Aspects

There are ever increasing problems associated with the disposal of hazardous waste, and government and inter-governmental agencies have set up legislations, regulations and acts relating to hazardous waste management. Not until regulatory bodies and acts are established, manufacturing companies continue to remain ruthless in the disposal of hazardous substances.

The Love canal Tragedy reported by Miller (1992) which occurred in the US is worth mentioning. In 1977, an estimated 220 000 tons of toxic and cancer-causing industrial chemical waste, buried in a suburb of Niagara Falls, New York, decades ago by the Hooker Chemicals and Plastic Corporation, surfaced. Informal health surveys by alarmed residents revealed an unusually high incidence of birth defects, miscarriages, assorted cancers, nerve, respiratory and kidney disorders, led to complaints which were ignored by local authorities. Claims of injuries ranging from persistent rashes and migraine headaches to cancers and severe mental retardation were advanced to the company for compensation. Eventually, through court battles, millions of dollars were paid to individuals and families, and as at 1990 the New York State was claiming 250 million dollars from the company. A direct court also ruled that the company pay for clean up costs.

In 1989, the United Kingdom Control of Substances Hazardous to Health (COSHH) was established. In the US, the Congress passed the Resource Conservation and Recovery Act (RCRA) in 1976 and was amended in 1984. These acts and regulations operate in a system that enables wastes to be traced at any stage of its production, treatment and disposal. The EPA and other national bodies in MDCs publish and revise technical documents and guidelines relating to waste reduction and disposal.

Most developing countries do not have binding legislative acts which discourage the appropriate disposal of hazardous wastes. However, hazardous waste management is of growing concern due to recent expansion of heavy chemical manufacturing, agro-industrial and mining activities. Presently most

LDCs are seeking assistance in the development of legislative and/or regulatory policies binding the disposal of hazardous waste. In Botswana, hazardous waste management falls within the Ministry of Health, the Ministry of Mineral Resources and Water Affairs, and the Ministry of Local Government and Housing. An integrated assessment of Hazardous Waste Management by WASH Projects (USA) is being carried out which provides a reference base for the National Conservation Strategy (NCS) and its reference group.

Recommendations

Due to the implications arising from hazardous waste management, The following recommendations are advanced:

- ❑ Governments, institutions and environmentally concerned organisations should emphasise on waste prevention and reduction. Manufacturers and users of hazardous waste are advised, encouraged and obliged to reduce their production and re-use as much as possible of the generated waste.
- ❑ Governments and intergovernmental agencies should be pressured by environmentally concerned NGOs and lobby groups to institutionalise training programmes embodying all aspects of hazardous waste management. These short courses (an example is the series of short courses in Pollution Control and Waste Management sponsored by the Commonwealth Secretariat at the University of Botswana for the Africa region), workshops and seminars/conferences should cover discussions and instructions on biology, chemistry and physics of hazardous materials, toxicology, industrial hygiene, rights and responsibilities of workers, monitoring equipment, hazard evaluation, site safety plan, standard operating procedures, engineering controls, personal protective equipment (PPE), medical programme, decontamination, legal and respiratory aspects, and emergencies. EIA should be used as a technological tool in determining the best practical environmental options in hazardous waste management.
- ❑ Hazardous waste information and reference centres should be set up in cities to educate citizens on its consequences. Universities and research institutions should prioritise their research efforts on ways of reducing and eventually eradicating the production of hazardous substances through alternative technologies. Journals on pollution and waste management should be made to proliferate. Publications should be made readily available covering all aspects of hazardous substances. An example of a journal dealing with hazardous waste is the Journal of Hazardous Materials, which covers the following areas:
 - 1 Properties of hazardous substances (toxicity, corrosiveness, flammability,

explosiveness, radioactivity, information data banks and dose-response relationships).

- 2 Safety and health hazards (manufacturing, processing, transport, storage, disposal, major hazards and hazardous installations).
 - 3 Legislation (international, national, and local codes of practice, threshold values, standards).
 - 4 Incidents (prevention, control, clean-up, communication, labelling, sources of information and assistance, case histories).
 - 5 Assessment (economic and general risk assessment, insurance, test methods, technical aspects of risk assessment of industrial hazards, reliability and consequence modelling, decision making in risk management).
- ☐ Mass-media educational campaigns should be promoted. Consumers need to be educated on the hazards associated with what they are buying.
 - ☐ Recycle or reuse at least 80% of selected types of hazardous wastes instead of burying or burning them. Tax breaks and economic incentives should be granted to organisations and firms that recycle/reuse hazardous wastes.

Conclusion

This chapter has addressed pertinent issues related to transboundary movement of hazardous wastes. It has attempted to define and classify hazardous waste. Also, the boundary concept was examined in the light of movement/migration of hazardous substances. The political, health, environmental and geochemical implications relating to hazardous waste management have been addressed. Countries, governments and institutions are advised on the implementation of legal/regulatory policies in minimising and, if possible, eradicating the production of hazardous waste. Some useful recommendations have been advanced in the management of hazardous waste.

It should, however, be noted that a chemical is declared guilty until proved otherwise by the people proposing to use or manufacture it. As custodians of Planet Earth, everyone has a moral obligation to hand it over to posterity in a better state than we found it. It is the responsibility of individuals, organisations and institutions to ensure Planet Earth's survival in an environmentally-sound state.

