

Poor Medical Waste Management (MWM) Practices and Its Risks to Human Health and the Environment: A Literature Review

Babanyara Y. Y., Ibrahim D. B., Garba T., Bogoro A. G., Abubakar, M. Y.

Abstract—Medical care is vital for our life, health and well-being. But the waste generated from medical activities can be hazardous, toxic and even lethal because of their high potential for diseases transmission. The hazardous and toxic parts of waste from healthcare establishments comprising infectious, medical and radioactive material as well as sharps constitute a grave risks to mankind and the environment, if these are not properly treated / disposed or are allowed to be mixed with other municipal waste. In Nigeria, practical information on this aspect is inadequate and research on the public health implications of poor management of medical wastes is few and limited in scope. Findings drawn from Literature particularly in the third world countries highlights financial problems, lack of awareness of risks involved in MWM, lack of appropriate legislation and lack of specialized MWM staff. The paper recommends how MWM practices can be improved in medical facilities.

Keywords—Environmental pollution, infectious, management, medical waste, public health.

I. INTRODUCTION

It is ironic that the healthcare delivery system, which is established to provide treatment and safeguard the health of the people against illnesses, becomes a source of infection and means of spreading diseases in the process of healthcare delivery. Healthcare institutions/facilities generate different types of infectious and/or hazardous medical waste that poses enormous risk to patients, healthcare providers, waste pickers, and the community at large, if their disposal is not comprehensively and scientifically managed [1], [2].

It is well known, that hospitals, clinics, nursing homes, laboratories, veterinary clinics and many more establishments have to dispose of waste materials that have been generated in the process of medical care and treatment. Medical wastes (MW) constitute a larger portion of infectious wastes, which are potentially dangerous, because they may be resistant to treatment and possess high pathogenicity or ability to cause disease [3]. Medical waste is also a source of contamination of land and water sources if not rendered harmless before its burial on land or disposal in water. Furthermore, medical waste emits harmful gases, which leads to atmospheric

pollution, when treated in open burning or burning in incinerators. These emissions can cause respiratory and skin diseases or even cancer, if precautionary protocols are ignored [4].

Over the decade, the growth of the medical sector around the world combined with an increase in the use of disposable medical products has contributed to the large amount of medical waste generated [5]. As such, poor medical waste management causes environmental pollution, unpleasant smell, growth and multiplication of insects, rodents and worms, and may lead to transmission of diseases like typhoid, cholera, and hepatitis through injuries from sharps contaminated with blood [6], [7].

In developing countries such as Nigeria, where health concern are competing with limited resources medical wastes have not received sufficient attention and the priority it deserves [8], [9]. Hazardous and medical wastes are still handled and disposed- off together with domestic wastes, thus creating a great health risk to municipal workers, the public, and the environment [10], [11], [9]. The proper collection and disposal of this waste is of great importance as it can directly and indirectly impact the health risks to both public and the environment. Unfortunately, practical information on this important aspect of healthcare management in Nigeria is inadequate and research on the public health implications of poor management of healthcare wastes are few and limited in scope [8], [6], [5].

In view of all the above, this study is motivated and focused on the following:

- a. Risk associated with poor handling of medical waste,
- b. Current practices pertaining the management of medical waste in Nigeria and
- c. Current technologies to safeguard the environment and the health of the community.

Other countries of the world are mentioned for comparative purposes or just as example. The findings will help Planners, healthcare institutions and policy makers in making decisions in Nigeria.

II. SOURCES OF MEDICAL WASTE

The main sources of medical waste are hospitals and other healthcare facilities (dispensary, outpatient departments and offices, facilities for blood transfusion or dialysis, emergency team, autopsy facilities), as well as laboratories and research institutes [12], with the proliferation of blood borne diseases, more attention is being focused on the issue of infectious

Y.Y Babanyara is with the Urban and Regional Planning Program, Abubakar Tafawa Balewa University, Bauchi, Nigeria (phone +23423747882; e-mail: yybabanyara@gmail.com).

D.B Ibrahim and Tijjani Garba are with the Environmental Management Technology Program, A.T. B. University, Bauchi, Nigeria.

A. G Bogoro and M.Y Abubakar are with the Urban and Regional Planning Program, A.T. B. University, Bauchi, Nigeria.

medical waste and its disposal [13]. Health care institutions must be aware of the potential risk in handling infectious waste, and adhere to the highest standards of disposal and transport. Education of the staff, patients and community about the management of the infectious waste is crucial in today's health care arena.

III. TYPES OF MEDICAL WASTE

Reference [14] documents that; there are two types of Medical Waste (Fig. 1, from [15]).

