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Solid medical waste management in Africa

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Increased awareness about inadequate management of solid medical waste (SMW) has led to increased independent surveys in African countries and yet published data remain scanty on the subject in Africa as compared to the rest of the world. To evaluate the overall compliance with World Health Organization (WHO)'s ten recommendations on SMW practices in Africa through a literature review, we conducted literature search using search terms as "medical waste OR clinical waste OR biomedical waste OR hospital waste OR healthcare waste OR hazardous waste AND Africa" in PubMed, African Journals Online, Web of Science, Proquest, Embase, Google scholar and Scopus. Additional articles were included from open google search. Articles were selected for inclusion if they described SMW management activities such as waste segregation, collection, transport (on-site and/or off-site), temporary storage, treatment and final disposal; were located in an African country and were written in English; or if written in a different language, had an English abstract with the relevant information. Evaluations were based on fifty eight (58) full text articles which were pooled together. The fifty eight (58) full text articles represented research undertaken in 20 countries. Overall, six countries (30%) broadly met half of the WHO's 10 recommendations. Based on the reviewed articles, the greatest compliance was shown with "daily collection of waste from the service areas" (100%). Areas of least compliance were "appropriate use of color codes" (18%) for labeling waste bins, "off-site conveyance" (16%) and "periodic training" (18%). In spite of growing awareness, SMW management in most African countries was sub-standard. Appropriate use of color codes, periodic training and off-site conveyance need to be addressed in terms of reporting and practice. Common challenges and unremarkable progress in SMW management in Africa raise a question about whether a unified approach should replace independent country efforts.

Key words: Africa, hospital waste, solid medical wastes, waste management.

INTRODUCTION

Solid medical waste has been referred to as any discarded solid material generated from activities involving health protection, medical diagnosis, treatment, scientific research, dental and veterinary services (US Congress Office of Technology Assessment, 1988; Rao, 2008; Coker et al., 2009; Hossain et al., 2011). This type of waste has been considered potentially harmful to humans and requires special treatment. Non-hazardous waste from health-care facilities is comparable to domestic waste and often ends up in the municipal solid waste stream discarded in landfills (Pruss et al., 1999).

Solid medical waste has remained a source of concern

because of the potential to transmit diseases, contaminate soil, surface and ground water with pathogenic microbes, toxic and heavy metals often present in it (Pruss et al., 1999). Diseases associated with poor medical waste management include nosocomial diseases, typhoid, skin disorders, intestinal parasitosis and hepatitis (Bassey et al., 2006).

In addition, there is a potential risk of HIV transmission to a susceptible human host from percutaneous injury by infected sharps (WHO, 2004). Therefore, inadequate handling and disposal of medical waste has consequences for patients, relatives or carers, healthcare workers, waste workers, scavengers, the public and the environment (Abor, 2007; Coker et al., 2009; Mesdaghinia et al., 2009).

Africa is estimated to have 67,740 health facilities and produce approximately 282,447 tons of medical waste every year (AGENDA, 2009, Udofia and Nriagu, 2013). However, the composition of the waste stream considered hazardous and requiring special treatment may be higher than the expected 10 to 25% because of poor waste handling practices reported in many studies (mixing hazardous with non-hazardous waste (Haylamicheal et al., 2011; Fadipe et al., 2011; Abah and Ohimain, 2011). Studies in Africa indicate the continent is not positioned to tackle the quantity of hazardous waste it produces. Much of the waste is dumped without treatment in open dumps and poorly functioning incinerators (Nkhuwa et al., 2008, Nemathaga et al., 2008, Sawalem et al., 2009, Coker et al., 2009, Saad, 2013). While increasing awareness has driven many individual country reports on general solid waste streams in Africa, the overall picture of solid medical waste management is unclear. Consequently information on solid medical wastes in Africa appears to remain on shelves and only scanty in scientific literature.

To the best of our knowledge, this review is the first on solid medical wastes in Africa and sought to compare medical waste management activities (segregation, collection, storage, transport, treatment and final disposal) reported in studies done in Africa with WHO recommendations (WHO, 2014). The general objective of the review was to determine how many of WHO standards were broadly met in each country in Africa and how specific waste management activities compared across the countries included in the review.

