CHAPTER 32

TRANSBOUNDARY MOVEMENT OF HAZARDOUS WASTE

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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 benefication 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 chemicalwastes,

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.

- **Cyrogenic 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 selants 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, liqiud, 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 abcesses.

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 degration 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 conglemerates but could also affect carbonate minerals. The infiltration of hydrocarbonated wastes could lead to secondary porosity. Zuhair (1981) reported that secondry porosity is the result of dissolution of carbonate minerals, felspars, 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 karsification 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 prevenion 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 shouls 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 persistant 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 Wadte Manangement 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), medial 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 reserach 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 (toxity, 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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