- Non-hazardous or non-risk waste; approximately 75-90% of the waste generated in healthcare establishment is non-hazardous. This includes waste comprising of food remnants, paper cartons, fruit peels, packaging materials etc.
- Hazardous or risk medical waste; the remaining 10-25% of medical waste is hazardous and can be injurious to humans or animals and deleterious to the environment.

It is important to note that if both these types are mixed together then the whole waste becomes harmful (see Fig 1).

Furthermore, the hospital wastewater requires special treatment because water can contain pathogenic micro-organisms, chemical substances and pharmaceutical preparations, as well as radioactive isotopes.

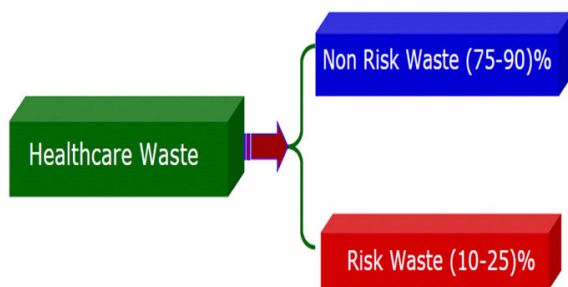


Fig. 1 Type of Medical Wastes [15], [14]

IV. CATEGORIES OR CLASSIFICATION OF HAZARDOUS MEDICAL WASTE

According to [16], [17], and [15] health-care waste is classified as Sharp waste (e.g., hypodermic needles, scalpels etc.), Chemical waste (e.g., reagents, solvent etc.), Pathological waste (e.g., human tissues, body parts, fetus, etc.), Infectious waste (e.g., blood and body fluids etc.), Pressurized containers (e.g., gas cylinders, aerosol etc.), Pharmaceutical waste (e.g. out-dated medications, etc.), Genotoxic waste (e.g., cytotoxic drugs and genotoxic chemical) and Waste with high heavy metal content (e.g., batteries, thermometers etc.) (See Fig. 2):



Fig. 2 Categories of hazardous medical waste [15]

V. POTENTIAL RISKS ASSOCIATED WITH MEDICAL WASTE

It has been established that, worldwide, about 5.2 million people (including 4 million children) die each year from waste related diseases [18]. The hazards of exposure to hospital waste can range from gastro-enteric, respiratory, and skin infections to more deadly diseases such as HIV/AIDS, and Hepatitis [1], [2]. Additionally, Medical waste contains potentially harmful micro-organisms which can infect hospital patients, health-care workers and the general public. Other potential infectious risks may include the spread of drug-resistant micro-organisms from health-care establishments into the environment.

Waste and by-products can also cause injuries, for example:

- Radiation burns;
- sharps-inflicted injuries;
- Poisoning and pollution through the release of pharmaceutical products, in particular, antibiotics and cytotoxic drugs;
- Poisoning and pollution through waste water; and
- Poisoning and pollution by toxic elements or compounds, such as mercury or dioxins that are released during incineration.



Fig. 3 Risk at a Dump Site in KwaraState Nigeria [20]

VI. SHARPS

World Health Organization [19] opined that globally; injections with contaminated syringes caused 21 million hepatitis B infections (32% of all new infections), 2 million hepatitis C infections (40% of all new infections) and 260,000 HIV infections (5% of all new infections). Furthermore, [1] document that, in India, 2 million, new Hepatitis B, 400,000 Hepatitis C and 30,000 HIV positive cases occur in a year due to needle prick injuries.

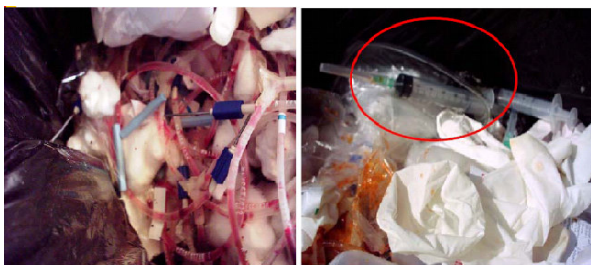


Fig. 4 Examples of hazardous Waste [2], [20]

More specifically medical waste has a high potential of carrying micro-organisms that can infect people who are exposed to it, as well as the community at large if it is not properly disposed of [21]. Many of these infections were avoidable if the syringes had been disposed of safely. The re-use of disposable syringes and needles for injections is particularly common in certain African, Asian and Central and Eastern European countries.

In developing countries, additional hazards occur from scavenging at waste disposal sites and the manual sorting of hazardous waste from health-care establishments.



Fig. 5 Medical Waste Scavenging in Bangladesh [15]

These practices are common in many regions of the world. The waste handlers are at immediate risk of needle-stick injuries and exposure to toxic or infectious materials.

