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Chapter 5

Household Hazardous Waste Management in Sub-Saharan Africa

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Additional information is available at the end of the chapter

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Abstract

Household hazardous wastes (HHWs) have not been given serious attention in sub-Saharan Africa. There is little or no information on HHWs in many developing countries of the world. This is regardless of the fact that they are very toxic and contain constituents which are persistent in nature. Once released into the environment, they can remain stable for exceptionally long periods of time. They have the potential to be harmful to public health and the environment if not handled, used, and disposed properly. This study reports the level of knowledge and management of HHWs in three tertiary institutions in sub-Saharan Africa. Several factors were found to be responsible for poor management of HHWs. These include lack of awareness, inadequate treatment technologies, financial constraints, lack of realistic policies and legal frameworks, and unplanned settlements, among others.

Keywords: Environment, Hazardous wastes, public health, sub-Saharan Africa, waste management

1. Introduction

Household hazardous wastes (HHWs) are a subset of wastes which are used and/or generated at the household level [1]. These wastes have the potential to cause irreversible damage to public health and other living organisms when disposed into the environment without proper treatment. Greater risks are often posed by hazardous substances to the environment and

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public health than nonhazardous substances. Therefore, it requires a strict control regime. HHWs have a significant adverse effect on public health, other living organisms, and the environment because of their inherent toxic, chemical, and physical characteristics at low concentration [2]. Therefore, these types of waste stream require stringent control and management in order to protect the environment and human health from potential negative impacts. Although HHWs only make up a small percentage of household wastes in general, they are considered to be potentially harmful [3].

The WRc [4] defines HHWs as "such wastes that could potentially increase the hazardous properties of municipal solid waste when landfilled, incinerated or composted." HHWs can also be described as leftovers from household products containing corrosive, toxic, ignitable, or reactive ingredients [5, 6]. The National Household Hazardous Waste Forum (NHHWF) in the United Kingdom defined HHW as "any discarded material by a household, which is difficult to dispose of, or which puts human health or the environment at risk because of its chemical or biological nature" [7]. Certain types of HHWs may pose potential physical injuries to sanitation workers, contaminate septic tanks, or wastewater treatment systems if poured down drains or toilets. They can also present hazards to children and pets if left around the house unattended [1].

HHWs must be separated from other domestic wastes and should not be disposed of together with municipal wastes because they require special treatment before disposal. They are harmful and are potential risks to humans [1]. HHWs vary in forms; some exists as liquids, solid, and gases making their treatment and management a bit complex. The list of HHWs differs between countries. Common examples include pesticides, paints (latex, nonlatex antialgae), motor oil, vanishes, antifreeze, various types of batteries (such as laptop batteries, car batteries, cellphone batteries), fluorescent light bulbs, fertilizers, thermometers, thermostats, solvents, unused medicines, bathroom and tile cleaners, brake fluid, asbestos, household cleaners (spot remover, degreaser, oven cleaner), stain, adhesives, lead acid, used gasoline, polish, wax, several electronics (such as television, computers, radio, and cellphones), photographic chemicals, flea powders, insect repellents, polish, rodent control, fabric, transmission fluid, and microfilm [1, 5–11]. The above examples of HWWs contain hazardous ingredients and require special attention for their disposal and treatment.

Improper disposal of HHW may change the way the biosphere functions, depletes the ozone layer and causes irreversible damage to domestic water sources. This could result in reduction of the productivity of global ecosystems at a time when millions of people are looking for livelihoods and sustenance to be provided by the environment [12]. For several reasons ranging from inadequate knowledge, lack of educational campaigns, lack of awareness on the impacts of HHWs and financial mismanagement are responsible for their improper disposal. HHW management is not usually given priority in most developing countries of the world, priority is mostly given to poverty alleviation, unemployment, and other economic problems. HHWs are usually disposed of with other domestic wastes such as disposal in drains, on the ground, into storm sewers, or in some cases with regular trash (**Figure 1**). Hence, HHW management, including disposal and recycling, seems to be urgent especially in the developing countries (sub-Saharan Africa) where domestic waste management technologies are still limited.

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Figure 1. Illegal disposal of solid waste with HHW in different countries in sub-Saharan Africa.

Household hazardous wastes discarded in the trash may ignite or explode in the collection truck. Trash collectors may be injured from fumes and splashing chemicals. In landfills, leachate from the waste pollutes soil, surface water, and groundwater aquifers [4]. Disposal of hazardous household wastes in drains might also pollute drinking water [5]. In septic systems, hazardous wastes can kill the organisms that make the system work [3]. This may cause the bulk of untreated wastes to drain into the soil and eventually seep into the groundwater. Sewage treatment systems such as septic systems can be contaminated by improper disposal of hazardous household wastes [2–5, 13]. Due to the danger and risk posed by household hazardous wastes, good practices of handling, treatment, and disposal of these wastes should ideally begin in the household [1, 5, 14].