METHODS

Search strategy

A review of literature was conducted using electronic databases wide distribution of studies on healthcare and solid medical waste management. The search strategy employed was as follows:

1. PubMed was searched applying the terms ‘medical waste OR biomedical waste OR clinical waste OR hospital waste OR hazardous waste OR healthcare waste AND Africa’. Additional databases searched using the same search terms included Web of Science, Embase, Scopus, Proquest and African Journals Online.
2. The search was repeated with the same keywords but replacing Africa with names of individual countries. The list of African countries was adapted from World Bank websites: www.worldbank.org/en/region/mena (North African countries) and www.worldbank.org/en/region/afr (Sub-Saharan Africa) with the addition of Mauritius.
3. A more in-depth search on medical waste in Ghana and Madagascar using the search terms “medical waste in Ghana” and “medical waste in Madagascar” respectively, added 3 articles. All searches covered the period from 1997 up to October, 2014.

Articles were selected for inclusion in the review if they: described SMW management activities such as waste segregation, collection, transport (on-site and/or off-site), temporary storage, treatment and final disposal; with the study location in an African country and were written in English; or if written in a different language, had an English abstract with the relevant information. Articles which did not meet the selection criteria and focused on liquid waste management and veterinary services were excluded. Duplicate publications were removed manually.

The papers included for review were categorized and evaluated according to the following items: segregation into at least 2 categories of waste (sharps and non-sharps waste); appropriate use of color coded bags, containers and symbols; waste collected at least once a day from generation points; on-site transport with dedicated vehicle; secured temporary storage area; stored waste is treated or discarded not later than the second day; off-site transport in enclosed vehicles with back loading; treatment option includes an advanced thermal method for infectious waste; final disposal at sanitary landfill or disposal site; and periodic training of healthcare staff. These items were based on recommendations by WHO (2014) as the standard set for acceptable waste management activities.

RESULTS

Literature search

Table 1 summarizes the number of hits identified by databases and shows the number of articles involved in the preliminary screening. The flowchart (Figure 1) depicts the literature search process. The search in PubMed produced a total of 299 articles of which 278 articles were excluded on preliminary screening (Figure 1) and 1 full text unavailable in the databases. The other databases yielded a total of 38 articles in full text, after excluding those which were not available (4 articles). Finally, 58 full text articles that met the selection criteria were reviewed.

The reviewed articles covered twenty (20) countries

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Table 1. Distribution of articles according to databases searched.

Database	Number of hits (no filters)	Number of hits (with filter)
PubMed	299	299
African Journal Online	1,240	1,240
Web of Science	17,957	13,081 (Journal articles)
Embase	855	615 (Journal articles)
Scopus	96	69 (Journal articles)
Proquest	1,655,609	391,589 (Journal articles); 164,464 (scholarly articles)
Google Scholar	164,000 (Without patents, citation)	164,000

*In Proquest, journal articles refers to articles listed using search terms; scholarly articles refers to articles listed using 'scholarly articles' as a filter.