A. Vaccine Waste

In June 2000 six children were diagnosed with a mild form of smallpox (vaccinia virus) after having played with glass ampoules containing expired smallpox vaccine at a garbage

dump in Vladivostok (Russia). Although the infections were not life-threatening, the vaccine ampoules should have been treated before being discarded.

B. Radioactive Waste

The use of radiation sources in medical and other applications is widespread throughout the world. Occasionally, the public is exposed to radioactive waste, which originates from radiotherapy treatment, which has not been disposed of properly. Serious accidents have been documented in Brazil in 1988 (where four people died and 28 had serious radiation burns), Mexico and Morocco in 1983, Algeria in 1978 and Mexico in 1962.

Risks associated with other types of health-care waste, in particular blood waste and chemicals, may be significant but have not been fully assessed. In the meantime, precautionary measures should be taken.

VII. RISKS ASSOCIATED WITH WASTE DISPOSAL

Although treatment and disposal of health-care waste reduces risks, indirect health risks may occur through the release of toxic pollutants into the environment through treatment or disposal.

A. Landfills

Landfills can contaminate drinking-water if they are not properly constructed. Occupational risks exist at disposal facilities that are not well designed, run, or maintained.

B. Incineration

Incineration of waste has been widely practiced but inadequate incineration or the incineration of unsuitable materials results in the release of pollutants into the air and of ash residue. Incinerated materials containing chlorine can generate dioxins and furans, which are human carcinogens and have been associated with a range of adverse health effects. Incineration of heavy metals or materials with high metal content (in particular lead, mercury and cadmium) can lead to the spread of toxic metals in the environment.

Dioxins, furans and metals are persistent and bio-accumulate in the environment. Materials containing chlorine or metal should therefore not be incinerated.

C. Occupational Health Hazards

Occupational health concerns exist for janitorial and laundry workers, nurses, emergency medical personnel, and refuse workers. Injuries from sharps and exposure to harmful chemical waste and radioactive waste also cause health hazards to employees in institutions generating bio-medical waste.

Proper management of waste can solve the problem of occupational hazards to a large extent [22].

D. Hazards to the General Public

The general public's health can also be adversely affected by bio-medical waste. Improper practices such as dumping of bio-medical waste in municipal dustbins, open spaces, water bodies etc., leads to the spread of diseases. Emissions from

incinerators and open burning also lead to exposure to harmful gases which can cause cancer and respiratory diseases [23], [24].

Plastic waste can choke animals, which scavenge on openly dumped waste. Injuries from sharps are common feature-affecting animals. Harmful chemicals such as dioxins and furans can cause serious health hazards to animals and birds. Certain heavy metals can affect the reproductive health of the animals [25].

VIII. MICRO-ORGANISMS ASSOCIATED WITH HEALTH CARE WASTE

The following groups of persons are at the risk of health care waste Medical staff: doctors, nurses, sanitary staff and hospital maintenance personnel; In and out-patients receiving treatment in healthcare facilities as well as their visitors. Workers in support services linked to healthcare facilities such as laundries, waste handling and transportation services; Workers in waste disposal facilities and the general public. Presence of various microorganisms such as pathogenic viruses and bacteria have been investigated by both cultivation and by (RT)-PCR assays. A number of (opportunistic) pathogenic bacteria, including *Pseudomonas* spp., *Lactobacillus* spp., *Staphylococcus* spp., *Micrococcus* spp., *Kocuria* spp., *Brevibacillus* spp., *Microbacterium oxydans*, and *Propionibacterium acnes*, were identified and reported from the various medical wastes. In addition, pathogenic viruses such as noroviruses and hepatitis B virus have been also detected in human tissue wastes. Commonly identified bacterial and viral pathogens such as *Pseudomonas* spp., *Corynebacterium diphtheriae*, *Escherichia coli*, *Staphylococcus* spp., and respiratory syncytial virus (RSV) have been reported to be part of the medical wastes. Medical waste should be carefully controlled and monitored to prevent nosocomial infection associated with the exposure to these wastes [26].

Health service waste gives rise to controversy regarding its importance for human, animal and environmental health [26]. Occurrences of clinically relevant bacteria in piles of health service waste in a sanitary landfill and their antimicrobial susceptibility profile have been previously studied by [26]. Reference [26] reported that aliquots of leachate from health care waste in Brazil contained pathogenic strains of *Staphylococcus* sp, Gram-negative rods of the *Enterobacteriaceae* family and non-fermenters.

Bacterial resistance to all the antimicrobials tested was observed in all microbial groups, including resistance to more than one drug. This makes it possible to suggest that viable bacteria in health service waste represent risks to human and animal health. Furthermore, occurrences of multi-resistant strains support the hypothesis that health service waste acts as a reservoir for resistance markers, with an environmental impact. The lack of regional legislation concerning segregation, treatment and final disposal of waste may expose different populations to risks of transmission of infectious diseases associated with multi-resistant microorganisms.