The use of materials with hazardous ingredient is likely to increase in sub-Saharan Africa due to increased industrialization and population growth [15–17]. If industrial and population growth is not balanced with efficient interventions to manage HHWs, most surface and groundwater sources are prone to varying degrees of pollution, some of which is irreversible. The effects of inadequate disposal of HHWs are not usually felt at the time of disposal, but with time, they pose significant risks to users of the resource further downstream [16, 17]. Most constituents of HHWs are persistent in nature and nonbiodegradable; once released into the environment, they transform from one form into a more toxic form [5, 9, 11]. Fauziah and Agamuthu [15] stated that one of the reasons for inadequate disposal and management of HHWs is inadequate awareness among the public as hazardous waste such as medicines, clinical bandages, and batteries that are commonly found in the refuse sent to landfill. This is one of the reasons why high concentrations of heavy metals are often detected in landfill leachate [16].

2. Classification and effects of household hazardous wastes

Household chemicals—a subset of hazardous wastes—are contaminants that are released during the use of various products in daily life. Several studies indicate that indoor air pollution

is far worse than that of outdoor because homes, for energy efficiency, are made somewhat airtight [17, 18]. Moreover, household chemicals are trapped in houses causing further deterioration of indoor air quality. Household hazardous chemicals are potentially dangerous chemicals that can be found within households [19]. Some very important products needed for comfortable living in various households contain hazardous ingredients. Hazardous products generally divided into six groups as shown in **Table 1** [17]. Household hazardous products may cause health and environmental problems to their users and when disposed into the environment. If the unwanted portions of these products go down the drain, into the trash, or get burned, they may cause harm to the environment.

Class	Hazardous products	Examples
I	Automotive products	Gasoline, motor oil, brake fluid, wiper fluid, hydraulic oil, and car batteries
II	Home improvement products	Paint (oil-based and latex), caulk, varnish, air freshener
III	Health and beauty products	Nail polish, finger nail polish remover, nail varnish, hair dye, bath salts/bubble bath, and skin creams
IV	Pesticides	Rat poison, flea killer, insecticide, fungicide, moth balls, ant poison, and herbicide
V	Household cleaners	Furniture polish, oven cleaner, toilet bowl cleaner, scouring agent, shoe polish, stain remover, disinfectant, and bleach
VI	Miscellaneous items	Fabric dyes, fluorescent tubes, low energy light bulbs, ink cartridge and toner, glue, antifreeze, and among others.

Table 1. Classification of the household hazardous products.

As stated earlier, household products are considered hazardous if they are radioactive, have dangerous biological characteristics, toxic, or flammable [6]. Many hazardous products have more than one of these hazardous characteristics. Corrosive substances destroy metal surfaces and living tissues and have the ability to chemically change whatever they come in contact with. Corrosive substances are acidic (pH less than or equal to 2) or caustic (pH higher than or equal to 12.5) [20]. Reactive substances are very unstable and interact with the substances around them. They are explosive and can sometimes create toxic fumes. Flammable substances will burst into flames if they come into contact with sparks or flames at certain temperatures. The temperature at which this occurs is referred to as the flash point. Flammable liquids have a flash point of 60°C [21]. Toxic substances cause immediate or long-term negative health problems. Exposure to toxic materials may result in injury, illness, or death [21, 22].

The effects of hazardous substances on humans and other organisms vary greatly [23–26]. This often depends on the extent of exposure, the concentration of the substance, the nature of the hazardous substance, and the unique characteristics of individuals [20, 21]. The characteristics that influence toxicity of a substance include:

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- Genetic factors: For example, the efficiency of the kidney can affect the ability to excrete toxins.
- Lifestyle of the individual: Smoking, alcohol consumption, obesity, and previous medical history all affect how the body reacts to toxins. In general, healthier individuals are able to fend off some toxins.
- Gender: Some toxins have different effects on males and females. Generally, women have a larger percentage of fat in their total body weight, meaning they can accumulate more fat soluble toxins in their bodies than men.
- Age: Old and very young people are more vulnerable to the effects of toxic substances. Because infants and young children (less than 5 years old) have underdeveloped immune systems, they are the most susceptible to HHWs. In addition, because children have high respiration rates, they are more susceptible to toxins through inhalation.
- Allergic sensitivity: Individuals who are particularly sensitive to chemicals will experience allergic reaction to some toxic chemicals at low concentrations.

Table 2 presents some household products and their hazardous components as well as the potential health hazards. The health risks associated with HHWs are numerous and these substances must be managed appropriately in order to prevent possible risks to public health.

Product type	Class	Hazardous components	Hazardous status	Potential health hazards
1. Air fresheners and deodorizers	II	Formaldehyde	Toxic flammable	Carcinogen; irritates eyes, nose, throat, and skin; nervous, digestive, respiratory system damage
2. Bleach	V	Sodium hypochlorite	Corrosive toxic	Irritates and burns skin and eyes; nervous, respiratory, digestive system damage
3. Disinfectants	V	Sodium hypochlorite	Corrosive toxic	Irritates and burns skin and eyes; nervous, respiratory, digestive system damage
		Phenols	Toxic flammable	Respiratory and circulatory system damage.
		Ammonia	Toxic	Vapor irritates skin, eyes and respiratory tract
4. Drain cleaner	V	Sodium/potassium hydroxide	Corrosive toxic	Burns skin and eyes; nervous, digestive and urinary system damage
5. Flea powder	IV	Carbaryl	Toxic	Irritates skin; causes nervous, respiratory and circulatory system damage
		Dichlorophene	Toxic	Irritates skin; causes nervous and digestive system damage
		Chlordane and other chlorinated hydrocarbons	Toxic	Irritates eyes and skin; cause respiratory, digestive and urinary system damage