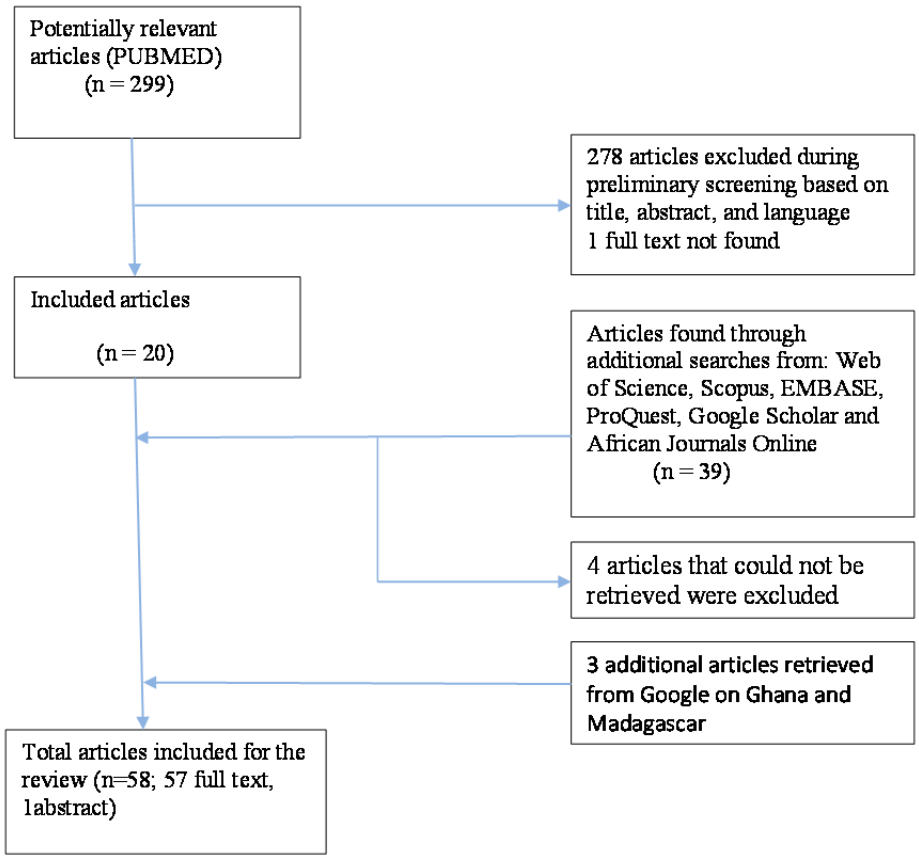

Figure 1. A schematic representation of the literature search process.

namely: Algeria, Botswana, Cameroun, Egypt, Ethiopia, Ghana, Kenya, Lesotho, Libya, Madagascar, Mauritius, Morocco, Nigeria, Senegal, Somaliland, South Africa, Sudan, Tanzania, Uganda and Zimbabwe (Table 2). Figure 2 shows the distribution of articles by these countries. Figure 3 shows the distribution of articles over the study period and indicates increasing interest and research in solid medical waste management in Africa.

Table 3 summarizes the characteristics of the identified articles. Twenty eight (28) studies (48%) covered a variety of healthcare facilities, such as public and private healthcare facilities or were a mix across the levels of the healthcare system– primary, secondary, tertiary level healthcare facilities. Most studies (55%) employed mixed methods. This often comprised of waste surveys (measuring the quantity and determining the composition of solid waste, that is, waste stream analysis) in healthcare facilities, questionnaire surveys of healthcare workers and housekeeping staff and direct observation of waste handling practices. In other studies, key informant

Table 2. List of reviewed articles on solid medical waste management in African countries.

Country	No. of articles	Reference (first author)*	Year of publication
Algeria	2	Bendjoudi	2009
		Beghdadli	2010
Botswana	1	Mbongwe	2008
Cameroun	1	Manga	2011
Egypt	2	Soliman	2007
		El-Salam	2010
Ethiopia	4	Azage	2010
		Haylamicheal	2011
		Debere	2013
		Muluken	2013
Ghana	4	Squire	2013
		Abor	2013
		Asante	2014
		Akum	2014
Kenya	1	Mazrui	2010
Lesotho	1	Majara	2009
Libya	1	Sawalem	2009
Madagascar	1	Odette	2014
Mauritius	1	Mohee	2005
Morocco	1	Mbarki	2013
Nigeria	23	Bassey	2006
		Longe	2006
		Babatola	2008
		Oke	2008
		Nguluka	2009
		Odigie	2009
		Coker	2009
		Ajimotokan	2009
		Ngouakam	2010
		Adedigba	2010
		Samuel	2011
		Johnson	2011
		Fadipe	2011
		Chima	2011
		Morenikeji	2011
		Abah	2011
		Jiburum	2012

Table 2. Contd.

Country	No. of articles	Reference (First author)	Year of publication
		Ogbonna	2012
		Oruonye	2012
		Longe	2012
		Tobin	2012
		Idowu	2013
		Uwa	2014
Senegal	1	Ndiaye	2012
Somaliland	1	DiBella	2012
		Nemathaga	2008
South Africa	3	Abor	2008
		Gabela	2009
Sudan	1	Saad	2013
		Mato	1997
		Mato	1999
Tanzania	5	Manyele	2006
		Manyele	2010
		Nilsson	2013
Uganda	1	Mugambe	2012
		Taru	2005
Zimbabwe	3	Jerie	2006
		Mangizvo	2008

*See appendix for full reference of the articles.

interviews were conducted with management staff regarding the awareness of existing policies, availability of waste plans and teams, as well as protocols on medical waste management in the healthcare facility. Eight articles involved review of secondary data, relevant documents and analysis of existing data. One article was a desk review of existing studies in Tanzania.

Waste management activities

Table 4 summarizes information reported on activities conducted in compliance with WHO's recommendations on solid medical waste management (WHO, 2014). In the table, the number of articles reporting compliance was inserted in parenthesis beside the countries. Forinstance, Nigeria, Tanzania (3) means that Nigeria and Tanzania each had three articles that reported compliance with the standard for the specific solid medical waste management activity.