TABLE I
MICROBIAL DISEASES ASSOCIATED WITH HEALTH CARE WASTE [27]

MICROBIAL GROUP TYPE OF DISEASE CAUSED	
Bacterial	Tetanus, gas gangrene and other wound infection, anthrax, cholera, other diarrhea diseases, enteric fever, shigellosis, plague etc.
Viral	Various Hepatitis, Poliomyelitis, HIV-infections, HBV, TB, STD rabies etc.
Parasitic	Amoebiasis, Giardiasis, Ascariasis, Ancylostomiasis, Taeniasis, Echinococcosis, Malaria, Leishmaniasis, Filariasis etc.
Fungal infections	Various fungal infections like Candidiasis, Cryptococcoses, Coccidiomycosis etc.

IX. WASTE MANAGEMENT: REASONS FOR FAILURE

Lack of awareness about the health hazards related to health-care waste, inadequate training in proper waste management, absence of waste management and disposal systems, insufficient financial and human resources and the low priority given to the topic are the most common problems connected with health-care waste. Many countries either do not have appropriate regulations, or do not enforce them. An essential issue is the clear attribution of responsibility for the handling and disposal of waste. According to the 'polluter pays' principle, the responsibility lies with the waste producer, usually the health-care provider, or the establishment involved in related activities. To achieve the safe and sustainable management of health-care waste, financial analyses should include all the costs of disposal.

A. Steps towards Improvement of MWM

Improvements in health-care waste management rely on the following key elements:

- ❖ Building a comprehensive system, addressing responsibilities, resource allocation, handling and disposal. This is a long-term process, sustained by gradual improvements;
- ❖ Raising awareness of the risks related to health-care waste, and of safe and sound practices;
- ❖ Selecting safe and environmentally-friendly management options, to protect people from hazards when collecting, handling, storing, transporting, treating or disposing of waste.

Government commitment and support is needed for universal, long-term improvement, although immediate action can be taken locally.

X. DISPOSAL METHODS

Different methods are used for the disposal of bio medical waste and are discussed below:

A. Incineration

It is a controlled combustion process where waste is completely oxidized and harmful microorganisms present in it are destroyed under high temperature.

B. Autoclaving

Autoclaving is a low-heat thermal process where steam is brought into direct contact with waste in a controlled manner and for sufficient duration to disinfect the wastes. For ease and

safety in operation, the system should be horizontal type and exclusively designed for the treatment of medical waste. For optimum results, pre-vacuum based system is preferred against the gravity type system. It shall have tamper-proof control panel with efficient display and recording devices for critical parameters such as time, temperature, pressure, date and batch number etc [28], [29].

C. Microwaving

Microbial inactivation occurs as a result of the thermal effect of electromagnetic radiation spectrum lying between the frequencies 300 and 300,000 MHz Microwave heating is an inter-molecular heating process. The heating occurs inside the waste material in the presence of steam [30].

D. Hydroclaving

This is similar to autoclaving except that the waste is subjected to indirect heating by applying steam in the outer jacket. The waste is continuously tumbled in the chamber during the process.

E. Shredder

Shredding is a process by which waste are reshaped or cut into smaller pieces so as to make the wastes unrecognizable. It helps in prevention of reuse of bio-medical waste and also acts as identifier that the wastes have been disinfected and are safe to dispose of. A shredder is to be used for shredding in medical waste with minimum requirements [31]-[33].

XI. GLOBAL PERSPECTIVES OF THE HAZARDOUS MEDICAL MANAGEMENT

Environmentally sound management involves taking all practical steps to protect human health and the environment from hazardous wastes, like medical waste.

In an ideal world, this would mean reducing the generation of hazardous wastes to zero. In practice, environmentally sound management means strictly controlling the storage, transport, treatment, reuse, recycling, recovery and final disposal of wastes [34]. When segregated and properly managed, medical waste streams are usually very small in quantity [16]. In addition, most waste generated in the healthcare facilities can be treated as regular municipal solid waste except for a varying portion needing special attention such as sharps, pathological wastes, and other potentially infectious wastes, pharmaceutical, biological and hazardous chemical wastes, collectively known as "Special healthcare wastes" and requires proper packaging, storage, transportation and disposal [35]. The lack of segregation between hazardous and non-hazardous waste, an absence of rules and regulations applying to the collection of waste from the hospital wards and the on-site transport to a temporary storage location, a lack of proper waste treatment, disposal of hospital waste along with municipal garbage, insufficient training of personnel, insufficient personal protective equipment and lack of knowledge regarding the proper use of such equipment are among the problems highlighted in literature are prominent

factors contributing to poor medical waste management [36], [37].