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CHAPTER 33

WASTE MANAGEMENT SERVICES IN BOTSWANA: Evolution of Problems, Perspectives and Responses

V T C Matsoga

**Department of Environmental Science
University of Botswana
Private Bag 0022
Gaborone, Botswana**

**Phone: 267-3552524 Fax: 267-356591
E-mail: matsogav@noka.ub.bw**

Waste Management Services in Botswana:

Evolution of Problems, Perspectives and Responses

Introduction

This chapter examines waste management services in Botswana. Since Botswana's Independence in 1966, until the early 80s, waste services received only lip service from the authorities.

The evolution of Botswana's waste management problems was characterised by the following aspects.

- ☐ No service was provided by the colonial administration;
- ☐ Lip service syndrome in the first years of independence;
- ☐ Lack or absence of service structures at both central and local levels for a long time;
- ☐ Perception of waste as a useless matter and only fit for disposal at far away places;
- ☐ Lack or deficiency of sufficient resources channelled into the service sector;
- ☐ Low ranking in priorities due to lack of political and higher administrative support;
- ☐ Lack of popular participation due to lack of official innovation vision;
- ☐ Absence of adequate legislative provision;
- ☐ Insensitivity to the Environment, in general, due to low environmental education; and
- ☐ Lack of training programmes to produce the required technical staff.

These problems gave rise to another cluster of problems, among them being:

- ☐ Unorganised services run by local authorities after inheriting virtually nothing from the central government(s);
- ☐ Wastes finding their way into ungazetted areas such as streams, dams, highways, pathways, fields and public spaces;

- ❑ Increasing volumes of wastes that could not be properly accommodated in the service system due to lack of vision; and
- ❑ Poor or lack of projection in waste production in response to changes in the political economy.

The eventual outcomes of the problems listed above continue to be experienced now and they include:

- ❑ There are now *a variety of waste streams to be dealt with* i.e. household, industrial, commercial, agricultural, institutional and gardens;
- ❑ The *amount of wastes now produced in the country and indeed other countries is fairly high*, requiring special programmes;
- ❑ The *disposal facilities are in deplorable conditions* because there was no initial environmentally friendly and sensitive planning due to lack of technical expertise; and
- ❑ There has been *lack of information compilation* on the service simply because of lack of sensitisation of the officers in charge.

One of the problems facing waste management is lack of a standard definition of waste that could appeal to the politicians, administrators, economists, technocrats and planners. As a result, the following *generalised scenario* presents itself:

- ❑ Politicians call for developments not knowing that they perhaps introduce various wastes;
- ❑ Economists cannot picture a situation where one wastes money on waste;
- ❑ Technocrats fail in their quest for a good service due to lack of support from the system; and
- ❑ Both physical and economic planners don't easily think of waste issues when they plan.

There appears to be no standard text book definition of 'WASTE'. Some sources define it as: *anything that has no value to anybody and only fit for discarding* (indicate source of definition). It should however, be that something can be valueless (have no value) to someone yet invaluable to another. It is in this spirit that the Chinese say that waste is something the value of which we have not yet assessed or appreciated (source). *The term waste is being used interchangeably with terms such as refuse, litter, garbage, trash, detritus, rubble, debris, dust, and useless matter. Many of these terms are subsets of waste.*

As the problems evolved and broadened, they encompassed everybody to the extent that a picture is shown of a hopeless situation. On the contrary, there have been steps taken to try and remedy the situation.

Intervention in Waste Problems in Botswana

In Botswana, the response has been in three main areas:

- ☐ Community sensitisation era;
- ☐ Refuse collection era; and
- ☐ An awakening era.

Community Sensitisation Era

The *Community Sensitisation Era* started in the early 1970s with the creation of Village Health Committees (VHC's) in 1973. This was the time when waste was addressed by the health personnel under what was then called Public Health, which is now called *Society Towards Community Health Principles*, especially in the areas of cleanliness. It was held strongly then that Cleanliness was next to Godliness. Even today the VHCs are still a force to reckon with in matters of waste management. The advantage with these committees is that they are part and parcel of the society whose attitude they want to change. They were and are still operating by making home visits in the village with the assistance of the family welfare educators.

Refuse Collection Era

The *Refuse Collection Era* brought in a concept of refuse collection whereby governmental officials urged people to collect waste and throw it far away. In the same era people were asked to dig pits in their homesteads and collect and dispose of the combustible waste in the same pits. There was no instruction on the non-combustible wastes. Consequently, the people used the pits for both wastes. This has created homesteads with many pits, making it problematic to build new huts or houses.

In the same era, Councils began the *refuse collection services* at a rudimentary level. There were disposal sites and only *dongas* and burrow pits could be used where found and where they were non-existent, waste was dumped indiscriminately in the field as long as it was "far away"; this idea was not taking care of the fact that far away is next to someone's home, cattle post, farm lands or development designated areas. This brought a chaotic situation in

the country.

In this era, waste service was done from a point of nuisance especially from the health point of view. Hence, it remained a service of collection more than a service of management. This was a traumatic era in the waste management chronology.