The least reported activity was off-site transport which 19 articles reported and only three articles (in two countries) indicated compliance with the recommendations. Although all papers reporting daily waste collection indicated compliance with recommendations, this represented less than half of the reviewed articles and half of the countries represented. Overall, Nigeria and South Africa had articles reporting compliance with at least nine (9) of the ten (10) recommendations by WHO. However, South Africa demonstrated a higher overall compliance with fewer reviewed articles (3) as compared to Nigeria (23). The majority of countries fulfilled less than five recommendations.

DISCUSSION

To the best of the authors' knowledge, this review is the first attempt to present an overview of the status of SMW management activities in sub-Sahara Africa. Available evidence from the 58 journal articles from across 20 countries in sub-Sahara Africa in the period 1997 to 2014 indicates that SMW management still face many challenges and that South Africa appears to meet

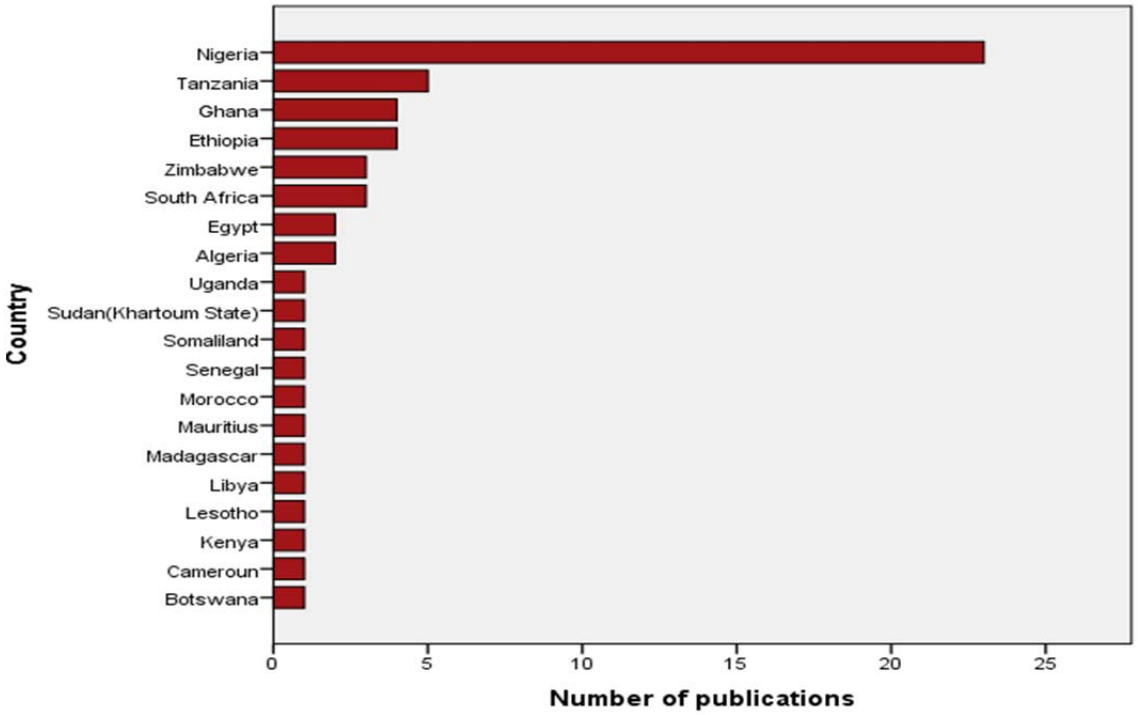

Figure 2. Distribution of studies by country.

