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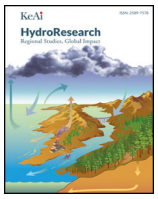

The pharmaceutical disposal practices and environmental contamination: A review in East African countries

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ABSTRACT

The aim of this review was to analyze the available information on methods used in disposing of unused or expired pharmaceuticals in East African countries and the possibility of environmental contamination. There are some concerns about how pharmaceutical wastes are disposed of and, because of their risks, it is a critical matter to examine. Improper pharmaceutical disposal is common in many countries, from home to hospitals. The review shows that, despite the presence of regulations and rules in developed and developing countries, this practice is still growing. Apart from the ecological effects of pharmaceuticals in the environment, antibiotic resistance is more likely where germs such as bacteria and fungi develop resistance to the drugs designed to kill them. One of significant source of pharmaceuticals into the environment is improper disposal. This review shows that improper pharmaceutical handling and disposal is a challenge in all East African countries. This poses a risk of environmental contamination, human health and developing antibiotic resistance. There is a need for more awareness enhancing, policy review and enforcement of laws to protect both human and environmental health.

Contents

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1. Introduction

Pharmaceuticals are natural or manmade chemical substances having biological activity that are intended to have a specific mechanism of action in humans or other animals (veterinary medicine) (Tijani et al., 2013; Shalini et al., 2010). Their biological activity is used for the treatment of diseases, for fighting infections, and for reducing symptoms (Jones et al., 2005). Different classes of pharmaceuticals such as antiepileptic, analgesics, hormones, beta-blocker heart drugs, antiseptics, contraceptives, antihypertensive, antibiotics, and psychotherapeutics have been detected in drinking water, ground water, surface water and wastewater effluents (Ohoro et al., 2019; Santos et al., 2013). Despite their low concentration (Fatta-Kassinos et al., 2011), usually ranging from ng/L to μg/L (Shalini et al., 2010; Kümmerer, 2009), they can pose serious environmental and health effects (Abhilash, 2012; Jones et al., 2005) due to their characteristics which include bioaccumulation, persistence, and toxicity (Ohoro et al., 2019).

According to studies, between 40% and 90% of the administered antibiotic dose is excreted as parent chemicals in the active form in the feaces and urine (depending on the class of medicine) (Polianciuc et al., 2020). Similarly, the metabolites and derivatives resulting from wastewater treatment processes may have a greater toxic effect than the original compound (Faleye et al., 2018). This means that the most commonly prescribed pharmaceuticals are also likely to be the most readily available in homes and in the environment (Ohoro et al., 2019). The mass production of antimicrobial substances, their excessive use for medical purposes, and the many pathways of their release into the environment have all been linked to a significant increase in the number of pathogens with multi-drug resistance genes. Such resistance is now posing a severe threat to public health (Serwecinska, 2020). If part of the dispensed pharmaceuticals reaches into the wastewater system by excretion or disposal, it causes greatest environmental impact particularly because the conventional wastewater treatment systems are not designed to remove pharmaceutical components (Fenech et al., 2013).

The risk of environmental contamination by the pharmaceuticals get on increasing due to inefficiency of the conventional wastewater treatment technologies on degrading this type of waste (Tijani et al., 2013) (Tijani et al., 2016). The presence and fate of pharmaceutical compounds in the environment has attracted the attention of the public and raised alarm among scientists all around the world (Phillips et al., 2010). In this review, the emphasis is put on how pharmaceuticals disposal practice may contribute to the presence of pharmaceuticals into the environment. The review starts with the possible sources, the effects and then concentrates to pharmaceuticals disposal practice.

2. Materials and methods

This review focused on East African countries which include Burundi, Kenya, Rwanda, South Sudan, Tanzania and Uganda. This region was chosen to represent developing countries. Pharmaceutical disposal methods at home and in health care facilities were among the information gathered. A total number of 94 papers were used. Google Scholar, PubMed, Science Direct, Scopus, Taylor & Francis online, Web of Science, and Wiley Online Library were searched for publications published up to January 10, 2022. The keyword phrases included pharmaceutical disposal, antibiotic resistance, wastewater treatment, and unused medicines. In some cases, the word medicine was used instead of pharmaceutical since some authors did not establish a clear contrast between the concepts. All previously published articles on the topic of pharmaceutical disposal and the risk of antibiotic resistance were eligible for inclusion. Only the most recent reviews were included if publications were updated by the same authors or research group. This systematic review eliminated papers that were not published in English. The East African countries which is the scope of this systematic review is shown in Fig. 1.