The Awakening Era

The Awakening Era started in the 1980s and continued into the late 1990s. In this era, the authorities experienced an unprecedented pressure from within and without. This pressure demanded some solution to the problems of waste. In fact, this was an exciting era and waste was seen by people as a problem from the health point of view. This era can easily be broken down in chronological sequences as follows:

- ❑ In the 1980s, there was mounting pressure from members of the community and the press. There were articles in the press that called for action from the authorities. Politicians, especially councillors, in selected local authorities started to sensitise the public and the council management imperative to do something on the control of wastes.
- ❑ In 1984, the government announced the *establishment of the Annual Keep Botswana Clean Day*. This day is tied to the World Environment Day. The latter falls on the 5th June and the former falls on the first Saturday after the 5th June. June was further declared the Environment month.
- ❑ In 1986, the government assembled a committee called *Interministerial Anti-Litter Sub-committee*. Its aim was *to co-ordinate waste collection services in the country and to advise council on new strategies to adopt to improve the service*. This committee worked since then until it organised the First International Waste Management Congress in 1993. Unfortunately, it has died a natural death due to other developments.
- ❑ In 1988, the government had to succumb to the ever *increasing calls for improvements and for the growing concern on the risks of ground water contamination due to the manner in which wastes were disposed*. There was made provision for logistics under LG 144 vote to buy refuse trucks and to fence refuse sites. At the same time, provision was made to develop landfill sites in urban areas.
- ❑ In 1989, there was started a *rigorous public campaign on waste management in the Central District*. This has proved successful and the programme is being replicated in other districts and towns. It involves cleanest competitions amongst villages and VHCs best choir

competitions. The programme has become so successful that there is no thinking of it being abandoned.

- ❑ In 1993, the First International Congress on Waste Management organised by the Anti Litter Committee took place. This congress attracted politicians, bureaucrats, technocrats as well as media personnel. It was at this congress that a resolution was made to the effect that *there should be a national policy on waste management*.
- ❑ During the same year (1993), the government *commissioned the first ever Waste Management Project*. The project was the first of its kind in Southern Africa. It was a joint venture between the Government of Botswana and the Federal Republic of Germany. The project was divided into two phases, one dealing with *data compilation plus some sensitisation work* and the other dealing with the *actual implementation* of some results from phase two. The end of these phases was scheduled for 1999.
- ❑ In 1995, there was the *Second International Waste Management Congress* which produced a 12 point blueprint in terms of recommendations and resolutions. These have since become point of reference in the project's operations.
- ❑ In 1996, the *government created a national waste management division to try and harness all waste management issues at both local and central levels in the government system*. In the same year, there was drafted the Waste Management Policy and Strategy. This document was still to undergo a lengthy consultation process. It was subsequently to be transformed into a Waste Management Act.
- ❑ In 1997, the *Third International Waste Management Congress* was scheduled for June, as part of the Environment Month.

During the span of time covering the two phases, a lot of work in community mobilisation was implemented. The outreach programme covered the parliamentarians in their caucus meetings, councillors in full council meetings, chiefs at *kgotla* meetings, communities at workshops and seminars. This has been given a boost through the production of waste videos. The project also introduced a good waste management hierarchy strategies which encouraged the participation of a wider cross section of the community since it was aimed at bringing about concepts of *reduction, refusal, reuse and recycling*. It is important to note that disposal method is part of this hierarchy. In Botswana, disposal of waste by landfill has been chosen as the appropriate method of final disposal. Standard national technical guidelines have already been made and are currently being used.

There was also organised *formal training* courses in waste management for staff in Councils who are engaged in the waste service. These courses produced the persons with the relevant skills and knowledge in waste management.

These chronological events are a good sign of response so far taken by the people of Botswana in an attempt to deal with waste management.

Conclusion

At the close of the 1990s Botswana was producing about 0.70 kg of waste per person per day. This automatically comes to 5,110 units of waste per year. The main problematic wastes continued to comprise cans, paper, plastic, scrap metal, used oil, clinical wastes and organic swill.

CHAPTER 34

A COMPARATIVE APPROACH TO LABORATORY WASTE MANAGEMENT

Georges Ekosse

Department of Geology
University of Botswana
Private Bag 0022
Gaborone, Botswana

Phone: 267-3552569 Fax: 267-3552784
E-mail: ekossege@noka.ub.bw

A Comparative Approach to Laboratory Waste Management

Introduction

This chapter reviews different types of laboratories and their specialised functions, and the classes of wastes generated from diverse sources. It further classifies the wastes into categories based on *comparative hazardous state: hazardous, less hazardous and non hazardous substances*. The roles played by laboratories in advancing science and technology for research and development is highlighted. The geographical distribution of laboratories is such that more than 85% of the sophisticated state-of-the-art laboratories are found in the More Developed Countries (MDCs).

Due to the trends of productivity and sustainability of research projects, it is evident that laboratories in MDCs generate more wastes than those in Less Developed Countries (LDCs). Economic constraints, government priorities, and lack of human resources account among many other factors for less waste production in laboratories of LDCs. On the other hand, lack of proper disposal equipment and implementation of technical knowledge are some of the disposal problems of laboratory wastes in LDCs countries.

The chapter makes recommendations for the need for standardisation of methods for different experimental techniques to assist in reducing the amount of laboratory wastes. *Government and intergovernmental agencies are encouraged to regulate, monitor and control the generation of laboratory wastes. Training programmes should be institutionalised on laboratory safety, and the storage, handling and proper disposal of laboratory wastes. Exchange of laboratory personnel and creation of network groups for laboratory waste management should be promoted.*

General

The ideas in this chapter were crystallised after having served as Principal Instructor of two short courses, during 1994 and 1995, in Laboratory Management Techniques for Middle Level Personnel of Teaching and Research Laboratories in the Southern Africa region held at the University of Botswana. In both courses, a strong component on Laboratory Waste Management was treated extensively.