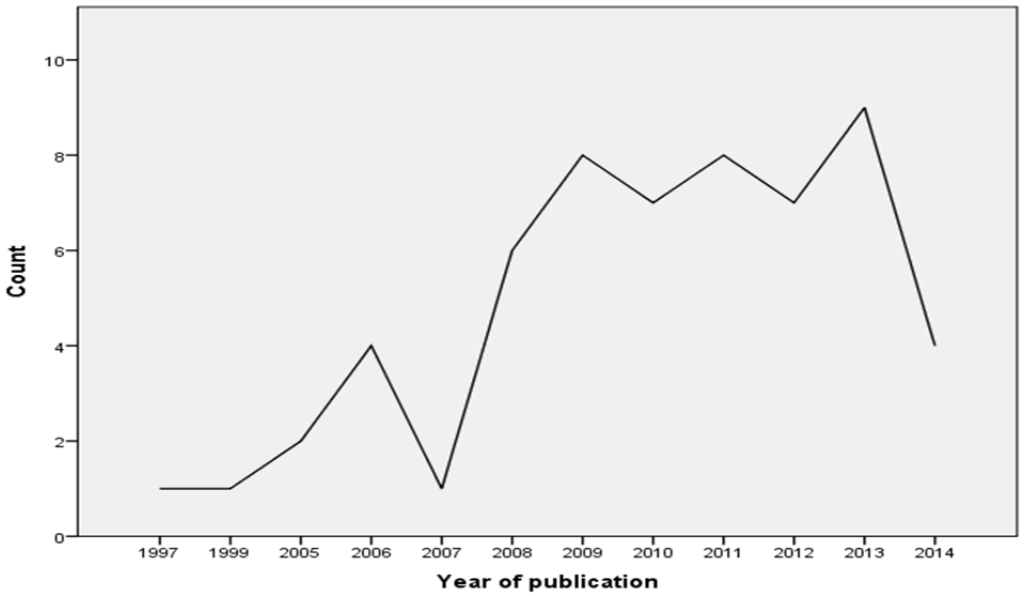

Figure 3. Distribution of articles by year of publication.

best practice according to the WHO-2014 recommendations on solid medical waste management practices. The fact that most of the papers were from reputable and credible scientific databases including peer-reviewed articles underlie the scientific validity of the findings, the most valuable information was obtained from surveys which covered a variety of healthcare facilities and was the method used in 35 articles. Case studies also provided greater detail and tended to cover most of the waste management activities discussed.

Table 3. Characteristics of articles reviewed on solid medical waste management activities in African countries, 1997-2014.

Characteristic	Description	Number of studies
Language	English	57
	French	1
Type of setting	Various health facilities	28
	Hospital(s)	20
	Clinics/Health centres	8
	Not specified	2
Type of research	Qualitative	9
	Quantitative	17
	Mixed	32
Research design	Survey/Cross sectional	35/13
	Desk review	1
	Case study	7
	Panel/Intervention study	2
Research technique*	Questionnaire administration	44
	Interviews	39
	Observation (checklists)	39 (4)
	Waste/other sampling	24
	Record review	8
	Focus group discussion	2

*More than one research technique was used in the studies.

Table 4. Compliance with WHO-2014 standards.

Standards for medical waste management	Number of articles reporting activity	Number of articles reporting compliance with standard N (%)	Number of countries reporting activity	Number of countries reporting compliance with standard N (%)	Countries showing compliance with standard
Waste segregation into at least 2 categories	57	31 (53)	20	18 (90)	Nigeria (3), Tanzania, South Africa, Ghana (3), Egypt (2), Botswana, Cameroun, Ethiopia, Kenya, Lesotho, Libya, Madagascar, Morocco, Senegal, Somaliland, Sudan, Uganda, Zimbabwe (1)
Appropriate use of color codes and symbols	45	8 (18)	17	6 (35)	Nigeria (3), Egypt, Ghana, Lesotho, Madagascar, South Africa (1)
Daily waste collection from service areas	21	21 (100)	10	10 (100)	Nigeria (8), Ethiopia (3), South Africa, Tanzania (2), Cameroun, Egypt, Ghana, Sudan (Khartoum State), Uganda, Zimbabwe (1)
Dedicated vehicle for onsite transport	37	11 (30)	17	9 (53)	Nigeria (3), Ghana, Libya, Madagascar, Senegal, Somaliland, South Africa, Sudan, Uganda (1)

Table 4. Contd.