3. Possible sources of pharmaceuticals into the environment

From 1977 when the presence of pharmaceuticals in wastewater and natural water was reported, the knowledge on their sources, fate and toxicity has advanced (Caban and Stepnowski, 2021). Prior to 2012, there was no evidence on the presence of pharmaceuticals in aquatic environment in Africa (Fekadu et al., 2019). The increase in pharmaceuticals detected in the environment has been related to the population growth rate while their prevalent distribution is based on their physical and chemical properties (Tijani et al., 2013). Pharmaceuticals may get into the environment through various sources like excretion, bathing, disposal of unused products, flushing down toilets, effluents from wastewater treatment plants, residues and wastes from hospitals and health facilities, and wastes from pharmaceutical industries (Ohoro et al., 2019; Sui et al., 2015). The primary source of pharmaceuticals into the environments includes effluents from wastewater treatment plants, hospitals and livestock breeders (Tijani et al., 2013). Pharmaceuticals are transported in the environment primarily through water transport and the food chain due to their low volatility (Nikolaou

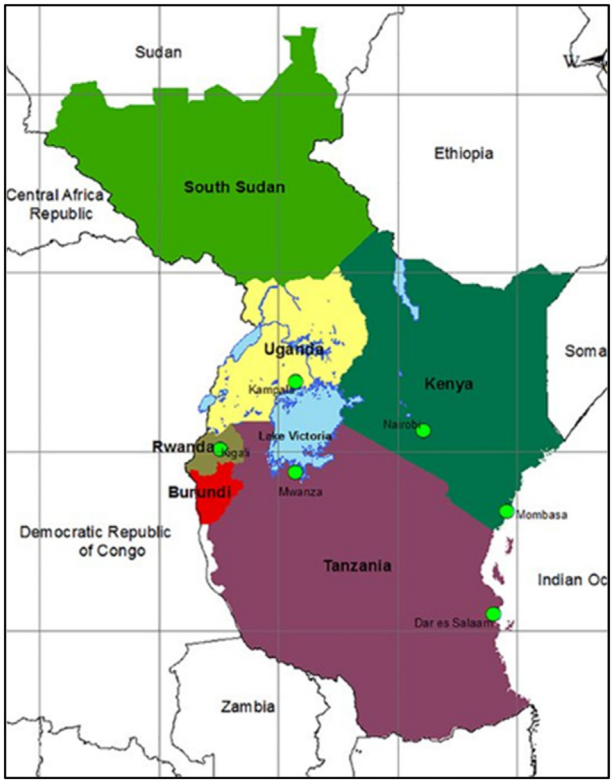

Fig. 1. A map of East African countries involved in the study.

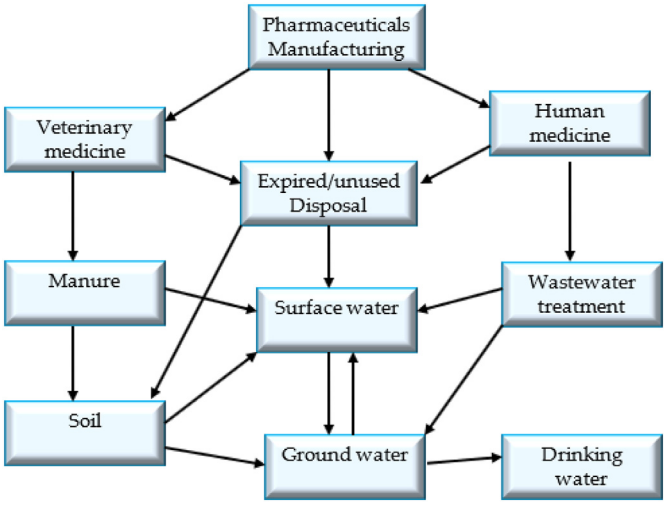

Fig. 2. Potential sources of pharmaceuticals in the environment.

et al., 2007). The pathways of pharmaceuticals into the environments are shown in Fig. 2.

3.1. Municipal wastewater effluents

Many researchers point out wastewaters as the major pathway for pharmaceuticals to enter the environment (Phillips et al., 2010). This is due to the fact that after ingestion, these compounds get metabolized and excreted in feaces and urine, either as metabolites or the parent compounds (Santos et al., 2013). Wastewater is treated at wastewater treatment plants (WWTPs) before it is released into the environment. The efficiency of WWTPs in removing contaminants depends on different factors, namely the physico-chemical properties of the compound, climatic conditions, treatment processes involved and design which means removal efficiencies always vary from plant to plant (Gracia-Lor et al., 2012). The removal of pharmaceuticals in the typical activated sludge treatment process is partial due to the fact that WWTPs are not intended to properly remove these micropollutants (Gao et al., 2012). As a result, pharmaceutical residues may remain in effluent after treatment and they finally enter the environment (Abhilash, 2012; Marwa et al., 2021).