Laboratory Waste Management is becoming an aspect of increasing concern to environmentalists, technicians, technologists, scientists, support staff and researchers who work in laboratories. Not until recently, most teaching and research laboratories in Africa were involved in bench-type wet chemical

analyses. But with the rapid rate of global technological advancement, African, Asian and South American countries are also drifting into the age of artificial intelligence applications (AIA) in laboratory analyses of the kind being presently experienced in European and North American countries.

Due to the availability of plentiful mineral resources (diamond, gold, copper, nickel, uranium), good government and sound economic policy, a few African countries such as Botswana and South Africa are able to boast of Laboratory Instrumentation Technology close to that which is presently applicable in developed countries. Their continental counterparts in West, Central and East Africa do appear, somewhat, to have equipment and instruments that are two or three generations behind those of developed countries.

In the more developed countries (MDCs), guidelines and standards have, in the main, been put in place, which set out *recommendations, general procedures and regulations designed to promote the safe disposal of laboratory waste*. These standards are strictly enforced by legislation. It is not usually the case with the less developed countries (LDCs). This chapter will look at the different types of laboratories and the waste generated from them. It will focus on *chemical and radioactive wastes and attempt to compare basic laboratory waste management in MDCs and LDCs*. Some useful recommendations are suggested in helping to improve laboratory waste management in LDCs.

Contemporary Laboratory Operations

Laboratory operations in MDCs such as France, USA and Japan are far more advanced than those in LDCs. One cannot discuss in depth laboratory waste management without considering *advances in instrumentation and equipment technology in various basic and applied sciences*. Advanced technology has highlighted the use of lasers in a number of investigative and applied research, especially in the area of molecular spectroscopy and surface enhance spectroscopy, ultra-short scales of observations and measurement of phenomena as well as enhancement of energy resolutions in molecular monolayer. Mass spectrometers, electron microscopes and X-ray diffractometers, to name a few, are currently crucial for scientific research and must be readily available.

Computer instrumentation has advanced enormously through the application of artificial intelligence (AI) in a analytical laboratory environment. Laboratory robotics are created as original devices to perform specific and generally invariant mechanical tasks (Insenhour et. al., 1989) such as automatic titration, sample collection and auto analyses in the laboratory. The use of AI is on the increase due partly to the availability of inexpensive microelectronics and microcomputer technologies.

While MDCs are already flourishing in the use of laboratory AI to cover a wide range of activities including analyses, maintenance, service and repair of equipment, laboratory waste and safety, the LDCs are unable to cope. In LDCs where technology is often a decade or two behind, there are a number of problems that have to be addressed related to laboratory safety and waste management (Ekosse and Nkoma, 1995). In MDCs, the complexity of waste generated calls for effective laboratory waste management programmes that are environmentally-friendly.

Types of Laboratories

It is useful to have an understanding of laboratory classification in order to examine specific issues affecting them. *Traditional classification of laboratories is based on types of analyses carried out, often referring to a subject or discipline.* Examples of such classification include acoustics, water quality, mineralogy, geochemistry, microbiology and virology laboratories. Ruy (1990) developed a model which classifies laboratories by their objectives and then process complexities. He developed a scheme for 5 classes of laboratories, and Ekosse and Nkoma (1995) suggested a sixth class. The six classes can be summarised as follows:

- ❑ **Basic Science Laboratory:** essentially involved with *research oriented towards primary discovery regardless of apparent application*, usually at bench scale & personally supervised by an individual;
- ❑ **The Invention Laboratory:** intended for the *invention of marketable products*. The facilities are similar to Applied Science Laboratories, but require more workers due to market pressure;
- ❑ **The Analysis Laboratory:** involved with assisting other types of laboratories. It is similar to Basic Science Laboratory, concerned with accuracy, truth and specific knowledge without assessing data and frequently using electronic equipment;
- ❑ **The Teaching Laboratory:** *student-oriented*, with lightly serviced bench space and area for preparation as well as technician office; and
- ❑ **The Product Quality Control and Quality Assurance Laboratory:** *mostly linked to industry*, serving specific needs and concerned with quality control and specifics set by bureau of standards.

The Invention, the Analysis and the Teaching Laboratory types are not common in LDCs. They are expensive to set up and maintain. Although the other types of laboratories may exist in LDCs, they are nagged with several problems ranging from laboratory analytical techniques, human resources and waste management.

Waste Generation

There are three main classes of waste generated in laboratories. These are:

- ☐ Used samples;
- ☐ Waste derived from analytical processes; and
- ☐ Old and dilapidated instruments/equipment that have outlived their usefulness.

The above three classes of laboratory waste could further be *classified according to their biological, chemical and/or physical characteristics*. All the wastes generated are characterised by chemical constitutions, irrespective of the state of matter (solid, liquid, gas and plasma) in which they exist.

Biological and Medical Waste

Biological and medical waste may be categorised into the following three classes:

- ☐ **Sharps:** this category of biological waste includes syringes with needles, broken glass, scalpel blades and Pasteur pipettes;
- ☐ **Non-infectious material:** waste paper, plastic and paper products; and
- ☐ **Infectious material:** sample remains, carcasses, used petri dishes, tissues, used gloves, culture bottles and various equipment.

Chemical Waste

The Environmental Protection Agency (EPA) allows chemical waste substances to be classified as *explosive, corrosive, flammable, ignitable, reactive* or *toxic*. To this end, laboratory chemical waste is discussed based on its chemical forms.

