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The Management of Hazardous Waste in Developing Countries

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Abstract

This book chapter discusses the management of hazardous waste in developing countries, with particular emphasis on industrial hazardous waste, medical waste, and household hazardous waste. It seeks to identify the current situation and also aims to provide a review of the existing strategies that are particularly related to hazardous waste management. In developing countries, hazardous waste management systems lack a systematic approach to administer waste management programmes; inability to effectively collect and manage wastes as well as to reduce the negative impacts of those activities. The current regulatory frameworks and regulations do not adequately address hazardous waste treatment and final disposal. There are inadequacies in the implementation of regulations associated with hazardous waste management due to fragmented responsibilities among government departments and local authorities. The chapter provides practical best processes for the management of hazardous waste aimed at improving the current situation.

Keywords: hazardous waste, developing countries, recovery, recycling, disposal

1. Introduction

Wastes are classified as being hazardous when they display one or more radioactive or hazardous properties, including explosive, oxidizing, flammable, irritant, harmful, toxic, carcinogenic, as well as harmful effects on the environment and human health [1]. The relevant property or properties are determined by property testing or where applicable, concentration based criteria.

Hazardous wastes are materials which are discarded after use from e-products, vehicles, clinical and medical products, fuel products (e.g. oil), gas exploration and extraction. Scientific research indicates that these include materials such as industrial solvents, waste oils, industrial sludges and chemical wastes. Households, small businesses, farms, and the healthcare and construction sectors also generate quantities of hazardous waste including batteries, electrical equipment, healthcare risk waste, solvent based paint and varnish waste, sheep dip, and fluorescent lamps [2]. Hazardous waste not only poses risks to the surrounding air, water, and soil, but also do harm to the ecological environment and human health through diversified channels [3]. Developed countries (such as United States and some European Union members states) are the main producers of hazardous waste in the world [4]. The management of hazardous wastes is of great importance due to environmental health, social, and economic impacts. During the past two decades the world experienced a dramatic increase in the amount of hazardous waste generated [5]. In developing countries, the management of hazardous is exacerbated by lack of comprehensive legislation, unauthorized scrap yards dealing with e-waste, and end of life vehicles. Poor conduct and inappropriate disposal methods exercised during the handling and disposal of hazardous wastes are increasing significant health hazards and environmental pollution due to the harmful nature of the waste [6].

Past research studies [5, 6] have established that the key driver to hazardous waste management is the involvement of all the stakeholders including waste generators, regulators, decision makers, waste processors, and informal and formal sectors. These stakeholders have a crucial role in improving the system by ensuring the development and delivery of an effective and efficient hazardous waste management program. The aim of this book chapter is to describe the management of hazardous waste in developing countries, in terms of treatment, prevention of hazardous waste, and the best practices of hazardous waste management.

2. Definition and sources of hazardous waste

In recent decades, researchers have defined and classified hazardous waste as waste with inherent chemical and physical characteristics, such as toxicity, ignitability, corrosivity, carcinogenicity, or other properties [6]. Nevertheless, in developing countries there is insufficient definition and classification, which leads to difficulties in identifying the needs of treatment and disposal of hazardous waste. For instance, in China, hazardous waste has been classified into three types, household hazardous waste, industrial hazardous waste, and medical waste [7]. It has been established that in many developing countries, only industrial hazardous and medical waste are disposed separately [8]. Other hazardous waste type, such as household hazardous waste (HHW) are somewhat neglected. Thus, in the developing countries, there is limited classification carried out in terms of the composition, type, and purpose.