3.2. Improper disposal of pharmaceuticals

Improper disposal is one of the sources of pharmaceuticals in the environment (Paut Kusturica et al., 2020; Madikizela et al., 2020). Previously, it was thought that disposing of any expired or unused prescribed medications in the toilet or down the drain was the best way to prevent accidental intake rather than dumping them in the garbage, where humans or animals were more likely to come into contact with them. As the public became more aware of the potential environmental and public health consequences of medicine flushing, guidelines for pharmaceutical disposal procedures began to evolve (Dar et al., 2019). At different levels, from households to health facilities, the disposal of unfit pharmaceuticals, for instance flushing them down the drain, poses an environmental risk (Persson et al., 2009). Some researches in developing countries have indicated that people have a significant number of unused or expired pharmaceuticals (Kassahun and Tesfaye, 2020). Unfortunately, most people flush unneeded pharmaceuticals down the toilet or throw them away in the trash. Some people distribute their prescription drugs to family members or friends (Naser et al., 2021). These chemicals reach our streams, lakes, and rivers through the sewer system when pharmaceuticals are flushed down the toilet or down drains (Kinrys et al., 2018).

4. Effects of pharmaceuticals in the environment

In the majority of investigations, the concentrations of pharmaceuticals in the environment is less than the known amount that would produce acute effects. However, chronic exposure to pharmaceuticals has the potential to cause major consequences (Abhilash, 2012). There is limited information on the effects of active substances on aquatic organisms. The available risk assessment information is based on single pharmaceuticals. In real environments, pharmaceuticals do not exist in isolated form, but as a complex mixture of different components. According to studies, the effects of a pharmaceutical mixture may differ from those of a single pharmaceutical (Kümmerer, 2009). Whenever it comes to the existence of pharmaceuticals in the environment, the greatest concern is bacterial resistance (Gracia-Lor et al., 2012). Studies show that the exposure of bacteria to antibiotics creates resistance. Bacterial resistance to antimicrobial agents makes infection treatment difficult (Abhilash, 2012).

The impact of the disposal of pharmaceuticals depends on the properties of the particular pharmaceutical, such as toxicity, bioaccumulation, mobility and persistence. Persistence is the characteristic of some chemicals to resist natural decomposition, such as photolysis biodegradation or hydrolysis and makes them stay for a longer time in the environment (Schwarzenbach et al., 2006). The behavior of chemicals being transported in soil and aquatic systems is referred to as mobility. Pharmaceuticals with these properties can remain in the soil, dissolve easily in water, and quickly transfer into water (Mehta et al., 2016). Lipophilic behavior (possibility to penetrate the lipid bilayer of most cellular membranes) of pharmaceuticals makes them potentially bio accumulative. This means, apart from the low concentrations (ng/L) in aquatic systems, bioaccumulation may result in a raised concentration (μg/L) in the bodies of aquatic organisms (Valdés et al., 2014). Some information available on the toxicity of the pharmaceuticals tested in algae, invertebrates and fish in laboratory studies shows that the acute effect is observed at concentrations higher than those detected in the environment. Some reported effects include modification of reproduction or growth rates, which have been observed to occur at much lower concentrations (Deblonde and Hartemann, 2013). The effects can be summarized as in Fig. 3.

Additionally, the presence of pharmaceuticals, particularly endocrine-disrupting compounds, in the environment may result in endocrine disruption for a variety of reasons (Kumar et al., 2020). First of all, some pharmaceuticals, like contraceptives, are used to regulate hormonal functions. Second, while most pharmaceuticals are only effective for a short time in the target organism, they may stay in the environment considerably longer after excretion. Third, the hormonal systems of environmental target species may differ from those found within the organism under treatment, causing them to react differently to the presence of a pharmaceutical (Ingerslev et al., 2003). These compounds, which include estriol and estrone, have an effect on hormone regulation

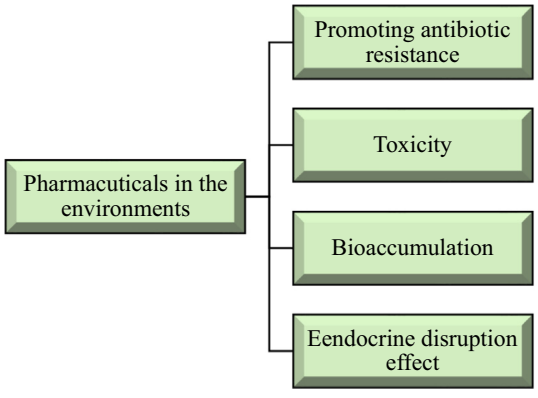

Fig. 3. Effects of pharmaceuticals in the environments.