Product type	Class	Hazardous components	Hazardous status	Potential health hazards
6. Floor cleaner/wax	V	Diethylene glycol	Toxic	Causes nervous, digestive and urinary system damage
		Petroleum solvents	Flammable	Carcinogenic; irritate skin, eyes, throat, nose and lungs
		Ammonia	Toxic	Vapor irritates skin, eyes and respiratory tract
7. Furniture polish	V	Petroleum distillates or mineral spirits	Flammable toxic	Carcinogen; irritates skin, eyes, nose, throat and lungs
8. Oven cleaner	V	Sodium/potassium hydroxide	Corrosive toxic	Burns skin, eyes; causes nervous and digestive system damage
9. Paint thinner	III	Chlorinated aliphatic hydrocarbons	Toxic	Cause digestive and urinary system damage
		Esters	Toxic	Irritates eyes, nose, and throat
		Alcohols	Flammable	Cause nervous system damage; irritate eyes, nose, and throat
		Chlorinated aromatic hydrocarbons	Flammable toxic	Digestive system damage
10. Paints	II	Ketones	Flammable toxic	Respiratory system damage
		Aromatic hydrocarbon thinners	Flammable toxic	Carcinogenic; irritates skin, eyes, nose and throat; respiratory system damage
		Mineral spirits	Flammable toxic	Irritates skin, eyes, nose and throat; respiratory system damage
11. Pool sanitizers	V	Calcium hypochlorite	Corrosive	Irritates skin, eyes, and throat; if ingested cause severe burns to the digestive tract
		Ethylene (algaecides)	Flammable toxic	Irritation of eyes, mucous membrane and skin; effects reproductive system; probable human carcinogen of medium carcinogenic hazard
12. Toilet bowl cleaner	V	Sodium acid sulfate or oxalate or hypochloric acid	Corrosive toxic	Burns skin; causes digestive and respiratory system damage
		Chlorinated phenols	Flammable toxic	Cause respiratory and circulatory system damage.
13. Window cleaners	V	Diethylene glycol	Toxic	Cause nervous, urinary and digestive system damage
		Ammonia	Toxic	Vapor irritates skin, eyes and respiratory tract.
14. Motor oil	I	Heavy metals	Toxic	Can cause nerve and kidney damage; is thought to cause cancer
		Hydrocarbons	Flammable	Some forms thought to cause cancer

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Product type	Class	Hazardous components	Hazardous status	Potential health hazards
15. Batteries (car, boat, tractor)	VI	Sulfuric acid	Toxic corrosive	Can cause severe skin burns, and blindness
		Lead	Toxic corrosive	Can cause nerve and kidney damage; is thought to cause cancer
16. Windshield washer fluid	I	Methanol	Flammable toxic	Can damage the nervous system, liver, kidneys; inhalation can lead to lung disease; ingestion can cause blindness
		Ethylene glycol	Flammable toxic	Can cause severe damage to heart, kidneys, and brain. Inhalation can cause dizziness
		Isopropanol	Flammable	Can irritate mucous membranes; ingestion results in drowsiness, unconsciousness and death
17. Laundry detergent	V	Cationic, anionic, or nonionic solutions	Reactive	If swallowed, cationic detergents can cause nausea, vomiting, shock, convulsions, and coma. Nonionic detergents can irritate skin and eyes
18. All-purpose cleaners	V	Ammonia	Toxic	Fumes can irritate eyes and lungs; can cause burns or rashes on skin; can produce deadly chloramine gas if mixed with chlorine-containing products
		Ethylene glycol monobutyl acetate	Flammable toxic	Can cause severe damage to heart, kidneys, brain. Inhalation can cause dizziness
		Sodium hypochlorite	Corrosive	Corrosive to skin and lining of nose mouth and throat; fumes irritating to eyes and respiratory tract
19. Pet flea and tick treatments	IV	Organophosphates and carbamates	Toxic	Can cause headache, dizziness, twitching, nausea; known to cause cancer in animals
20. Insecticides	IV	Organophosphates and carbamates	Toxic	Can cause headache, dizziness, twitching, nausea; known to cause cancer in animals
21. Household foggers	IV	Pyrethrins	Toxic	Can cause severe allergic dermatitis, systemic allergic reactions. Large amounts may cause nausea, vomiting, tinnitus, headache, & other CNS disturbances
		Permethrin	Toxic	Can cause itching and burning of the skin and eyes; irritates the upper respiratory tract
		Methoprene	Toxic	Can irritate the skin and eyes
22. Swimming pool chloride tablets	II	Sodium (or calcium) hypochlorite	Corrosive reactive	Corrosive to skin and lining of nose mouth and throat; fumes irritating to eyes and respiratory tract
23. Insect repellants	IV	Butopyronoxyl	Toxic	Can cause mild necrosis in liver and kidney –in animals
		Dimethyl phthalate	Toxic	Can cause central nervous system depression if swallowed