- ☐ **Explosives and unstable chemical substances** are hazardous substances, such as peroxides and azides, that can explode as a result of heat, flame, shock or friction. Auto-ignitables could also be considered as unstable.
- ☐ **Flammable substances** are hazardous materials that include combustible liquids, flammable solids, flammable gases, hydrocarbons and solvents with low flash points and easy ignition affinity.
- ☐ **Corrosive and irritant substances** include concentrated inorganic acids

and bases that have the ability to damage or destroy material and living tissue by direct chemical action.

- ❑ **Toxic substances** include mercury compounds, carcinogenic, teratogenic and mutagenic substances. They are poisonous and can access living beings through the skin, eyes, ingestion and inhalation.
- ❑ **Reactive chemicals**, such as chlorine and ammonia, are those substances which, if contaminated, can cause burns, poisoning, fire or explosion.
- ❑ **Cryogenic substances** include liquid nitrogen and oxygen. They must be handled at extremely low temperatures. They have the tendency of destroying life and increasing the chances of fire outbursts.

Radioactive Waste

Radioactive substances include Uranium and Thorium. They affect the reproductive system of living organisms. High level radioactive waste include spent fuel rod and an assortment of waste from commercial nuclear power plants and military/ballistic laboratories. The storage and disposal of radioactive waste is still subject to debate.

Handling and Disposal

Biological and Medical Waste

The Australian Standards (1991) specifies that all *infectious materials* shall be sterilised by autoclaving or by chemical disinfection and then disposed of by incineration. *Sharps* shall be collected in a rigid puncture proof container and incinerated at high temperatures. *Cultures and liquids* may be discarded into sewers after complying with pre-disposal treatment standards. Aerosols and cans have the tendency of exploding in incinerators and as such they should be surface disinfected before disposal. Infectious material shall be collected in a double layer, robust autoclavable plastic bag which is retained in a solid tray.

Chemical Waste

Laboratories are required to collect liquid and solid chemical waste including unused dangerous chemicals, toxic residues and contaminated waste, containers from which stoppers are stuck, containers of chemical which are no longer needed, and unlabelled/unidentifiable containers and package them in two layered shipment containers with vermiculite or bentonite filling the layer gap. The hazards of disposing chemical waste such as acids, cyanide compounds,

caustics with phosphorus and arsenic's are many. It is usually advisable to have a trained and qualified waste disposal chemist to do the job.

Some chemical waste can be neutralised to salts before disposal. This method of disposal requires scrubber, holding tanks and final treatment facility. Deep well disposal requires money, geological investigation and approval by authorities. Furnace type method uses very high temperatures usually due to the introduction of excessive amounts of oxygen and is subject to air pollution control. These methods are not acceptable on campuses and residential areas.

Laboratory Spillage

One of the most common form of waste in laboratories is *spillage*. Spillages occur when storage containers rupture due to overpressure, when there is inadequate shelving space, lack of guards on shelves, inappropriate handling (storage and transportation) of containers, analysts are distracted while performing experiments, when storage containers are old, and when chemicals have exceeded their storage/shelf lives.

In the management of spillage, there must be a *spill prevention and spill response programme in the laboratory*. Each laboratory should develop an informed plan which explains to personnel of hazards and resources for clean up, provides tactics and capabilities for response, and schedule and maintain training of staff. The type and amount of clean up equipment depends on the type of spillage. Personal protective clothing must be worn by staff before entering into the scene of spill. First aid information, information on packaging spill debris and waste disposal, as well as chemical risks (health, fire and reactive hazards) information should be readily available.

Solid spills are very easy to clean compared to liquid and gas spills. Solid spills form small packages, have a controlled flow and can be physically removed in the presence of less special equipment. Toxic dust such as mercury compounds require filtered vacuum cleaners and white phosphorus in water and wet sand. Mineral oil should be used to handle water-reactive chemicals. Hazardous liquid spills easily contaminate other areas, emit gases and vapours that are toxic, cause a greater slipping hazard than solid, and are not easy to remove mechanically from surface. With proper guidance, chemical neutralisation and absorption techniques can be used. Gas spills are very dangerous because they can easily explode and cause fire.

Radioactive Waste

Radioactive waste of short half life should be stored in a safe place and allowed to decay or dilute in order to attain background level activity. The

disposal of radioactive waste depends on its state: solid, liquid or gas.

Solid radioactive waste of high radiotoxicity shall be disposed off only with the consent of the Statutory Authority. Putrefiable solid waste should be placed in recommended plastic bags and kept in the freezer to prevent decomposition until decay of radioactive matter has been attained before it could be disposed off as an inactive material.

Low specific activity liquids which are miscible with water should be discharged into drains through sinks connected by continuous plumbing into the sewerage system. Drains used for the disposal of radioactive liquids should be well labelled. Volatile liquids, liquids that are immiscible with water and high specific activity liquids shall be collected in labelled glasses. Organic liquid waste should be collected in separate containers from inorganic, aqueous waste. Glass vials are preferred for plastic vials because organic solvents do not tend to diffuse through them.

In cases where delay tanks are used to collect liquid effluent before discharge to the drains, mixing and dilution of contents of individual tanks must be carried out before sampling. Tank contents should not be discharged into the drains until measurements comply with Statutory Authority regulations. Monitoring of radionuclides in laboratories could be achieved by sampling the effluent, evaporating to dryness and measuring the residue using a conventional counting device.