Standards for medical waste management	Number of articles reporting activity	Number of articles reporting compliance with standard N (%)	Number of countries reporting activity	Number of countries reporting compliance with standard N (%)	Countries showing compliance with standard
Secured temporary storage area	31	7 (23)	14	5 (36)	Egypt, Nigeria (2), Ghana, Morocco, South Africa (1)
Stored waste treated no later than 2nd day	27	12 (44)	11	9 (82)	Egypt, Nigeria, Tanzania (2), Algeria, Ethiopia, Lesotho, South Africa, Sudan (Khartoum), Zimbabwe (1)
Off-site transport in enclosed back loading vehicles	19	3 (16)	11	2 (18)	Nigeria (2), Zimbabwe (1)
Treatment option includes advanced thermal option	56	41 (73)	19	18 (95)	Nigeria (12), Tanzania (5), Ethiopia (4), Zimbabwe (3), Algeria, Egypt, Ghana (2), Botswana, Cameroun, Lesotho, Libya, Madagascar, Mauritius, Senegal, Somaliland, South Africa, Sudan, Uganda (1)
Final disposal at sanitary landfill or dedicated site	44	17 (39)	15	10 (67)	Nigeria (7), Zimbabwe (2), Algeria, Egypt, Ethiopia, Ghana, Kenya, Mauritius, South Africa, Uganda (1)
Periodic training of healthcare staff	39	7 (18)	15	6 (40)	Nigeria (2), Algeria, Ghana, Morocco, South Africa, Tanzania (1)

*The total number of articles reviewed = 58; the total number of countries represented = 20.

More than half (53%) of the publications reported segregation of SMW but appropriate use of color coded receptacles was low (18%). Segregation was reported at least for sharps in most countries. Poorly separated waste increases the amount of waste sent for incineration or sent untreated to the landfill. Overloading incinerators eventually made them dysfunctional. Untreated waste in open dumps or unsecured landfills had the potential of transmitting infections to scavengers. Collection bags (including colour coded ones) were reported to be diverted to other uses such as storage of items by patients' relatives making it difficult to appreciate that the materials contained in the bags were potentially harmful (Mbongwe et al., 2008). The inappropriate use of black plastic bags for infectious waste in a bid to save costs has also been reported (Majara and Leduka, 2009). In healthcare facilities where waste is segregated, it often gets mixed at the temporary storage site or during collection by transporting companies or waste collection service providers (Coker et al., 2009; Debere et al., 2013; Sawalem et al., 2009). Appropriate segregation and resource recycling has been found to achieve a 15% reduction in the quantity of medical wastes (Sabour et al., 2007). This has economic implications for the health sector. For instance, it was noted that £15 million could be potentially saved in the UK, through improved segregation and waste minimization of the 40-60% of the healthcare waste stream which is non-hazardous (Tudor et al., 2009).

It has also observed in the UK that segregation of medical waste has not been given high priority. Some of the barriers are no different from those in African countries, limited space for multiple receptacles at service areas, inadequate budgetary provision for waste management activities and limited continuous training opportunities for healthcare workers (Tudor et al., 2009).

Our review indicated that nearly a quarter of articles reported compliance by most facilities having a secured storage area. Storage areas were often unsecure permitting access to both unauthorized persons and stray animals (Bendjoudi et al., 2009; Ndiaye et al., 2012; Nemathaga et al., 2008, Sawalem et al., 2009). In some cases, no temporary storage area existed in the facilities surveyed (Muluken et al., 2013). Scavengers and workers

often recover valuable items to recycle and re-sell to the public (Bassey et al., 2006; Taru and Kuvarega, 2005). Rodents may serve as vehicles for pathogens in untreated SMW. Both act in different ways as 'bridge populations' with potential to transmit infectious agents to the general population. Inadequate contain-ment of medical wastes, collection and storage has been reported in both advanced (Blenkharn, 2007) and developing countries (Manga et al., 2011; Mbongwe et al., 2008)

All papers that reported daily collection of waste showed that most facilities complied with this standard, but only 30% of the reviewed articles reported com-pliance by use of dedicated vehicles for on-site collection. Although conveyances used included wheeled carts, trolleys and wheelbarrows (Abor, 2013; Ndiaye et al., 2012), manual lifting of waste receptacles by hospital cleaners, waste handlers and auxiliary staff was also reported (Abah and Ohimain, 2011; Coker et al., 2009; Manga et al., 2011; Muluken et al., 2013). In Zimbabwe, a small vehicle with a carrying capacity of up to 14 waste bins at once (totaling 15kilograms in mass) was used to convey SMW from hospital corridors to the storage site. This vehicle was able to collect an estimated 124 bins daily (Taru and Kuvarega, 2005). In some of the studies reviewed, vehicles that were reportedly used to convey SMW to final disposal sites were not described in detail especially when municipal trucks (Manga et al., 2011) or waste companies were used (Abor, 2013).