Product type	Class	Hazardous components	Hazardous status	Potential health hazards
		Diethyltoluamide (DEET)	Toxic	Can irritate sensitive skin and respiratory tract tissues as well as loss of coordination, anxiety, behavioral changes, and mental confusion
24. Weed killers	IV	Diquat, 2,4-D, and glyphosate	Toxic	Can irritate the eyes and skin; can cause abdominal pain, nausea, vomiting, and diarrhea
25. Rodent control	IV	Warfarin	Reactive	Causes internal bleeding if ingested in large amounts
26. Rug, carpet, upholstery cleaners	V	Perchloroethylene	Toxic	Fumes cause dizziness, sleepiness, nausea, loss of appetite and disorientation; can cause cancer with long-term exposure
		Naphthalene	Reactive toxic	Can damage liver; prolonged vapor exposure has led to cataract formation
27. Antibacterial cleaner	V	Ammonia, detergents, lye	Toxic	Fumes can irritate eyes and lungs; can cause burns or rashes on skin; can produce deadly chloramine gas if mixed with chlorine-containing products
		Cresol	Corrosive	Can be corrosive to tissue; damages liver, kidneys, lungs, pancreas and spleen
		Phenol	Corrosive	Can cause central nervous system depression; severely affect circulatory system; corrosive to skin; suspected of causing cancer
		Pine oil		Can irritate eyes and lining of nose, mouth, and throat
28. Hair dyes	III	Pigment ammonia	Toxic	Can cause burns or rashes on skin; can produce deadly chloramine gas if mixed with chlorine-containing products
29. Skin creams	III	Heavy metals	Toxic	Can cause nerve and kidney damage; is thought to cause cancer
30. Glue	VI	Xylene, toluene	Flammable toxic	Irritation of eyes, mucous membrane, and skin; effects reproductive system; probable human carcinogen of medium carcinogenic hazard

Source: [14, 15, 18, 20–23].

Table 2. Household products containing hazardous components and their health hazards.

3. Method

To test the level of awareness and management of HHWs in sub-Saharan Africa, 50 questionnaires were administered to students at various levels of study in tertiary institutions in Kenya, Nigeria, and South Africa. The collected data were analyzed using Microsoft Excel 2013 version and the results were presented in bar charts.

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4. Management of household hazardous wastes

The management of hazardous wastes remains a central environmental issue internationally [2]. Otoniel et al. [27] reported that measures have been taken for the HHW management in some developed countries such as the USA. In developing countries, many of which are in sub-Saharan Africa, there is little information concerning the management of HHWs. Although there is a great challenge to the effective treatment and disposal of HHWs in most developing countries of the world, huge success has been recorded in some developed countries (such as the USA, Austria, Germany, Italy, Denmark, the Netherlands, and some other European nations) of the world. The key to this success involves creating adequate awareness on the potential health and environmental risk of HHWs through various informational campaigns [4]. Some of the developed countries have recycling and collection sites where citizens can drop HHWs at no cost. In other cases, there are collection centers such as shops take back or containers parked at public places where individuals can drop HHWs [4]. The success of this method depends largely on active participation from the public. Apart from this system, some countries also incorporate the collection of HHWs in special containers alongside with general municipal wastes, or sometimes by other special arrangements already known to the citizens. The citizens are taught to separate these wastes at the household level [4].

Due to the complexity of HHWs, they are not often collected as a composite waste from households. They are usually separated into different forms such as used and expired batteries, used oil, pesticides, low energy light bulbs and fluorescent tubes, pharmaceuticals, e-waste, fertilizers, and paints. Most recyclable HHWs such as batteries and florescent lamps are recycled and reused, while others that require further treatment are sent to chemical-physical treatment plants, thermal treatment and recovery plants, specialized treatment and recycling plants, biomechanical pretreatment plants for residual waste, sorting plants for separately collected waste, and internal thermal treatment plants [4]. There are also adequate policies and legislation on the use of HHWs in most of these countries. Otoniel et al. [27] reported that measures have been taken for the HHWs management in some developed countries but this is not true for many other developed and almost all developing countries of the world.

In developing countries, many of which are in sub-Saharan Africa, there is little information concerning the management of HHWs. Generally, solid waste management which is simpler compared to the management of HHWs in sub-Saharan African does not meet international collection, recycling, and disposal guidelines. Most wastes generated including HHWs are disposed along roads, highways, vacant land, river banks, and canals, and among others (**Figure 1**). A few cities in sub-Saharan Africa (such as Cape Town in South Africa and Mbabane in Swaziland) have a well-planned solid waste collection system comparable to that of developed countries; while majority of cities (e.g. Onitsha in Nigeria and Kumasi in Ghana) have poor solid waste collection and disposal management. Many villages in the region do not have any form of waste collection and disposal system (**Figure 1**).

Recently, some contaminants, known as emerging contaminants, have been detected in drinking water of most places in the world. Notable emerging contaminants include: pharmaceuticals and personal care products (PPCPs), flame retardants, endocrine disrupting

compounds (EDCs), pesticides, hormones, and disinfection by-products (DBPs) [28]. Most of these contaminants have been linked to the use and improper disposal of HHWs. They are currently receiving global attention due to the perceived threat they could pose to public health and the environment.