3. The current situation

In developing countries, the quantities of hazardous wastes has not been documented because these waste streams are incorrectly managed, thereby posing greater environmental impacts than reported. Based on the 2013 environmental statistics annual report released by the Ministry of Environmental Protection of China, it has been observed that the Chinese industries produced 31.57 million tons of hazardous wastes belonging to 49 types in 2013. Furthermore, 53.9% of these hazardous wastes is recycled and reused, while 22.2 % is treated and disposed, and 25.7% is stored [11]. Therefore, determining the accurate estimates of hazardous is not an easy task [6]. As a result, this waste stream may end up mixed with general domestic or commercial, or disposed of in an uncontrolled manner through burning, burying, or discharged to sewer, water, or ground surface. Currently, in developing countries there are limited options for generators of hazardous waste to manage it appropriately [8]. In some cases, there are no commercial hazardous waste collection services, retail take back systems and periodic drop-off services provided by the municipalities. In terms of responsibilities, developing countries have not designed and implemented producer responsibility for hazardous waste materials including human and farm animal medicines, waste oil, oil filters, paint and paint containers, pesticides and herbicides (household), ink and ink containers from publishing organizations [9]. In particular, there are no national take back schemes for unused or expired human medicines and e-products considering the widespread consumption of medicines and e-products. In addition, no pilot schemes have been carried out focusing on collection of hazardous waste such as plant protection product containers, unused or out-of-date animal health medicines and pesticides, waste oils, oil, filters, empty cartridges, aerosols, e-waste, paints, batteries, and other hazardous waste [10].

4. Legislation framework

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal is the most important regulatory framework for the management of hazardous waste. However, other developing countries such as China has adopted several regulations and standards based on the international safety standards in combination with the Chinese situation. These are developed in order for waste producers to:

- Minimize waste in fuel production and fuel cycles, materials classification and purification.
- Guarantee a high volume reduction [7].

Based on the previous scientific research, it has been established that in developing countries, the Basel Convention is not adequately implemented [8]. Consequently, hazardous waste from developed is still received by the developing countries. As noted by some scholars, some of the problems related to legislation in developing countries include: unambiguousness in waste classification due to the subsuming unspecific nature of the waste codes, and the liberty given to waste generators to choose their own names for the wastes they generate; potential over-

lapping of source-based and constituent-based waste codes [12]. Furthermore, there are no identification standards of ignitable and reactive characteristics for hazardous wastes [10]. Therefore, the present methods and standards continue to hamper and impede the development of sustainable management systems in the developing countries.

5. Treatment and disposal of hazardous waste

The treatment of hazardous waste should take place under regulated and controlled conditions [13]. Hazardous waste management includes the possession, transportation, handling, storage, and ultimate disposal of waste. However, in developing countries the treatment of hazardous waste takes place in unregulated or uncontrolled conditions, and in some cases hazardous waste are exported to developing countries by the developed countries [14]. It has been established that for most parts, hazardous wastes are treated in unlicensed facilities using conventional methods such as landfilling. The remainder of the waste stream is treated at authorized facilities with low technologies and low environmental standards [15]. These include incineration plants, landfills and oil recovery. An important fraction of hazardous wastes is still mixed with non-hazardous wastes, being mainly landfilled and producing serious environmental impacts regarding heavy metals and persistent organic pollutants content in landfill leachate, thus creating a great health risk to municipal workers, the public, and the environment. The main problems affecting the management of hazardous waste in developing countries include the following:

- Lack of necessary rules, plans, regulations, and instructions on different aspect of collections and disposal of waste.
- Lack of policy directions or incentives for existing local authority or private sector landfill operators.
- Inadequate Institutional capacities.
- Lack of hazardous waste prevention activities.
- Shipment of hazardous to developing countries from developed countries.
- Mixing of hazardous waste with domestic waste or commercial waste.
- Lack of collection facilities for hazardous waste.
- Failure to quantify the hazardous waste generated in reliable records.
- Existing environmental permits mostly fail to contribute to Best Available Technology (BAT).
- Not all regional environmental authorities register the generated waste types in the permit using waste classification codes.
- Information about waste production rates corresponding to the recorded waste generation is usually missing. The developing countries waste information system is not detailed

enough to gather information about concentrations of hazardous substances, only total mass.

- Lack of enforcement of and compliance with the existing regulations.
- Lack of priority sectors for prevention of hazardous waste.
- Lack of conformance with the best international practices on hazardous waste management.
- Inadequate infrastructure and self-sufficiency in hazardous waste management.
- Absence of dedicated waste managers and committees, as well as plans responsible for monitoring hazardous waste practices.
- Absence of dedicated national facilities.
- Lack of guidance, awareness, capacity building training on the management of sectoral hazardous waste management.
- Absence of specific policies dedicated to the management of hazardous household waste.