All *radioactive gaseous waste* shall be diluted, filtered or treated at the point of discharge so that the quantities comply with all the necessary regulations. Currently radioactive wastes are disposed in the Arctic and Antarctica, neutron bombardment, and sea bed disposal.

Military/Ballistic Waste

Waste derived from ballistic laboratories are biological, chemical or radioactive in nature. Used bombs, cartridges and explosive chemicals must be handled with caution. Information on military/ballistic waste is classified and cannot be easily accessed. There have been many accidents in both MDCs and LDC resulting from improper disposal of military/ballistic waste from laboratories and test sites.

Comparative Approach

More Developed Countries

All types of laboratories exist in MDCs and have the lead in quality and

for the exchange of ideas not only in Laboratory Waste Management, but other aspects of Science Laboratory Technology. Such a forum should be a network of technologists and technicians, which should be affiliated to overseas institutions such as the Institute of Science and technology in Britain that provides similar services.

Presently, a number of fellowships and grants that support exchange of scholars, researchers and lecturers exist. The technical cadre should equally be given opportunities to benefit from exchange grants whereby participation should involve both LDCs and MDCs.

Running of specialised short courses in various aspects of Science Laboratory Technology including Laboratory Waste Management should be promoted by donor agencies and international institutions. Workshops and conferences should be organised regularly to bring together experts in various fields (Ekosse and Nkoma, 1995).

Economic Aspects

Appropriate Laboratory Waste disposal is expensive. People who are satisfied with their jobs are least likely to cause accidents than those who are not. Good housekeeping incorporating appropriate waste management, and very encouraging incentives are necessary parameters that must be addressed. In MDCs, laboratory workers are well paid especially those with the Private Sector. In LDCs, laboratory technicians and technologists are exposed to hazards resulting from very poor working environments. They are faced with challenges of improvising, using old equipment, at times outdated chemicals and reagents (Ekosse and Nkoma, 1995). An equal remuneration is lacking and as such the mind of the worker is not fixed on his/her daily tasks. There is no job satisfaction and accidents are caused, leading to the generation of undesirably more waste which will call for its proper disposal.

Governments of LDCs should increase their financial obligations to the training of more scientists and technicians. This is an imperative step for research and development in Africa. Likewise, laboratory waste management funds should be augmented. If these measures are implemented, laboratory working conditions will become more conducive, less laboratory accidents and disasters will occur coupled with substantive waste reduction.

Conclusion

The Laboratory head shall assume responsibility for ensuring that the laboratory wastes are safely collected, identified, stored and disposed of, and shall advise

personnel on any special facilities and procedures required for waste disposal. Waste disposal equipment should be properly handled and maintained. Emergency equipment for combating spillage must be in working form at all times. All laboratory waste shall be disposed off in accordance with municipal, state, health and local government regulations. All laboratory waste should be disposed off by highly trained individuals under strict supervision.

Not until recently, laboratory waste management was not an issue of concern in LDCs. Environmentalists are having a growing concern regarding the disposal of laboratory waste. In this chapter, an attempt has been made in classifying laboratories based on their instrumentation.

CHAPTER 35

MANAGEMENT OF EFFLUENT AND SLUDGE FROM TREATMENT SYSTEMS

Yvonne Gotlop Bogatsu

**Department of Environmental Science
University of Botswana
Private Bag 0022
Gaborone, Botswana**

**Phone: 267-3552524 Fax: 267-356591
E-mail: gotlopyk@noka.ub.bw**

Management of Effluent and Sludge from Treatment Systems

Introduction

The type of effluent and sludge produced in developing countries especially in rural centres is known to be primarily of sewage characteristics. On the contrary the ongoing bloom of industrial development and technological advancement alters the composition of effluent in most developing countries. As such, the common practice of using combined wastewater treatment should be capable of treating wastewater which contains not only typical bacteria and chemical constituents but also complicated organic substances and heavy metals. Sludge from these systems is no longer the stabilised harmless sludge but is a hazardous type that requires proper disposal or treatment prior to reuse.

In the past, limited attention has been given to processes of treatment, handling, disposal and reuse of effluent and sludge especially in developing countries. *The aim of this chapter is to address methods used to handle effluent as well as sludge in the developing world, and to suggest ways of improving these practices.* While the constituents of these wastes vary due to changes in agricultural practices, industrial development and even changes in types of domestic wastes, the process of handling these pollutant loads has not improved, especially in less developed countries.

Reuse of effluent and sludge becomes a necessity as water demands exceed the available resources, and as such an improved quality effluent should be produced. Sludge is not only a by-product of wastewater treatment processes but even potable water treatment produces sludge. This sludge also requires to be dried, reused, or disposed of in an environmentally sound way. *As a reuse application, sludge could be used in place of chemicals in agricultural practices as soil conditioner and fertiliser, but even that exercise requires use of stabilised 'good' quality sludge.*

General

The word management is used in the environmental field to denote treatment, control through monitoring and legislation, and assessment to protect the environment from pollution and disposal or reuse. Effluent and sludge comprise water and solid matter out-flowing from domestic, institutional or industrial facilities. This may be in the form of treated wastewater from treatment plants, grey water in instances where it is not mixed with sewage water, effluent from potable water treatment plants, and industrial effluent. Grey water which usually comes from kitchen and bath water is usually allowed to directly soak away

into soil unless it is reused. In some instances it may be treated separately in lagoons to reduce treatment costs in conventional treatment plants

This chapter focuses on assessing management of effluent and sludge from various treatment facilities. Limited work has been done in this area particularly in the Africa region. Most of the previous work in developing countries focuses on aspects dealing with potable water systems, partly due to the scarcity and inadequate techniques of managing all types of water. This is demonstrated by the series of papers written on water in order to curb the way for water supply programmes, to mention but a few: WASH (1981), Snowy mountains Engineering, Swedish Geological International AB, WLP (1991), Gieske and Gould (1994). Since priority is given to water supply to meet the needs of the communities, only scarce attention has been paid to managing the wastes that emanate from such supplies.