In most sub-Saharan countries, the common methods for HHWs management and treatment include open burning of wastes, incineration, and landfilling. These methods are preferred over other methods because they are cheap, easy to operate, and generally accessible. As stated earlier, HHWs in domestic wastes are not separated from the nonhazardous components and are treated as a composite waste.

1. Open burning technique which include all forms of controlled and uncontrolled waste combustion practices is used in for the treatment of HHWs [29, 30]. This method is often used because it is cheap and easy to operate and its energy requirement is low. It does not require any formal training to burn hazardous materials. A major disadvantage to this method is the formation of harmful products such as polycyclic aromatic hydrocarbons that are easily formed from the combustion reaction of carbonaceous materials with free oxygen in air [5]. The combustion of chlorine-containing substances can lead to the formation of dioxins and furans that are highly carcinogenic to humans [9]. Also, smoke and unpleasant odors often accompany open burning practices which is a threat to public health (**Figure 2**) [31]. The use of open burning techniques of HHWs has been reported in Nigeria, Cameroon, Ghana, Kenya, Tanzania, South Africa, and other countries in sub-Saharan Africa [29–34].

Figure 2. Open burning of some HHWs [31].

2. Incineration technique is a very useful method for the treatment of HHWs globally. It is one of the methods still in use in different developed countries of the world [4]. Incineration of HHWs should be done in a controlled environment where the release of toxic substances is eliminated [4]. This is not true for most developing countries as incineration is usually done in an uncontrolled environment [29]. This technique is very useful for the treatment of wastes with low-water content but its application is inefficient in treating wastes containing high

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quantity of water; hence, it is not suitable in developing countries [34]. The release of toxic metals such as mercury, cadmium, and lead into the environment has been linked to the incineration of HHWs under the uncontrolled environment.

3. Landfilling is not accepted as an efficient way of treating HHWs in most developed countries due to various health and environmental risks associated with it. However, in most developing countries, HHWs end up in landfill sites as mixed waste with other domestic and medical wastes. This practice has been reported to have several environmental consequences including contamination of groundwater resource, injury of waste workers, and risks to local waste collectors who collect some discarded materials for recycling [5]. Landfilling of hazardous wastes has been reported to be unsuitable due to the complexity and nature of the wastes [2, 5, 9]. Fauziah and Agamuthu [35] reported a mixture of HHWs and nonhazardous wastes in a municipal landfill in Malaysia, of which about 1.5% of household wastes were classified as hazardous waste. Such a system of disposal is very dangerous to scavengers of valuable and recyclable wastes as they are faced with all forms of risk going through a pile of solid wastes. Cases of HHWs in landfills of developed countries have been reported despite several measures that have been setup [36].

Apart from the general methods discussed above, several countries in sub-Saharan have devised other initiatives for the management of certain classes of HHWs. In South Africa, a private company that makes rechargeable batteries organized with a well-known food stores nationwide to collect all types of batteries. The recyclable batteries are sorted from the nonrecyclable batteries and are sent to France for recycling because there are no facilities in South Africa that can recycle batteries. The nonrecyclable batteries are encapsulated in concrete and disposed of safely to a licensed landfill [37]. Similarly, a nonprofit organization known as Recycling Oil Saves the Environment receives used oil from various locations in South Africa and recycles them for use [38]. In Maldives, Bluepeace [39] reported the use of a ditch (**Figure 3**) at the waste collection center for the disposal of used engine oil. This consequently led to groundwater contamination.

Figure 3. Used engine oil in a ditch in Male, Maldives contaminates the groundwater [34].

Other methods reported for the treatment of HHWs include using them as a fuel in cement kilns, as components of building materials (roads, bricks etc.), and autoclaving and electrothermal deactivation. These methods are used in some sub-Saharan Africa countries but the unintended consequences of these technologies are still not known [37].

4.1. Factors affecting effective management of HHW

Several factors that usually interfere with the management of HHWs in sub-Saharan Africa include:

1. Lack of awareness: One of the major factors affecting HHW management is lack of awareness of what household hazardous wastes are. The limited information on the management of HHW in sub-Saharan Africa attests to the fact that very little is known about them in the region. Most people in sub-Saharan Africa hardly read the labels on the product they purchase to follow the disposal procedure. Even those that read the labels ignore the disposal instructions from the manufacturers of those products. This is because there is limited understanding of the possible risk HHWs have on humans and the environment. Children play with flammable substances at home or after improper disposal. One of the greatest successes that can be recorded in HHW management is the separation of these substances from other wastes at the household level.

From the results obtained from the questionnaires administered, the participants were majorly undergraduate and postgraduate students within the age group of 15–40 years. The participants were males comprising 58, 88, and 40%from South Africa, Nigeria, and Kenya, respectively (**Figure 4**).

