

# **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](mailto: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 an 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.