In Africa, the situation of poor medical waste management is similar in South Africa, Mozambique, Swaziland, Kenya and Tanzania [38]-[41], [4]. Illegal dumping is a serious problem in most developing countries. Almost all the countries recognized poverty as a basic factor that dwarfed the success of African efforts in the area of environmentally sound management of hazardous waste.

An additional challenge was the state of the medical waste incinerators of the low operating temperatures (~200°C), resulting in excess generation of toxic gases like HCl, CO, co organics, dioxins and furans. Since the locations of these facilities (in hospitals) are usually located in very close proximity of communities, the emissions from the incinerators present a serious health risk to the same community which the hospital is meant to serve [4].

XII. NATIONAL PERSPECTIVE OF HEALTHCARE WASTE MANAGEMENT (HCWM)

Nigeria, like in most other developing countries, lacks specific strategy for HCW management and there is limited information on HCW management in the country [41]. Additionally, [8] in Nigeria noted that, health concerns are competing for limited resources, it is not surprising that the management of healthcare wastes has received less attention and the priority it deserves. Unfortunately, practical information on this important aspect of healthcare management is inadequate and research on the public health implications of inadequate management of healthcare wastes are few and limited in scope[8]. Although reliable records of the quantity and nature of healthcare wastes and the management techniques to adequately dispose of these wastes has remained a challenge in many developing countries of the world, it is believed that several hundreds of tons of healthcare waste are deposited openly in waste dumps and surrounding environments, often alongside with non-hazardous solid waste [42], [8].

A near total absence of institutional arrangements for HCW in Nigeria has been reported by others [6]. Various methodologies have been used all over the world to assess and quantify HCW. They include the use of physical observation, questionnaire administration and quantification [43]-[45], as well as checklists [46] and private and public records [6]. Recent studies in Nigeria has estimated waste generation of between 0.562 to 0.670 kg/bed/day [8] and as high as 1.68 kg/bed/day [8]. As reported in the literature, there may not be much of a difference in the way and manner wastes generated in various health care institutions are managed in Nigeria. A good example is given by the findings of the study in Lagos by Olubukola which reported the similarity in waste data and HCW management practices in two General hospitals, characterized by a lack of waste minimization or waste reduction strategies, poor waste segregation practices, lack of instructive posters on waste segregation and disposal of HCW with general waste [47]. The mismanagement of healthcare waste poses health risks to people and the environment by

contaminating the air, soil and water resources. Hospitals and healthcare units are supposed to safeguard the health of the community. However, healthcare wastes if not properly managed can pose an even greater threat than the original diseases themselves [48].

A study of Health Care Waste management in Jos Metropolis, Nigeria has demonstrated that the waste management options in the hospitals did not meet the standard practices [49]. Waste management with safe and environmentally sound methods cannot be over-emphasized. The hospital management board and the hospitals should make a conscious and deliberate effort to ensure they do not contribute to the present and future threats to human health and the environment by poor waste management practices. In order to execute standard waste management, an understudy of a healthcare establishment with standard waste management practices in or outside the country may be the first practical step to undertake [49]. A waste management team should be constituted which will prepare waste management plan, policy documents and technical guidelines and in addition supervise waste management activities [49].

In another study in Port-Harcourt metropolis, Nigeria carried out to assess hospitals waste management practice [50]. The study enquired into waste generation rates and various waste disposal options by different categories of hospital. It was further evident in this study that hospital waste management issues and problems are not peculiar to Port Harcourt metropolis alone. Solid waste disposal methods indicated that open dump sites is most preferred while incineration was nonexistent in the hospitals, clinics. Most other hospitals do not segregate wastes into marked or color coded containers for the different waste streams neither do they keep records of waste generation and disposal [50]. In addition, the survey revealed that both hospital waste generators and handlers treat hospital wastes as a usual domestic waste [50].

Therefore disposal of ashes containing toxic metals from Hospital waste incineration can be done through solidification-stabilization of fly and bottom ash with cement because it appears to be the best method to render ash less toxic. Similarly, the concentration of toxic heavy metals in the ash of hospital waste incinerator can be avoided to some extent through segregation of the waste prior to incineration. Lack of relevant training and protective equipment for waste handlers was a common feature in the survey. Generally, Port Harcourt, as a fast growing city in Nigeria, like most developing countries, lacked the infrastructure, as well as institutional capacity necessary to effectively manage medical wastes as part of the effort to enhance protection of human life and the environment from health hazards arising from improper management of hazardous waste [50].

It was further observed that open dump sites are not even engineered or treated, thus exposed the entire public to risks of infection. Reference [50] reported that except for the oil company clinics such as the SPDC, all the other hospitals sampled do not have any unit or department responsible for waste management. Knowledge, attitude and practices towards

environmental issues are relatively low among the various actors in the tasks of hospital waste management.