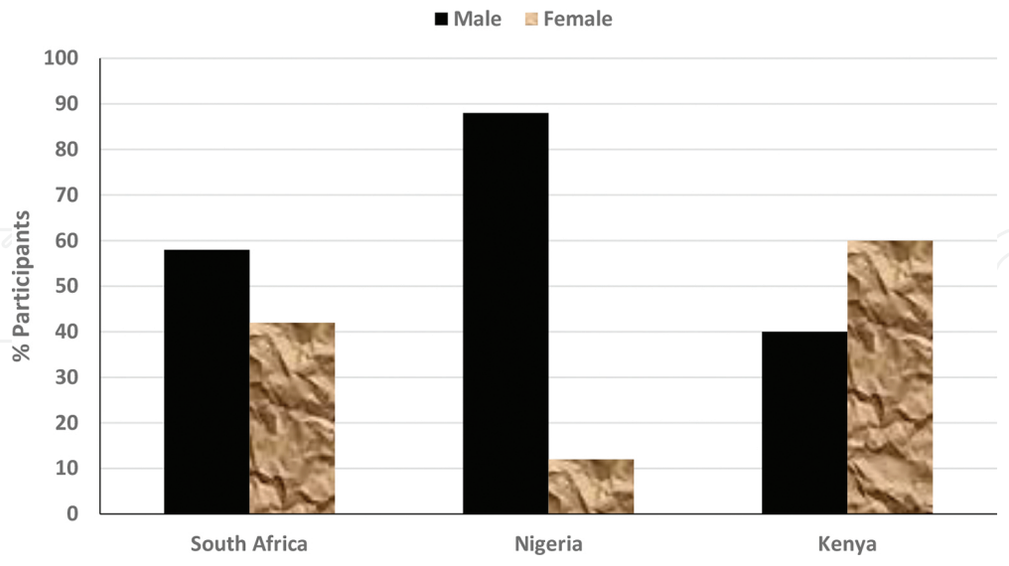

Figure 4. Gender distribution of participants.

In South Africa, 68% of the participants claimed to have adequate knowledge of household hazardous wastes, while 32% of the participants did not know (**Figure 5**). In the classification

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on the types of HHWs, various types of HHWs were included in the questionnaire as a follow-up question to help in estimating those who truly have adequate knowledge of HHWs. Based on this classification, 43% (out of this 68%) of the participants actually knew what HHWs were while 57% of the participants did not know. There was high variation in the awareness of HHWs, inferring partial awareness of HHWs among tertiary students of South Africa. In Nigeria, 69% of the participants also claimed to have adequate knowledge of HHWs while 31% lacked adequate knowledge of HHWs (**Figure 5**). But based on the classification on the types of HHWs, 40% (out of the 69%) of the participants actually knew what HHWs are and 60% of the participants did not know. The awareness level in Nigeria is similar to that in South Africa. In Kenya, a different scenario was obtained compared to South Africa and Nigeria. 36% of the participants claimed that they had adequate knowledge of HHWs and 64% of the participants did not know (**Figure 5**). From the classification of various types of HHWs, all the participants who claimed to have adequate knowledge of HHWs truly had a good level of awareness on HWWs based on the follow-up questions. The level of awareness in Kenya seemed to be low compared to other two countries used in this study. The awareness level in each of the three countries could be as a result of literacy level of individual country [40] but this may not only be the case as the sincerity of each participant in answering the questions can be a contributing factor. Some people who claimed to have adequate knowledge of HWWs from South Africa and Nigeria actually did not adequate knowledge, as demonstrated from a follow-up question on the classification of various substances as HHWs and nonhazardous wastes. Some of the respondents who initially claimed to have adequate knowledge on HHWs classified hazardous substances as nonhazardous.

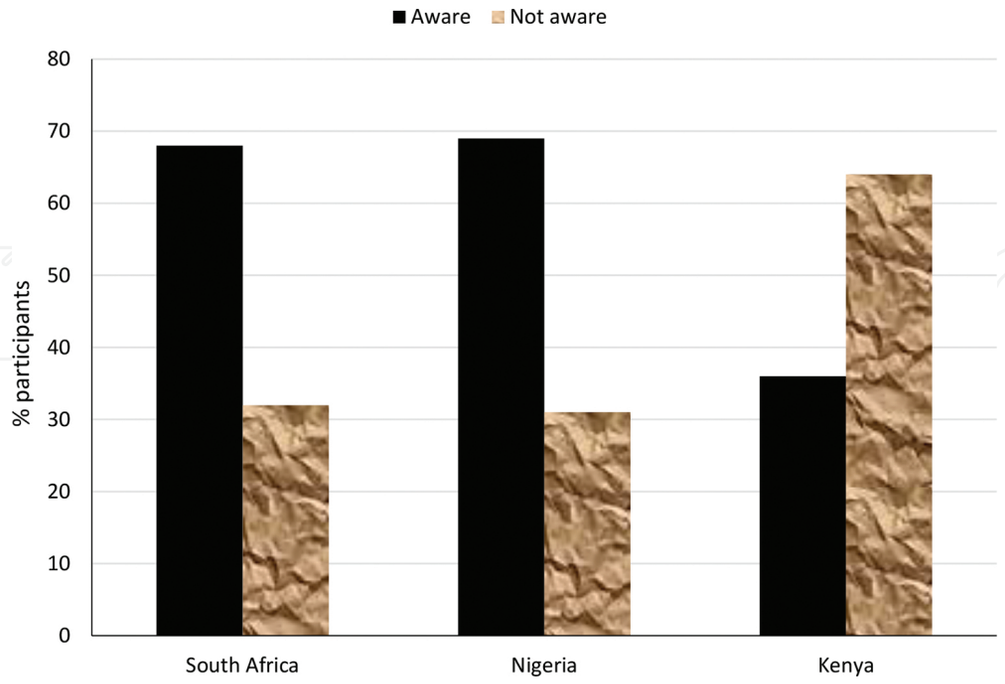

Figure 5. Percentage level of participant's knowledge on HHWs.