as well as reproductive and sexual behavior (Miraji et al., 2016). Endocrine disrupting substances can be toxic to receptor organisms through continuous exposure rather than bioaccumulation when exposed to the body (Rahman et al., 2009). The evidence from the scientific literature reveals that exposure to low concentrations of endocrine disruptor compounds is related to the abnormalities and health issues that aquatic organisms experience (Pironti et al., 2021; Khan et al., 2020; Kyzas et al., 2015).

5. Measures to control pharmaceuticals release in the environment

Different measures can be taken to limit the presence of medicines in the environment. Reduced emissions from the pharmaceutical industry is one of the short-term solutions. Different stakeholders have responsibility of controlling eco-toxicity resulting from presence of pharmaceuticals in the environment. For instance, doctors should prescribe only the required medicine and provide awareness about hazardous properties of pharmaceuticals. Pharmacists should provide awareness and information to patients on good disposal practice. The patients should comply to the proper disposal methods and make sure that they take drugs only prescribed by a doctor. Following that, governments are responsible for coordinating all stakeholders and enforcing the specified threshold for pharmaceuticals and other chemicals in diverse environmental compartments (Kar et al., 2018).

The medium-term measures include change of prescriptions to drugs which are more environmentally-friendly and less excreted active ingredients. The long-term measures should include designing of pharmaceuticals with environmentally friendly characteristics (Klatte et al., 2017). It can generally be summarized as in the Fig. 4.

According to WHO (1999), pharmaceuticals pose a threat to public health and the environment not only because they expire, but also because they are improperly disposed of, which can lead to water contamination. The WHO points out some risks resulting from improper disposal of pharmaceuticals, like contamination of drinking water due to inadequate construction of landfills, killing of bacteria necessary for sewage treatment, and air pollution by burning pharmaceuticals at low temperatures. The best healthcare waste disposal system must have minimal risk evaluation for waste management facilities, little human health impact, minimal environmental impact, and be cost-effective and easily deployed (Ghasemi and Yusuff, 2016). The major disposal methods in health facilities include incineration, chemical decomposition, return to donor, sewage, immobilization, landfill, burning in open containers, and fast-flowing watercourses (Kagonji and Manyele, 2011; WHO, 1999).

5.1. Return to donor or manufacturer

Wherever appropriate, the option of returning unsuitable pharmaceutical to the manufacturer or donor for safe disposal is recommended.

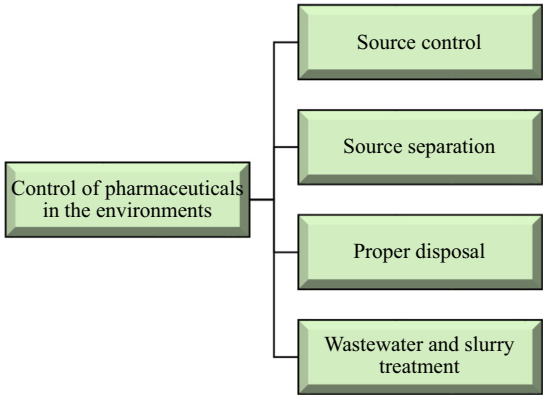

Fig. 4. Methods used to control pharmaceuticals release in the environment (Boxall, 2004).

It may be possible to return unwanted, unrequested donations to the donor for disposal, especially if they arrive with past or unreasonable expiration dates (TFDA, 2009; WHO, 1999). Due to transborder regulations, this option is generally not feasible and can be time consuming (Kadam et al., 2016).

5.2. Landfill

Landfills are physical structures or locations where solid waste and waste residuals are disposed, usually in a regulated and studied manner (Osazee, 2021). The landfill technique is one of the most preferred since all wastes, post minimization or treatment, require access to the land for final disposal in order to remove the residual healthcare waste materials with the least amount of environmental damage (TFDA, 2009). Landfill method is a simple and low-cost trash disposal option, if not handled carefully and appropriately, it can increase human health risks and environmental damage. In many ways, landfilling has been heavily criticized and is viewed as the polar opposite of sustainability, owing to the health risks and environmental load it entails (Osazee, 2021). This method generate three waste products that may contaminate the environment: solid-like deteriorated trash, liquid-like leachate (waste-polluted water), and gas as landfill gas (Ghasemi and Yusuff, 2016).