XIII. BENEFITS OF PROPER MEDICAL WASTE MANAGEMENT

- ❖ Minimizes the spread of infections & reduces the risk of accidental injury to staff, patients, visitors & the community,
- ❖ Reduces the likelihood of contamination of the soil or ground water with chemicals or micro-organisms,
- ❖ Attracts fewer insects and rodents and does not attract animals,
- ❖ Helps to provide an aesthetically pleasing atmosphere.

XIV. REVIEW OF EXISTING ENVIRONMENTAL LEGISLATIONS IN NIGERIA

At an international level, Nigeria has ratified the Basel Convention on the Control of Trans-boundary Movements of Hazardous Waste and their Disposal (1992). It is also a party to the Stockholm Convention on the Persistent Organic Pollutants (2002). Although currently there is no specific legislation, regulations or bye-laws for the management of health care waste in Nigeria, there are relevant laws and regulations pertaining to the protection of the environment and health:

A. Decree Number 58 of 1988

This establishes the Federal Environmental Protection Agency (FEPA) with: a) the responsibility to monitor and help enforce environmental protection measures; b) the duty to cooperate with Federal and State Ministries, Local Governmental Councils and research agencies on matters and facilities relating to environmental protection; c) the powers to establish standards, inspect, search, seize and arrest offenders.

B. Decree Number 42 of 1988 Harmful Waste (Special Criminal Provisions, etc)

Prohibits the carrying, depositing and dumping of harmful wastes (injurious, poisonous, toxic or noxious substance) and prescribes penalties for those found guilty of improper practices.

C. Decree Number 86 of 1992

It sets out the procedures and methods for impact assessments on both public and private projects and states that the "construction of incineration plants" requires an environmental assessment.

Three regulations dealing with environmental issues have been identified including:

D. National Effluent Limitation of 1991

This makes it mandatory for industrial facilities to install anti-pollution equipment and make provision for effluent treatment. It also prescribes maximum limits of effluent parameters allowed for discharge.

E. National Pollution Abatement in Industries and Facilities Generating Wastes of 1991

This imposes restrictions on the release of toxic substances and stipulates requirements for monitoring of pollution to ensure that permissible limits are not exceeded.

F. Management of Solid and Hazardous Wastes Regulation of 1991

Deals with facilities that generate solid and hazardous waste; It also covers hazardous waste treatment and disposal facilities and indicates requirements for such facilities including contingency planning, emergency procedures, and alike.

Despite all these laws no specific mention is made of MW, although a number of points can be applied to hazardous substances. This document could eventually serve as a basis for the National MW policy which must be prepared regarding MWM in Nigeria.

XV. CONCLUSION AND RECOMMENDATION

Nigeria will gain a lot from the battery of Public health benefits of Medical waste Management. It is still not well understood why Nigeria at its level of development, Medical Waste management is not well legislated and thus proper attention has not been given to it by Environmental regulators and Health Care operators. The issues are to be treated as urgent and very critical by Government. Immediate interventions are also required. All hands including the National Orientation Agencies and communities must be on deck to get over this challenge.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to Abubakar Tafawa Balewa University, Bauchi, and the Federal Government of Nigeria for financing this research through TET FUND.