This suggests that integrated strategies for hazardous wastes recovery are needed in the developing country industry that may reduce the disposal rate of these wastes in communal landfills and impulse resource recovery and recycling of valuable materials of these wastes. Therefore, it is necessary to develop high technologies; promoting recovery and recycling centers and hazardous waste management strategies, which are environmentally, socially, economically, and technically feasible.

Doing so recognizes the proximity of best international practices to manage hazardous waste: maximizing the reuse, recycling, and recovery of potential materials, precious metals and where practical through the provision of a range of local treatment options; ensuring the availability of recovery and disposal outlets and stimulating green economy opportunities within nations.

Currently, many developing countries have no dedicated hazardous landfill disposal facilities. A few countries such as South Africa have hazardous landfill disposal facilities [16]. However, in many developing countries there are considerable challenges to develop hazardous waste landfills, including social acceptance, regulatory, technically skilled manpower, financial resources, limited technology or provision of such infrastructure. It is demonstrated that while landfill is the least favoured option on the waste hierarchy, it is recognized that for some non-recoverable or non-combustible hazardous wastes it will need to be considered [15].

Satisfactory infrastructure and monitoring of movement of hazardous waste are non-existent [17]. Indiscriminate disposal of solid waste materials such as e-waste, used oil, poses major environmental problems including the soil contamination and threat to animals. Hazardous wastes such as wastewater from healthcare facilities are often discharged into storm channels, which are not periodically cleaned. Monitoring of the health and environmental risks associated with these practices is not done due to the lack of technically skilled manpower, health and safety personnel.

Also, scientific, engineering, and organizational challenges, which need to be taken care, are indicated in **Table 1**. What is so worrying here is that the recycling base in the developing countries is very weak.

Engineering challenges	Scientific challenges	Organizational challenges
<ul style="list-style-type: none"> • Scientific collection, transportation, segregation, and disposal of hazardous waste • Practical techno-economical solutions <ul style="list-style-type: none"> ◦ Recycling ◦ Reuse ◦ Recovery 	<ul style="list-style-type: none"> • Value addition of recyclables for reuse • Disposal of process waste and residues • Eco-friendly recovery solution 	<ul style="list-style-type: none"> • Organization and structuring hazardous waste management system • Training and awareness

Table 1. Scientific, engineering and organizational challenges in developing countries.

5.1. Industrial hazardous waste

Industrial hazardous waste is defined as waste generated from industrial sectors and pose immediate danger to the environment and the public [17]. Industrial hazardous wastes are characterized in terms of toxicity (acute, chronic, and extrinsic), inflammability, reactivity, and corrosiveness. The main important sources of industrial hazardous wastes are mining, chemical, mechanical, pulp and paper industries, cement production facilities, wood remanufacturing facilities, etc. Important industrial hazardous wastes include used oil and oil contaminated materials, spent solvent [14]. Industries in developing countries such as Lebanon are estimated to generate 3000 to 15,000 tons/year of hazardous wastes due to deficient physical infrastructure and absence of environmental management plans, which will inevitably amplify environment impacts associated with industrial activities [18]. Nevertheless, there is limited data on the quantities of industrial hazardous waste, where is going, where it is generated and disposed of. However, due to the accelerated development of economies, mass manufacturing and processing industries and less strict standards on environmental quality assessment, the quantities of industrial hazardous waste (IHW) will continuously increase. Meanwhile, in developing countries it has been confirmed that an important fraction of hazardous waste is still mixed with non-hazardous wastes, mainly through landfilling, and producing serious environmental impacts regarding heavy metals and persistent organic pollutants content in landfill leachate [16]. Scientific research has observed that wastes are not separated in origin into hazardous and non-hazardous materials. Furthermore, non-hazardous are also not separated into recyclables, non-recyclables, and domiciliary. In fact, scientific research has found that developing countries lack regulations that specifically deal with industrial hazardous wastes. In addition, in the developing countries there are no hazardous waste management

plans and authorized facilities to manage, treat, and eliminate hazardous wastes. The separation of all the waste streams for possible waste reuse is not implemented in the developing countries. This suggests that there is an urgent need to establish policies geared towards stimulating industries, commerce and societies to manage hazardous waste in a sustainable manner; encouraging the shift from traditional waste management practices to “cradle-to-cradle”, and a reduction of the problem of management of hazardous wastes.