5.3. Incineration

Incineration is a designed process that utilizes thermal decomposition at high temperatures (normally 900 °C or higher) to degrade the organic component of wastes. This method permits up to 70% reduction in mass and a 90% reduction in volume. Wastes are converted into heat, gas, steam, and ash (Jaseem et al., 2018). Medical waste incineration has been regarded as the most preferable disposal method and is frequently used (Seehusen and Edwards, 2006). Inadequate incineration or incineration of materials that are not appropriate for incineration, on the other hand, results in the release of harmful pollutants in high concentrations into the air, which can travel vast distances before returning to earth (Manyele and Lyasenga, 2010). In addition to bottom and fly ashes, trash incineration produces hazardous organic and inorganic chemicals (Zimmermann and Szyca, 2012; Singh and Prakash, 2007).

5.4. Waste immobilization: encapsulation

Encapsulation means immobilizing pharmaceutical materials in a solid block within a plastic or steel drum that has been cleaned prior to use and has not previously housed explosive or hazardous compounds (TFDA, 2009). The pharmaceutical items are filled to one-third of the capacity of these drums, and the remaining space is filled with cement, cement lime mixture, or bituminous sand (WHO, 1999). This mixture necessitates a substantial amount of water in order to achieve a paste with an appropriate liquid consistency. The barrels are subsequently sealed and deposited at the bottom of a landfill, where they are covered with municipal rubbish (Bhattacharyya and Bhowmick, 2021). Encapsulation alone is not advised for non-sharps trash, although it can be used in conjunction with other waste treatment methods. The process's key advantage is its efficiency in minimizing the possibility of scavengers getting access to hazardous health-care waste (WHO, 2014).

5.5. Waste immobilization: inertization

Inertization is a version of encapsulation where pharmaceuticals are then pulverized and combined with water, cement, and lime to make a uniform paste (Jaseem et al., 2018). This is subsequently transformed into a liquid by a concrete mixer truck and after solidification it can be disposed within the municipal solid wastes (Mohan, 2021). This method lowers the possibility of dangerous chemicals in the waste

moving into surface or groundwater. It is especially useful for pharmaceuticals and incineration ashes (Kulkarni, 2020) with a high metal concentration (the technique is also known as "stabilization" in this case) (WHO, 2014).

5.6. Sewer

Some liquid pharmaceuticals, such as syrups and intravenous (IV) fluids, can be diluted with water and flushed into sewers in relatively small amounts over time without causing harm to public health or the environment. Small amounts of well-diluted liquid pharmaceuticals or antiseptics can also be flushed via fast-flowing watercourses (Jaseem et al., 2018). According to research, dumping pharmaceuticals into sanitary sewers is a one of significant environmental threat (Musson et al., 2007).

5.7. Burning in open containers

Toxic substances may be emitted into the air if pharmaceuticals are burned at low temperatures in open containers (Alnahas et al., 2020). If paper and cardboard packing cannot be recycled, they can be burned. However, polyvinyl chloride (PVC) plastic should never be burned (Kadam et al., 2016). While it is not recommended as a means of disposal for pharmaceutical waste, it is acknowledged that it is routinely used in many countries including Tanzania (Manyele, 2004). Only extremely little volumes of waste medications should be disposed of in this manner, according to experts (WHO, 1999; TFDA, 2009).

5.8. Chemical decomposition

The chemical procedure entails using chemicals to degrade the pharmaceutical waste. This is only considered when recommended by the manufacturer or in the presence of a chemical experts (Kadam et al., 2016) and special materials needed (Orina, 2018). Small amounts of pharmaceuticals, such as antineoplastic agents, can be disposed of using prescribed chemicals. In the lack of a suitable incinerator, this procedure can be utilized, followed by landfills (Kaur and Singh, 2020).

6. Disposal practice of pharmaceuticals in healthcare facilities in EA countries

Pharmaceutical disposal in East African countries is regulated by national medicines regulating authorities. These organs are tasked with ensuring the health and well-being of the people in their respective countries. The major goal of these organs is to protect the public from dangerous pharmaceutical products. They are also in charge of encouraging the sensible use of pharmaceuticals and reducing the availability of falsified and substandard pharmaceuticals. (Ndomondo-Sigonda et al., 2021; Barry et al., 2020). The countries with respective authorities are summarized in Table 1.

Table 1
National medicines regulatory authorities.