With the exception of level of knowledge of the respondents, many participants claimed to know how to manage HHWs from their homes. In South Africa, 62% of the participants had adequate knowledge of HHWs management whereas 38% did not know (**Figure 6**). The participants suggested various ways of storage of HHWs which included: closed container (64%), open container (2%), plastic bag (14%), pile in yard (2%), recycling (4%), and do not know at all (14%). 74% of the participants admitted that HHWs could have many negative effects on humans and the environment; 14% suggested that they will only have mild effects; 2% agreed that HHWs would have no effect on man and the environment. In Nigeria, 48% of the respondents claimed to have adequate knowledge of HHWs management, while 52% did not know (**Figure 6**). 73% of the participants suggested that HHWs should be separated from other household wastes. Similarly, 71% of the participants suggested that HHWs should be stored in a closed container; 2% suggested open container; 2% plastic bags, and 25% did not know how to store HHWs. 56% of the participants admitted that HWWs could have many ill-effects on humans and the environment while 17% believed they may have mild effects and 27% were not sure of their effects. In Kenya, 32% of the participants had good knowledge of HHWs management whereas 68% did not know how to manage HHWs (**Figure 6**). A majority of the participants suggested that HHWs should be separated from other household wastes and that closed container was the best way to store HHWs in the household. 68% of the participants admitted that HWWs could have many ill-effects on humans and the environment while 32% claimed that they will only have mild effects.

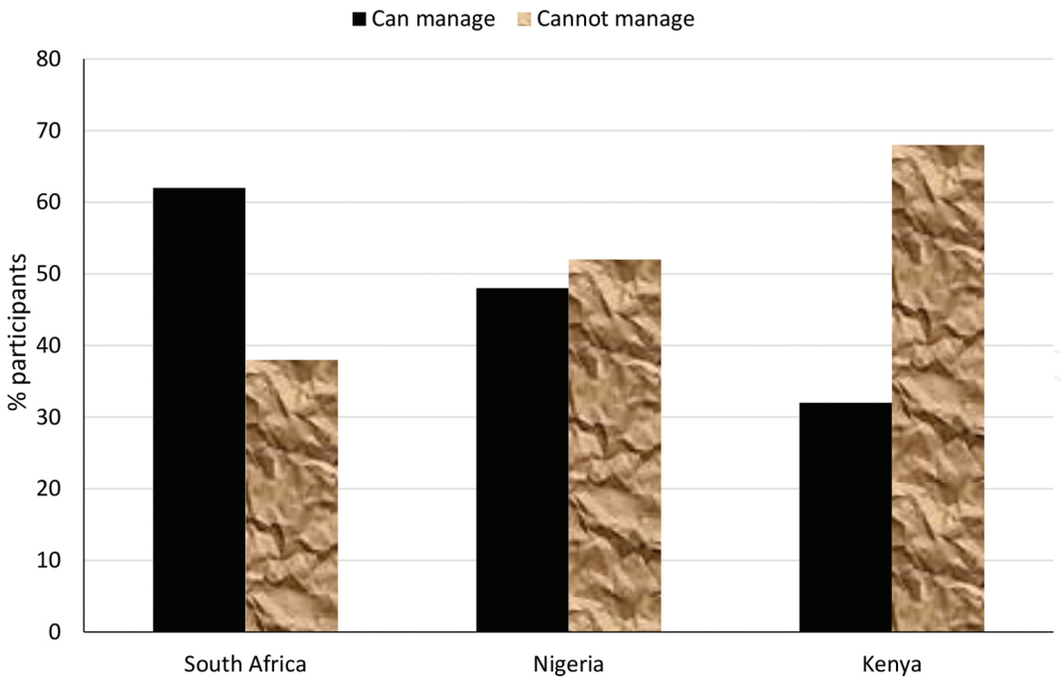

Figure 6. Percentage of participant's level of knowledge on HHWs management.

The government and other private bodies such as NGOs must educate people in sub-Saharan Africa on HHWs and their management. This can be achieved through rallies, posters, social

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media (such as Facebook, twitter, WhatsApp), newspapers, television, and using other respected authorities like traditional leaders (e.g., chiefs), school teachers, university lecturers, and religious leaders.

2. Financial constraints: Most countries in sub-Saharan Africa are faced with unprecedented population growth which is often unbalanced with much of the disposable municipal expenditure devoted to high profile infrastructure whereas waste disposal and management are low on the list of priorities in terms of allocation of funds [41]. Poverty and unemployment are the major focus of most governments in sub-Saharan countries. The treatment of HHWs is cost intensive and without proper allocation of funds such management systems cannot be effective. Most countries in the region have attempted to carry out solid waste management in one form or the other and have reported minimal success due to limited financial commitment from government, the people and NGOs. Most people in the region are striving to meet their basic needs and are not willing to pay an extra cost for waste disposal. Several countries in developing countries have placed a ban on certain product containing hazardous ingredient. The accumulation of such products already in the country occurs due to financial constraints and lack of appropriate technologies to treat and dispose them. Also despite the ban, illegal importation of such products is common due to poor monitoring for compliance and corruption [42].