REFERENCES

- [1] H.P, Rao, "Report: Hospital waste management- awareness and practices: a study of three states in India". *Waste Management & Research*, 2008, Vol.26, pp297-303.
- [2] Y. Y. Babanyara, "An assessment of medical waste management practice(s) of Ahmadubello university teaching hospital (ABUTH) Zaria, Nigeria." 2012.Unpublished M.Sc. Thesis. Abubakar Tafawa Balewa University, Bauchi, Nigeria.
- [3] A. Fayed, A. Q. Hani, and R. Atallah, "Sites investigation on medical waste management practices in northern Jordan". *Waste Management*. 2008, Vol. 28 450–458.
- [4] S. V. Manyele, "Effects of Improper Hospital Waste Management on Occupational Health and Safety", *African Newsletter on Occupational Health and Safety*, Vol.14 pp30-33.
- [5] J. J. Edmund, "Characterization and analysis of medical solid waste in Osun State, Nigeria" *African Journal of Environmental Science and Technology*. December 2012, Vol. 5(12), pp. 1027-1038.
- [6] A. Coker, and M. K. C. Sridhar, "Increase in healthcare facilities and rapid environmental degradation: A technological paradox in Nigeria's urban centers", *African Journal of Environmental Science and Technology*. September, 2010. Vol. 4(9), pp. 577-585.
- [7] S. Yitayel, A. Tamrat, and M. Adane, "Sharps injuries and exposure to blood and bloodstained body fluids involving medical waste handlers." *Waste management and Research*, 2012. Vol. 30, pp. 1299-1305.
- [8] S. O. Abahand E. I. Ohimain, "Healthcare waste management in Nigeria: A case study" *Journal of Public Health and Epidemiology* March, 2011, Vol. 3(3), pp. 99-110,
- [9] I. Ibijoke, A. Babajide, A. Williams and A.K, Rafid, "Profile of medical waste management in two healthcare facilities in Lagos, Nigeria" *Waste management and research*, 2013. Vol.31, pp494-501.
- [10] C. E. Silva, A. E. Hoppe M. M. Ravello, and N. Mello "Medical waste management in the south of Brazil" *Waste Management*, 2005, Vol. 25(6) pp. 600–605.
- [11] D. N. Ogbonna, A. Chindah, and N. Ubani, "Waste management options for health care wastes in Nigeria: A case study of Port Harcourt hospitals" *Journal of Public Health and Epidemiology*. June 2012 Vol. 4(6), pp.156-169
- [12] P. Palanisamy, S. Sivaraman, S. P. Babu, and A. Athimoolam, "Biomedical waste management for health care industry" *International Journal of Biological & Medical Research*.2011, Vol. 2(1) pp. 472-486
- [13] A. E. Toyobo, A. O. Baba, and A. B. Oyeniyi, "Appraisal of university teaching hospital medical waste management in Nigeria: Case Studies of University College Hospital (UCH) Ibadan and Obafemi Awolowo University Teaching Hospital (OAUTH) Ile-Ife". *Universal Journal of Education and General Studies*, September, 2012 Vol. 1(9) pp. 290-297.
- [14] E. Shinee, E. Gombojav, A. Nishimura, N. Hamajima, and K. Ito, "Healthcare waste management in the capital city of Mongolia", *Waste Management*, 2008 Vol. 28, 435–441.
- [15] C. Visvanathan, "Hazardous waste disposal Resources" *Conservation and Recycling*. 2006 Vol16, 201–212.
- [16] WHO, "Safe Management of Wastes from Health Care Activities", World Health Organization, 1999. Geneva. Switzerland.
- [17] WHO, "Management of Solid Health-Care Waste at Primary Health-Care Centers: A Decision-Making Guide" World Health Organization, 2005. Geneva. Switzerland.
- [18] N. Akter, "Medical Waste Management: A Review." Asian Institute of Technology y, 2000. Thailand.
- [19] WHO, "Safe health care-waste management policy paper. Available at, www.healthcarewaste.org. Accessed 20th March, 2012.
- [20] O. A. Mokuolu, "Health-care waste management, Microsoft power point presentation for HCWM-SQHN" Kwara state 2009, Nigeria.
- [21] S. V. Manyele, and H. Anicetus, "Management of medical waste in Tanzanian hospitals" *Tanzania Health Res. Bull*, 2006, Vol. 8(3) pp177-182.
- [22] A. D., Patil, and A.V., Shekdar, "Health-care waste management in India". *Journal of Environmental Management*, 2001.Vol. 63, pp. 211–220.
- [23] D. Manohar, P.R. Reddy, and B. Kotaih, "Characterization of solid waste of a super specialty hospital: a case study". *Ind. J. Environ. Health*, 1998, Vol. 40, pp. 319-326.
- [24] C. E. Da Silva, A.E. Hoppe, M. M. Ravello, and N. Mello, "Medical Wastes Management in the South of Brazil". *Waste Management*, Vol. 25, pp., 600–605.
- [25] A. Code, and J .Christen, "How are we managing our healthcare wastes?: St. Gallen,1999, Switzerland: SKAT.
- [26] T. C. Nascimento, W. A. Januzzi, M. Leonel, V. L. Silva, and C. G. Diniz, "Occurrence of clinically relevant bacteria in health service waste in a Brazilian sanitary landfill and antimicrobial susceptibility profile". *Rev. Soc. Bras. Med. Trop*. 2009, Vol., 42(4) pp., 60-79.
- [27] N. Akter and J. Trankler "An analysis of possible scenarios of medical waste management in Bangladesh". *Management of Environmental Quality: An International Journal*, Vol., 14 (2), pp., 242–255.
- [28] NEERI, "National Environmental Engineering Research Institute in Nagpur Comprehensive. Characterization of Municipal Solid Waste at Calcutta" 1995.
- [29] P. Baccini, and P. Brunner, "The Metabolism of the Anthroposphere," Springer Verlag, Berlin, 1991.
- [30] S. Pruthvish, D. Gopinath, R. M. Jayachandra, N. Girish, P. Bineesha, C. Shivaram, Health-Care Waste Management Cell, Department of Community Medicine, M. S. Ramaiah Medical College. Bangalore, India Information Learning Units for Health-Care Waste, 1998.
- [31] I. B. Singh and R.K. Sarma "Hospital wastes disposal system and Technology". *Journal of Academy of Hospital Administration*, July, 1996, Vol., 8(2), pp. 44-48.
- [32] S. Shah, M. Mehta, and M. D. Mukherjee, "Occupational Health Hazards Encountered at HealthCare Facility and Medical College in India" American Industrial Hygiene Association.2001.
- [33] S. Rasheed, S. Iqbal, and L. A. Baig, "Hospital wastes management in the teaching hospitals of Karachi" *Journal of Pakistan Medical Association*,2005, Vol., 55 (5), pp.192–195.