Effluent Handling

Effluent describes any water outflowing from a facility, and its handling depends on the type of effluent being dealt with. For instance the way potable water effluent is handled varies from the handling of wastewater effluent. The general processes involve treatment, disposal, and possible reuse.

The methods applied in handling effluent from potable water treatment plants include among others, *lagooning, deep well injection, and recycling*. Effluent from these plants is usually 'reject' water, water which is used to backwash filters, and water used to flash clarifiers herein termed 'flashwater'.

The developing world has adopted a simpler combined approach for wastewater treatment, this is also used in some developed countries. *This method is applied in sewered systems and it involves combining treatment of industrial, institutional and domestic wastewater.* In this process wastewater from all these facilities is collected by the same sewer line and treated at a central plant. For unsewered centres such as rural locations on-site treatment is applied. This kind of treatment involves use of pit latrines, septic tanks or stabilisation ponds at the site where the wastewater is generated.

Water Treatment Plant Effluent

Effluent from drinking water treatment plants (WTP) is not of sewage nature. It is virtually less polluted in the sense that it is either back-wash-water, used to wash filters or flash-water which removes settled coagulated material from clarifiers. WTPs may also produce reject water in the form of brine from such plants as desalination plants. The only contaminants in that water would tend to be constituents which were initially in the water prior to treatment, algae, and

chemical substances which were used to treat that water.

Due to its characteristics it is much easier to manage effluent from drinking water treatment plants. Brine from such water treatment processes may be disposed of through injection into deep wells where these wells penetrate brackish groundwater (McGee, 1991). It may also be allowed to flow into saline surface water sources such as oceans. The general trend in developing countries such as Botswana is to dispose of this effluent in lagoons or into natural streams. For instance reject water from a desalination plant in south west Botswana is channelled to a lagoon which is not fenced or secluded from access by human or animals.

It is quite important to properly design a WTP so that effluent from such a plant does not contaminate the very water which is being extracted. Such effluent may be lagooned provided the water does not pose hazardous threats to health and to the environment. In instances where the water is lagooned, it should be allowed to evaporate after which the salt may be disposed of as solid waste. The lagoon should be fenced or isolated to prevent harmful effects on health. Filter backwash water may be recycled in the water treatment plant. For instance in some areas of Botswana it is recycled to the raw water intake point where it is blended with the raw water.

Effluent from Wastewater Treatment Plants

The most appropriate and common wastewater treatment method is the use of stabilisation ponds. Ponds seem to suit developing countries because they do not require complex technology: they are easy to manage, and they are less expensive. There is also the advantage of long, warm climates which provide an optimum environment needed by micro-organisms which function in stabilisation pond treatment. One of the disadvantages is the inevitable occupation of a lot of land which could be a drawback in certain developing countries. Another setback is the potential inability to handle shock loads especially if waste contains highly toxic and chemical substances. Other treatment methods used include conventional treatment plants such as activated sludge plants, biological filtration treatment systems and the like.

Typically, effluent from these treatment systems is disposed of in streams or it forms its own channel to flow along. This effluent may replenish water resources, or it may be used for such purposes as irrigation, construction, or even for recreation. Some countries such as Namibia recycle effluent for drinking purposes. That is quite a giant step considering the extent of monitoring and treatment required, the human perception factors that has to deal with, all in all, where water is scarce reuse of effluent should be emphasised.

Problems of Pollution from Effluent

Effluent from treatment plants be it potable or wastewater, should not deteriorate the quality of receiving water or pollute the environment. In developing countries this seems to be an unforeseen achievement. There has been serious pollution of groundwater from effluent seeping from latrines in a village in south east Botswana. This has resulted in high nitrate contamination and some of the boreholes were closed as a result. In an attempt to alleviate the contamination to groundwater, a special type of VIP latrine was introduced whereby the entire pit becomes sealed with concrete lining, and the vacuum tankers are utilised to desludge the system. Another alternative which was used was to provide sewer lines to connect the whole village to the sewage ponds.

Poor management of effluent results in pollution of the environment, and eventually becomes a health hazard. A wide range of factors contribute to inadequate management of effluent, particularly in developing countries. Among others, insufficient resources, lack of environmental awareness such as consequences of pollution. Lack of specialised human resources lead to use of unskilled labour to manage treatment systems. At times insufficient financial resources also result in use of the least expensive yet inefficient method of treatment.

Environmentally unsafe reuse practices may result in disastrous pollution of the environment. Eutrophication of lakes and dams may occur as polluted effluent recharges surface water sources.