Country	National registration	Reference
Tanzania	Tanzania Medicines & Medical Devices Authority (TMDA) previously known as Tanzania Food and Drugs Authority (TFDA)	TFDA (2009); Ndomondo-Sigonda et al., 2021; TMDA (2015)
Kenya	Pharmacy and poisons board (PPB)	Ndomondo-Sigonda et al. (2021); PPB (2018)
Uganda	National Drug Authority (of Uganda) (NDA)	Ndomondo-Sigonda et al. (2021); NDA (2020)
Burundi	Burundi National Medicines Regulatory Authority (ABREMA)	Ndomondo-Sigonda et al. (2021)
Rwanda	Rwanda Food and Drugs Authority (Rwanda FDA)	Ndomondo-Sigonda et al. (2021); Barry et al. (2020)
South Sudan	South Sudan Drug and Food Control Authority (DFCA)	Kheder and Ali (2014)

Improper disposal of unused or expired pharmaceuticals have been reported by different authors across all EA countries.

6.1. Tanzania

A survey by Manyele and Anicetus (2006) on the existing medical waste management in Tanzanian hospitals showed that most of medical wastes are disposed by open pit burning. Their results are summarized in Fig. 5.

There are more challenges in low-level health facilities. A study was done in two municipalities in Dar es Salaam region, Tanzania to evaluate the management of medical waste. The study showed 70% (Ilala) and 83% (Kinondoni) dispose of medical waste in poorly designed incinerators, in open pit burning or on the ground. Around 70% of incinerators were not in good working conditions (Manyele and Lyasenga, 2010). Similar results were obtained in a study at Shinyanga regional referral hospital where around 11% of the wastes generated were incinerated without segregation in a locally manufactured incinerator leaving 89% of the waste dumped to the municipal solid waste dumpsite (Kuchibanda and Mayo, 2015). In another study to evaluate the disposal practice of unfit medicines in Mwanza, Tanzania, the results are shown in the Table 2.

Lack of training to pharmacists on management of this type of waste results into mixing of expired pharmaceuticals with other wastes (Manyele and Anicetus, 2006). In a research carried in Shinyanga, Tanzania, 96.7% of surveyed medicine store supervisors suggested formal training on pharmaceutical disposal, with 63.3% citing handling unwanted pharmaceuticals as a crucial area of training (Kuchibanda and Mayo, 2015). The majority of studies conducted in Tanzanian healthcare facilities focused on medical waste in general. Medicines in Tanzania may be deemed unfit if they are expired, inadequately sealed, incorrectly stored, defective, counterfeit, inappropriately labeled, contaminated, substandard, forbidden, or unapproved (Mwita et al., 2019b). This makes it necessary to investigate and control the way pharmaceutical wastes are disposed in Tanzania.

6.2. Kenya

Despite the fact that Kenya has established regulations for healthcare waste management, mixing different types of waste, crude dumping, and improper incineration are nevertheless frequent in public health institutions (Njue et al., 2015). The findings from a study in public health facilities in Garissa County revealed that, on average, hospitals separate medical waste properly. The waste storage area was in poor shape and needed to be renovated. There were waste management facilities available. However, the only incinerator facility accessible was in poor shape. The available waste handling equipment is in bad condition and requires immediate maintenance (Matan et al., 2018). The results are similar to what was observed in Kiambu county where majority of incinerators were positioned in populated regions, with 62.5% of all incinerators being located near agricultural areas. The majority of the incinerators were constructed in valleys and ridges, which

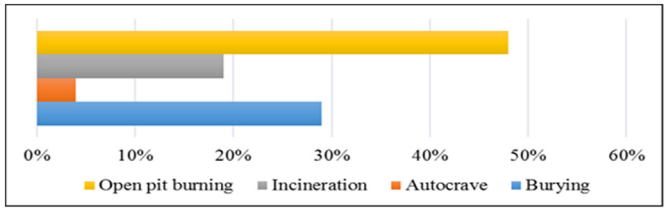

Fig. 5. Disposal methods for medical waste in hospitals in Tanzania (Manyele and Anicetus, 2006).

Table 2
Disposal methods used by health facilities (Mwita et al., 2019b).

Disposal method used	Number of health facilities studied (111)	Percentage
Landfill of untreated unfit medicines	23	20.7
Burning in open spaces	42	37.8
Other (pouring into sink and put into dustbin)	46	41.5

increased the dispersion area and health risk (Kungu et al., 2016). In 2010, the Kenya Performance, Analysis, Communication, and Evaluation (PACE) project conducted a Healthcare Waste Management Assessment for USAID/Kenya. The audit involved 111 health facilities highlighted issues (USAID-Kenya, 2012). Regarding the management of wastes, results are summarized in Table 3**.**

All these results tell that stakeholders make very little effort to follow the established regulations included by the Public Health Act, as well as the National Environmental Management Agency's (NEMA) hazardous waste management regulations (USAID-Kenya, 2012). For best practices, regulations must be strictly enforced (Abuga et al., 2019). As for the case of Tanzania, the majority of studies conducted in Kenya healthcare facilities focused on medical waste in general.