5.2. Medical waste

Medical waste is waste generated from health-related facilities such as hospitals, clinics, health centre, research institute, etc. [19, 20]. It contains toxic chemicals, heavy metals, and may contain substances that are genotoxic or radioactive, pathological waste, sharps (e.g. needles, syringes, scalpels, knives, broken glass, etc.), infectious waste, bulk human blood and blood products. Presently, in developing countries, there is no statistical data on medical waste. However, in most cases, the estimated quantities of medical waste are extrapolated using bed occupancy and number of beds in health institutions [16]. For instance, in Bangladesh, Dhaka City, it is reported that 37 ± 5 tonnes of medical waste is generated from hospitals, clinics, and other healthcare facilities [21]. However, scientific studies have shown that secure disposal of medical waste remains quite lower in several developing countries [22]. Meanwhile, significant fraction of medical waste is disposed as municipal solid waste (MSW) or discharged without monitoring and control; incineration is the only predominant formal way to treat medical waste. In addition, in developing countries, majority of the incineration facilities are not fully maintained and operational; use primitive technologies and simple equipment, which may consequently cause pollution [23].

5.3. Household hazardous waste

In the home, it has been pointed out that there are several jobs which generate hazardous waste because of the product used may contain hazardous substances. It has been confirmed that such products include paints, cleaners, stains and varnishes, car batteries, motor oil, and pesticides [13, 24]. As a result, the used leftover contents from such consumer products are known as household hazardous waste. Other HHW include e-waste. It is estimated that developing countries will discard 400-700 million obsolete computers by 2030. Most of the waste is sent to Africa or Asia under false pretences as donations from developed countries, especially Europe and the United States. Currently, in developing countries, it has been observed that a few national and local regulations have been developed and/or drafted for HHW management [25]. Due to the lax enforcement and monitoring, valuable hazardous wastes such as lead batteries, waste mineral oils, photographic chemical wastes, waste mercury lamps, and certain electronic waste containing heavy metals and printed circuit boards (PCBs) are improperly disposed of, thereby causing significant negative impacts on public health and the environment. Furthermore, in developing countries some HHW is almost managed as municipal solid waste [26]. The informal recyclers are the dominant sector recovering and recycling valuables. **Table 2** presents hazardous waste and country practice in developing countries. Most importantly, in developing countries, safe disposal methods of

hazardous wastes including incineration, landfilling, and special treatment (e.g. microwave, sterilization, etc.) are not well-founded. Thus, this inevitably accelerates pollution of HHW.

Waste	Practice						
	Equipment availability	Legal framework	Public awareness	Technology	Inventory	Separation of hazardous waste	Incentives or penalties
HHW	–	Nascent or non-existent	Lack of capacity and awareness	Low technology incineration	Lack of information on HHW	Unfriendly environmental collection, treatment and disposal system	Low incentives or penalties
Medical waste	–	No specific policy	Lack of capacity and awareness	Low technology incineration	Lack of information on medical waste	Inadequate collection, treatment and disposal system	Low incentives or penalties
Industrial hazardous waste	–	No specific policy	Lack of capacity and awareness	Low technology incineration	Lack of information on industrial waste	Comingled with MSW	Low incentives or penalties

Table 2. Hazardous wastes and country practice.

6. Prevention of hazardous waste

Scientific research studies have proven that in waste management, prevention is at the top of the hierarchy and represents the preferred policy approach to materials management and an alternative to reduce the wastage of materials or resources. As a result, it is substantiated that prevention of waste is preferable to its generation and to the monetary and environmental costs incurred as a result of its generation. It is proven that radioactive waste will continue to be a priority in order to achieve greater resource efficiency [27]. For this reason, an integrated approach should be adopted to design programs, and agencies to lead and coordinate a wide range of prevention initiatives to reduce the potential environmental and public health impacts [16]. These should include development of programs focusing on a number of strategic objectives in order to achieve the goal of prevention which will include the prevention of radioactive and hazardous wastes. This suggests that to reduce the public health and environmental impacts of radioactive and hazardous wastes, a range of regulations and innovative processes must be developed to control the content of these potentially hazardous and harmful substances.