- [34] UNEP, (United Nations Environment Program) "Minimizing Hazardous Wastes": A Simplified Guide to the Basel Convention; France, 2000. GE 04-03062.
- [35] World Bank, "Health care waste management guidance note," 2000, Yale, New Haven Hospital and Yale University 1997. Risk Management handbook: www.yale.edu/sustainability/envreport.pdf, Retrieved on 30th September 2011.
- [36] S. V. Manyele, and T. J. Lyasenga, "Factors affecting medical waste management in low level health facilities in Tanzania" *African Journal of Environmental Science and Technology*, 2010, Vol. 4(5), pp.304-318.
- [37] S. V. Manyele, "Medical Waste Management in Tanzania: Current Situation and the Way Forward", *Afr. J. Environ. Assessment Manage. AJEAM*, <http://ajeam-ragee.sl-writers-series.org/>; 2004, Vol. 8, pp, 74-99.
- [38] L. Leonard, "Health Care Waste in Southern Africa", A civil society perspective. Proceeding International Health Care Waste Management Conference and Exhibition, Johannesburg, S. Africa. 2003.
- [39] S. V. Manyele, H. Anicetus and M. H. Bilia, "Globalization and its effects on Medical Waste Management in Tanzania. IET Annual Conference and General Meeting AICC Arusha", Tanzania, 2003.
- [40] S. V. Manyele, "Effects of Improper Hospital Waste Management on Occupational Health and Safety", *African Newsletter on Occupational Health and Safety*, 2004, Vol. 14, pp., 30-33.
- [41] E. O. Longe and A. Williams "A preliminary study on medical waste management in Lagos Metropolis Nigeria". *Iranian Journal of Environmental Health Sciences and Engineering*, 2006, Vol. 3(3), pp., 133-139.
- [42] B. A. Z. Alagoz, and G. Kocasoy, "Treatment and disposal alternatives for health-care wastes in developing countries- A case study in Istanbul, Turkey". *Waste Management and Research*, 2007, Vol. 25, pp., 83-89.
- [43] A. O. Coker, K. A. Sikiru, M. K. C. Sridhar, and A. Y. Sangodoyin, "Characterization and management of solid hospital wastes" In: Proceedings of the 25th Conference of Water, Engineering and Development Centre held at Addis Ababa, Ethiopia, 7-12 September, 1999, pp. 331-334.
- [44] M. A. Adegbita, S. O. Nwafor, A. Afon, A. A. Abegunde, and C. T. Bamise "Assessment of dental waste management in a Nigerian tertiary hospital" *Waste Management and Research*, 2010, Vol. 28, pp., 769-777.
- [45] B. O. Olubukola, "Comparative Analysis of Health Care Waste Management Practice in Two General Hospitals in Nigeria". Available at: www.ecoweb.com/edi/index.htm, Accessed, August 10, 2012.
- [46] K. T. Townend and C. R. Cheeseman, "Guidelines for the evaluation and assessment of the sustainable use of resources and of wastes management at healthcare facilities" *Waste Management and Research*, 2005, Vol. 23, pp., 398-408.
- [47] A. Coker, A. Sangodoyin, M. Sridhar, C. Booth, P. Olomolaiye, and F. Hammond "Medical waste management in Ibadan, Nigeria: Obstacle and prospects," *Waste management Journal*, 2009, Vol. 29, pp., 804-811.
- [48] PATH, "Achieving effective sharps waste management in GAVI host countries". A proposed approach with estimates of cost 2006 Available at: www.Path.org/files/TS_ach_eff_swm.pdf Accessed 6th April, 2012.
- [49] N. Ngwuluka, N. Ochekepe, Odumosu, P. and S. A. John, "Waste management in healthcare establishments within Jos Metropolis, Nigeria" *African Journal of Environmental Science and Technology*, 2009, Vol. 3 (12), pp., 459-465.
- [50] D. N. Ogbonna, "Characteristics and waste management practices of Medical wastes in healthcare institutions in Port Harcourt, Nigeria," *Journal of Soil Science and Environmental Management*, 2011, Vol. 2(5), pp., 132-141.