6.3. Uganda

A study was conducted to assess the prevalence of, and primary contributing factors to, medicine expiry in medical supply outlets in Kampala and Entebbe, Uganda. According to the data, drugs prone to expiration include those utilized for vertical programs, donated medicines, and those with a slow turnover (Nakyanzi et al., 2010). All these contributes to the wastes requiring disposal. The treatment of hospital waste at Bwindi Community Hospital did not appear to follow the hospital waste management plan, with poor waste segregation, transportation, storage, and disposal, potentially posing environmental and occupational dangers (Kwikiriza et al., 2019).

Between August 2018 and December 2018 in a study to analyze cross-sectional qualitative data at Kiruddu Referral Hospital, with the primary goal of examining procedures and practices of handling medical waste. The findings revealed a general lack of systematic rules and principles, which were significant contributors to inefficient healthcare waste management (Katusiime, 2018). Another research looked into the waste management issues at Soroti Regional Referral Hospital. It was revealed from the study that poor waste management is caused by a lack of waste segregation, a lack of a waste management plan, an ineffective and inefficient waste management and coordination structure, ineffective and inefficient incineration equipment, and a lack of comprehensive waste management policies and guidelines, according to the study (Muhwezi et al., 2014).

Another study was done to evaluate the healthcare waste management strategies used by health professionals in Bushenyi District, western Uganda. According to the findings of this survey, open pit burning was the most popular technique of waste disposal. The study concluded that healthcare waste was inadequately managed, and the majority of healthcare professionals did not follow Ugandan health workers' guidelines (Aliyu et al., 2017). From March to April 2017, a study with different results was done at 8 basic health care facilities in Kampala City. The practices of healthcare personnel in terms of waste management were mostly appropriate. Health workers with a diploma, previous healthcare waste management training, and those who thought healthcare waste management was important all had higher probabilities of managing it (Wafula et al., 2019). There is a need to offer healthcare waste management trainings in order for health workers to improve their waste management practices.

Table 3
Healthcare waste management in Kenya (USAID-Kenya, 2012).

Attribute	Results (Out of 111 health facilities)	Percentage
Healthcare waste mixed during transport	During transportation, 96 of facilities mixed all categories of healthcare waste.	87.3
Presence of Standard Operating Procedures (SOPs) on healthcare waste	97 health facilities did not have SOPs	88.2
Presence of incinerators	16 health facilities did not have incinerators.	14.5
Presence of temperature gauge on incinerators	Temperature gauges were installed on incinerators at 7 health facilities	6.4
Presence of an incineration activities log book	A logbook for recording incineration activities was present in 8 of the health facilities.	7.3
Pretreatment of waste water from labor wards	In the sample, 96 of the health facilities did not pretreat their waste water before disposal.	87.3
Presence of expired pharmaceutical products	Expired pharmaceutical products were reported on the premises by 31 of the facilities.	28.2
Presence of storage for safekeeping of expired pharmaceutical products	85 health facilities did not have a cabinet for safekeeping of expired pharmaceutical products	77.3

6.4. Rwanda

The Rwandan government, through its Health Ministry, revised a 2002–2009 incineration policy for medical solid waste as part of a safer treatment of organic waste. The government is concerned that the policy will address all special healthcare solid waste in a significant way. The lack of proper technology and experienced employees, on the other hand, continues to be a barrier to the requisite incineration system. Despite the challenges in Rwanda, incineration is the best solution for the treatment of some pharmaceutical and municipal solid wastes (Kahigana, 2011). Sharps, pathological, and pharmaceutical trash are incinerated, infectious waste must be incinerated or deeply buried underground, while normal wastes are disposed of in a safe landfill, repurposed, or reused (Leoncie, 2017). A study was conducted three selected health care facilities in Kigali to assess the waste management practices. The results of this study show that waste management practices in all of the case study hospitals were unsatisfactory. There were no emission controls in place to prevent air pollution from incinerators. Furthermore, at the time the study was done, there were no plans in place to repair malfunctioning incinerators (Valentine, 2014). This makes a general conclusion that medical wastes which includes pharmaceuticals are not properly disposed.