7. Innovative processes used for treatment of hazardous wastes in developing countries

The negative environmental and public health impacts caused by hazardous wastes as well as the use of complex equipment, infrastructure, sophisticated controls, and dangerous processes have encouraged developing countries to develop innovative processes to treat these wastes. These innovative processes play a critical role in the final treatment of hazardous wastes, including the protection of the surrounding soil where these wastes are disposed of, and such technologies are cost-effective, easy to operate in the face of limited infrastructure, technical knowledge and expertise, and suitable for developing countries. One of these innovative processes is phytoremediation. Phytoremediation involves the planting of trees to prevent and repair environment from hazardous wastes, including restoration of degraded soil, and conservation. It is used in China, India, Pakistan, etc. However, scientific research has found that phytoremediation has limitation of long lasting and of low efficiency [28, 29]. Therefore, there is an urgent need for long lasting and high efficiency processes for the treatment of hazardous wastes.

8. Best practices of hazardous waste management in the world

It is important to note that policy makers, regulators, product producers, generators, and holders of hazardous waste need to play a critical role in ensuring that such materials are prevented, minimized, collected, and treated properly in accordance with the waste hierarchy or “cradle-to-cradle” [12, 29]. The best practices in managing radioactive and hazardous waste include the following:

- Adopting alternative strategies (e.g., physico-chemical treatment).
- Treatment with or without heat recovery. For instance, in Chile, used oil and spent solvents are used as raw materials for alternative fuels production [16].
- Making new regulations where necessary and appropriate.
- Ensuring that other government departments and public bodies fulfill their roles and responsibilities identified in hazardous waste management.
- Facilitating a two-way communication with sectoral and stakeholder interests.
- Municipalities fulfill their important role in providing small-scale collection services and generally raising awareness in hazardous waste management.
- Prevention: engaging with priority sectors on hazardous waste prevention waste activities through cleaner technologies and better compliance with regulation.
- Devising future new policies on the management of hazardous waste by also taking into consideration the generation rates of these types of wastes and potential savings from recovery of these wastes [30].

9. Conclusion

This book chapter discusses hazardous waste management in developing countries, with emphasis on industrial hazardous waste, medical waste, and household hazardous waste. It identifies the current situation on hazardous waste management. In developing countries there is lack of information on the quantities of hazardous waste generated, lack of capacity and awareness; low incentives or penalties; lack of clear roles and responsibilities for stakeholders; limited infrastructure; and inadequate institutional framework. Other challenges include: lack of technically skilled manpower, financial resources, know-how, testing facilities, and equipment; and the absence of an integrated framework regarding the monitoring and management of hazardous wastes. Also, inadequate collection, treatment and disposal system; and the lackadaisical response by the government makes it difficult for the local authorities to identify targets to be achieved either annually or strategically on a long term basis for solid waste management. For the successful implementation of best practices of hazardous waste management, there is an urgent need to consider the experiences of developed countries and this should be combined with the socio-economic context of the developing countries. Waste minimization through source reduction, reuse, and recycling has to be effectively implemented to decrease the amount of hazardous waste generated and disposed of. For this achievement, there is the need for a drastic reform of the current regulations in the developing countries.

10. Recommendations for developing countries towards hazardous waste management

The environmentally sound management of hazardous wastes is becoming a major concern in developing countries due to the diversity of the waste stream and toxic material within it, as well as the negative environmental and public health impacts caused. Hence, several practical recommendations are suggested which include the following:

- Creation of public awareness of the potential of recycling hazardous wastes.
- Source reduction.
- Capacity building and human resources development for hazardous wastes recycling.
- Monitoring and evaluation of hazardous wastes management systems as well a reporting programmes.
- Development of appropriate infrastructure, technical knowledge, and expertise.
- Strengthening and reforming existing regulatory frameworks.
- Development of decision support for identifying appropriate technologies for treatment of hazardous wastes.
- Provision of funding for identification of emerging best and state-of-the art technologies.
- Development of regional hazardous waste management system.

Conflict of interests

The authors declare that there is no conflict of interest regarding the publication of this book chapter.

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