It is quite necessary to set up an efficient system of monitoring effluent, in a way, this will reduce costs incurred in treating potable water polluted by effluent. This is carried out through assessing effluent quality from wastewater treatment plants. The process also involves monitoring the efficiency of water treatment, the methods used for disposal of effluent. Monitoring can be carried out through physical investigations, water quality testing, and recommendations for mitigating pollution caused by effluent.

An example of effluent monitoring is carried out in Botswana by government agencies. Although this only applies to effluent from wastewater systems, these agencies carry out inspections and they also assess wastewater treatment facilities in the country, and suggests ways of reducing pollution from these source where such effluent causes pollution.

Possibilities of Reusing Wastewater

The very fact that effluent enters channels implies replenishment of both surface and underground water sources. Good quality effluent allows continuity of flow

in streams and provides aquatic life with water and nutrients. The reuse of wastewater is a necessity for developing countries such as Botswana. As emphasised by Gotlop (1995) such factors as water scarcity, increasing water demands, and depletion of groundwater prompts the need to reuse water. Examples of such sources as the Notwane River in Botswana, Molatedi Dam in South Africa benefit from treated effluent. The Notwane, for instance, is known to be ephemeral, but due to replenishment from effluent it has become perennial from the point of discharge and downstream onwards. As indicated in TABLE 35.1 quite a sizeable amount of effluent flows from Gaborone sewage works into the Notwane River.

Effluent may also be used for agricultural purposes, for example in Lobatse, Botswana, treated wastewater is used for fodder crop watering.

Urban Centre	1990	1995	2000
A	14 475	23 513	35 543
B	5 010	7 308	11 493
C	4 393	5 837	8 058
D	3 224	3 903	4 704
E	1 261	1 625	2 049

Table 35.1: Estimated flows for treated wastewater effluent from urban centres of Botswana

Sludge Handling

Sludge from treatment facilities may be that from industrial plants such as slaughter houses, from wastewater treatment plants or from drinking water treatment facilities. In wastewater treatment, sludge is the largest of the by-products of the components removed by treatment (Tchobanoglous, 1992). Water treatment plants produce sludge in the form of waste from coagulation processes. The constituents of this sludge are usually organic wastes, flocculant matter consisting of chemicals used for coagulation.

Techniques of Handling Sludge

Techniques for handling sludge includes drying it then discarding it, reusing it

or incinerating it. Industrial waste sludge from meat industries is typically dumped or used for soil conditioning. For instance in Botswana sludge from abattoirs and piggeries is used as soil conditioner and fertiliser material. An example of such use is at Botswana Meat Commission, where dung and paunch contents are used as soil conditioner and fertiliser (German Technological Co-operation and the National Conservation Strategy, 1995). Another good example of sludge treatment is practised in Swaziland at Conco plant. At this plant waste sludge produced during wastewater treatment is further treated prior to disposal at the solid waste site.

Ideal methods of dealing with sludge from wastewater treatment processes include thickening and stabilisation. By the time sludge leaves ponds it is already at the stabilised stage, however, further stabilisation may be carried out to reduce odours and pathogens. The most common procedure for dealing with sludge from wastewater stabilisation ponds or other wastewater treatment facilities is to treat it in drying beds. In some instances untreated sludge has been dumped indiscriminately in the open or at waste dump sites. Sewage sludge in itself is not harmful to the environment, it in fact provides the necessary nutrients and organic material for the soil and plants. It becomes harmful when sludge contaminates land and water resources. *Sludge from combined wastewater treatment systems is likely to contain high levels of industrial pollutants such as heavy metals, persistent agro-chemicals and other similar substances.* As such care must be taken in handling such sludge. This implies the need to not only test water resources for pollution but also scrutinise possible pollution from sludge or soils which contain sludge.

Sludge from potable water treatment plants may be in the form of flocs which settle at the bottom of clarifying tanks during coagulation processes during water treatment. This sludge may contain organic matter such as algae, flocs of particulate matter, chemicals such as lime slurry, soda-ash, alum chlorine and other chemicals used in water treatment. If such sludge reaches sewer systems it may complicate and inhibit processes in sewage treatment. Waste sludge from water treatment systems may be lagooned for evaporation, then after being dried it may be discarded as solid waste. Depending on the liquid content drying beds may be used, sludge may then be reused or disposed of.

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Pollution Control & Waste Management in Developing Countries

Edited by

Rogers W'O Okot-Uma, Georges Ekosse, Yvonne Gotlop Bogatsu,
Kwesi Darkoh, and Otlogetswe Totolo

Pollution Control and Waste Management in Developing Countries represents a comprehensive, practical perspective of environmental management with focus on pollution control and waste management, including hazardous waste. It is the result of several years of sharing of the lessons of experience and best practices during regional seminars conducted within the Africa region under the auspices of the Commonwealth Secretariat. Air pollution, coastal and marine pollution and waste management in respect of domestic, industrial and mining waste, biomedical waste and nuclear and radioactive waste, treated from the purview of real examples, provide the reader with a set of varied and various experiences for pollution control and waste management. Solid waste reuse and recycling, wastewater treatment, bio-remediation, microbiological assessment and monitoring of environmental pollutants, as well as a comparative approach to laboratory waste management are a rich source of pollution control methodologies. Sociological perceptions and attitudes in pollution control, and waste management, an articulation of best practices for the realisation of a distributed waste management network, and expositions on transnational movement of hazardous waste all endow the book with a well balanced characteristic. The book will be of tremendous benefit to policy-makers, non-governmental organisations, intergovernmental organisations, university and research institutions as well as concerned citizens.



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