6.5. Burundi

Using official government reports, a study was conducted in Burundi on existing procedures of solid medical waste management in 12 health care facilities, from storage to final disposal. The study revealed that pharmaceutical wastes and discarded medical plastics were dumped in nature or at open dumping sites in health care facilities, where they were burned sporadically or processed at off-site uncontrolled landfills. However, half of the health care facilities did not keep track of how much waste was disposed of at uncontrolled landfills. 95.5% of pharmaceutical wastes and abandoned medical plastics buried at open dumping sites and landfills were attributed to public health care facilities (Niyongabo et al., 2019a). In another study researchers focused at the generation of medical wastes, their management approaches, and the risk from generation to storage in 12 healthcare facilities in Bujumbura, Burundi. The results demonstrate that none of the facilities evaluated followed the national guidelines completely, and the majority of medical wastes were not appropriately managed from the source separation stage. The storage of medical waste was the least handled phase in the facilities analyzed (Niyongabo et al., 2019b).

6.6. South Sudan

South Sudan has drafted a National Medical Waste Management Policy, Guidelines for Medical Waste Management, and a Medical Waste Action Plan. These documents mention the "polluter pays" principle, which states that individuals who generate garbage are accountable for ensuring its safe disposal. Waste segregation at the source is required, as is proper storage, transportation, treatment, and disposal of medical waste (Chachorovski et al., 2017). In our literature search we didn't get published document regarding pharmaceuticals disposal in South Sudan.

7. Disposal practice of pharmaceuticals in household

Patients discontinue using medications for a variety of reasons, including intolerance to side effects, stopping the medication, changing the dosage, or drug expiration. This makes possession of unused or expired medications to people. The possession of medications at home is also linked to self-medication which is characterized by taking drugs, herbs, or alternative treatments on one's own initiative, or on the suggestion of another person, without contacting a prescriber. Analgesics, anti-malarial, antibiotics, and cough syrups are all frequent self-medication drugs (Mwita et al., 2019b; Mwita et al., 2019a). Self-medication is worldwide, with a high prevalence in developing nations, the frequency varies by country and geographical area. In Africa, the prevalence of self-medication ranges from 11.9% to 75.7% (Kajeguka and Moses, 2017). In most cases, due to a lack of awareness, these drugs may end up be given to friends/family members or inappropriately disposed of by rinsing them in a water sink, flushing them down the toilet, or throwing them away in a garbage can (Seehusen and Edwards, 2006). The convenience, availability, and ease of access to disposal or waste facilities determine the variety of various disposal techniques (Peake et al., 2016).

Disposal practice of pharmaceuticals in household level has been studied by different researchers in East African countries. The major disposal methods includes flushing via sink, toilet, or dumping in dustbin or trash (Marwa et al., 2021; Peake et al., 2016; Angi'enda and Bukachi, 2016). Many other countries are in the same circumstance. According to a study conducted in Ethiopia to assess disposal practices of unused pharmaceuticals among patients, the majority of the respondents, 224 (85.17%), had leftover pharmaceuticals at home during the study period. The most prevalent form of disposal was reported as flushing into a toilet, which was reported by 66 people (25.09%). None of the people polled had ever returned unused prescriptions to a pharmacist. Furthermore, 85 (32.31%) of respondents said they never throw away their drugs and think it's fine to keep them at home for future usage (Kassahun and Tesfaye, 2020).

According to a survey conducted in Kenya, the most chosen method of disposal is to put unwanted medicines in rubbish bins (28.66%), followed by flushing in toilets (25.00%) and disposal in special garbage bins (17.68%), with the least favored methods being burying and burning leftover medicines. Returning them to hospitals or pharmacies was seen to be a safer alternative by only a small number of respondents (Angi'enda and Bukachi, 2016). Even in developed countries like the United States and Canada, 35% and 46% of research participants said they flushed unwanted pharmaceuticals down the toilet, respectively (Abahussain et al., 2006).

8. Conclusion and recommendations

The findings from the studied literature reflected the current situation with pharmaceutical/medical waste disposal procedures in East African residences, pharmacies, and hospitals. In some of the countries studied there was a lack of enough information on disposal of pharmaceutical wastes. In all countries there was a lack of understanding and awareness among people and the environment concerning inappropriate pharmaceutical waste disposal and its dangerous implications. In both the household and health facility levels, the regulations and guidelines are not fully adhered to. Where pharmaceutical disposal facilities are available, they are either non-existent or in poor condition. As a result, the majority of medical waste, including pharmaceuticals, will enter the environment from health care facilities. This means there is a high risk of environmental contamination. The governments should have a budget to buy or repair defective disposal facilities, such as incinerators in health facilities. It should also enforce laws to prevent human health and the environment from poor disposal of pharmaceuticals. It is strongly advised that patients, doctors, pharmacists, and environmental practitioners be educated on the proper handling and disposal of medical waste and, in this case, pharmaceuticals.

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