3. Unplanned settlements: Very few cities and villages within the region have planned settlements; the latter make collection of HHWs easy but within most cities, slums and high rate of urbanization make it very difficult for the government or private companies to effectively distribute waste bins and collect them. Some of the places where people live are not accessible to the collection vehicles.

4. Lack of appropriate technology: Government officials in most countries, as stated earlier, are more concerned with poverty eradication, solving unemployment problems, and provision of basic health care and education and are unwilling to invest in the technology for the management of HHWs. Most facilities present in a few countries lack the appropriate technology from the waste collection to disposal. If progress is to be made in this regard, there is an urgent need for the appropriate technologies and skillful personnel. Agamuthu [8] and Gatke [43] reported that the main components of HHWs in Malaysian landfills are batteries, aerosol cans, paints, pesticides, adhesive, drugs, and syringes. They lamented the reason of these contaminants in the landfills as the Malaysian government did not have the appropriate technologies for the management of HHWs hence their inclusion with general domestic wastes. Similar observation has been reported in many countries in sub-Saharan Africa.

5. Lack of proper legislation and enforcement of the legislation: Most countries within the region lack the legal framework for HHWs disposal; therefore efforts to control it would be unsuccessful. Most developing countries in sub-Saharan Africa have a legislative framework for solid waste management and wastewater whereas some developed countries such as Canada, Germany, and the USA have a realistic policy on household hazardous wastes with the aim of reducing it at the household level [4, 36]. The legislative framework for both liquid and solid wastes has not been enforced, even though present. There is no accountability system in the legal structure' thus, even when the laws exist there is no structure to ensure strict

compliance. South Africa has quite a number of legislations governing waste and these include: the South African constitution Act 108 of 1996, Hazardous Substance Act 5 of 1973, Environmental Conservation Act 73 of 1989 and Minerals and Petroleum Resources Development Act 28 of 2002, National Environmental Management: Waste Act 59 of 2008, and among others but there is no legislation that strictly governs HHWs in the country [44]. In Nigeria, several legislations regarding waste management include the National Environmental Standards and Regulations Enforcement Agency Act, 2007; the Environmental Impact Assessment Act, 1992; and the Harmful Waste Act, 1988 [34, 45]. The Harmful Waste Act of 1988 in Nigeria prohibits the sale, purchase, and generation of toxic, poisonous, and potentially injurious substances [34, 45]. Similarly in Kenya, the Environmental Management and Co-ordination Act (EMCA) No. 8 of 1999 prohibits the mismanagement of wastes and has a deterrent fine for industries that refuse to comply with the tenets of the policy. The Act also compels polluters to manage and recycle their wastes. There are several portions of the Act dealing with hazardous wastes [46]. Most countries in sub-Saharan Africa have different legislations on solid wastes and wastewater but specific legislations on HHWs management is completely missing. Several part of the legislations and policies deal with hazardous wastes in a broader sense but HHW was not the sole target of the legislations [15–18]. This may be one of the contributing factors to the low level of awareness and management of HHWs in the region.

4.2. Improving HHWs management in sub-Saharan Africa and recommendations

The way forward for effective management of HHWs in sub-Saharan Africa is to first create active awareness through information campaigns on HHWs and the health and environmental risks associated with them. The use of substances without hazardous components should be encouraged as this will lead to a reduction of total HHWs generated in sub-Saharan Africa. Collection, recycling and treatment centers should be opened by the government where hazardous wastes can be disposed without any financial cost on the citizens. Different types of HHWs such as batteries, engine oil, paints, and light bulbs should be collected separately and recycled for reuse. The government should make HHWs management a priority and should invest in it. Also, the government through the various ministries should seek for funding through the writing of good proposals soliciting for grants from donors to assist in the management of HHWs. Adequate technologies for HHWs treatment should be introduced and where there are no skilled personnel, scholarship should be given to interested individuals to study HHWs treatment and management from countries such as France and Austria where HHWs management have been successfully implemented for decades. Such individuals should be encouraged to return back to their respective countries to implement what they have learnt. Adequate policy and legislation on HHWs should be enacted and enforced through proper monitoring for compliance.

5. Conclusion

HHWs have high potential risks. In order to avoid this, it is desirable that strict monitoring be given to the use, storage, and disposal of hazardous substances at the household level.

Improper handling and disposal of these materials can be detrimental to human health and the environment at large. Results from this study have shown low level of awareness of HWWs among university students who are expected to be more enlightened than those who did not have the privilege to acquire tertiary education. Therefore, more ignorance on HHWs is expected from other citizens of the region because if university students could not identify what HHW substances are and do not understand the potential risk they pose to public health and the environment, then other less-educated people are not likely to have enough information on HHWs. Major steps to the efficient management of HHWs includes creating adequate awareness on3 HHWs, encouraging citizens to use alternative substances in lieu of them. People in the region should be enlightened on the use, disposal and the potential risk associated with HHWs. There should be adequate policies on HHWs management and the enforcement of such policies in sub-Saharan Africa. Little information and data exists on HHWs in sub-Saharan Africa, more studies should be encouraged and conducted to assess their levels.

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