In healthcare facilities where disposal was reported to be done on-site, open dumping in refuse pits, burning and burial have been described (Ajimotokan and Aremu, 2009; Manyele and Anicetus, 2006; Abah and Ohimain, 2011; Manga et al., 2011). Although incineration was available and compliance was reported by 73% of the articles, they were often rudimentary, dysfunctional and/or lacked regular maintenance (Abd El-Salam, 2010; Mbongwe et al., 2008; Nemathaga et al., 2008; Nkhuwa et al., 2008). Most incinerators described did not have modern technology such as air pollution control (APC) equipment and adequate air inlets. They often had a single chamber made from local bricks, which did not completely burn off the gases generated during combustion process.

Furthermore, coal or wood fuels were used for combus-tion which made it difficult to control the temperature. As a result, they became a source of air pollution themselves especially within the hospital premises and the surroun-ding communities (Jerie, 2006; Nemathaga et al., 2008). Incinerators were often loaded with plastics made of polyvinyl chloride (PVC) which released carcinogenic dioxins and furans on incineration (Nemathaga et al., 2008; Singh and Prakash, 2007).

Due to incomplete burning of the waste, a large quantity of ash has been reported to be generated with high concentration of heavy metals. Such ash may find application as manure for growing vegetables (Nkhuwa et al., 2008). Heavy metals find their way into the food chain and are ultimately consumed by humans with considerable implications for human health. In contrast, common methods used for medical waste treatment in advanced countries include steam sterilization, auto-claving and incineration (Patwary et al., 2011). Treatment technologies in the UK fall into two main categories: high temperature incineration/combustion and non-burn or low temperature alternative technologies (Tudor et al., 2009). In the first category, examples include incineration, pyrolysis, plasma technology and gasification whereas examples in the second category (non-burn technology), are: autoclaves, steam augur, dry heat, microwaves and macro-waves (Tudor et al., 2009). In Canada, there has been a shift from onsite incinerators towards centralized facilities, which handle medical waste generated over a wide geographic area (Walkinshaw, 2011). This approach helps to reduce air pollution resulting from on-site incineration.

An interesting dimension was the use of unlined placenta pits which are fed with acid digesters to prevent them from getting full (Nkhuwa et al., 2008). In areas where the ground water table is shallow and the soil porosity permits easy percolation, potential contamination of groundwater could be possible (Nkhuwa et al., 2008). Placentae were also taken home to bury in keeping with traditional (Manga et al., 2011) or religious practices (Abd El-Salam, 2010). Due to the natural decomposition of placental organic contents, it is considered less harmful in more stable soils.

In some of the articles that reported training of healthcare workers, training in solid medical waste management was found to be inadequate and was not undertaken periodically (Coker et al., 2009; Haylamicheal et al., 2011; Saad, 2013; Sawalem et al., 2009). Similarly, the present survey showed that only one of every six articles reported periodic training in the surveyed health-care facilities. It has been shown that there is a significant association between training in healthcare waste management and waste management practices (Muluken et al., 2013). However, Beghdadli and co-authors (2010) portend that while training and the provision of color coded receptacles are essential, these measures alone are not sufficient for segregation of solid medical waste. Accountability and remedial action for waste malpractices by health staff should be defined and upheld in relevant facilities (Beghdadli et al., 2010).

Conclusion

This review provides an overview of solid medical waste management practices in Africa as evident in published literature. Key weaknesses identified were the inappro-priate use of color codes and symbol, lack of periodic training for health staff and off-site transport in appro-priate vehicles. Although incineration was often used as an advanced thermal option, it was often dysfunctional or

lacked air pollution control equipment. Traditional methods of open burning and burial were still commonplace. Institutional challenges relating to appropriate use of colour codes and symbols, and periodic training can be addressed with adequate management commitment and technical support from health ministries. As off-site transport is often the responsibility of municipal authorities or privately contracted, it is essential that health and environment ministries, municipal authorities, private and public sector waste management firms collaborate to ensure that vehicles assigned for transport of solid medical waste are appropriately designed, labelled and dedicated for solid medical waste to minimize potential risk to the public. Selection of waste treatment technologies and final disposal options should be done in a manner that takes into account impacts on human health and the environment (healthcare facility and communities living in proximity to it), capital and maintenance costs, technical capability, local resource constraints and the prevalence of scavenging peculiar to SMW.

The review revealed that independent national efforts have made only slow progress in managing solid medical waste leaving the authors to question whether or not a unified approach across all countries would yield better results. A unified approach demands the assemblage of experts in solid medical waste management and related disciplines across the continent to identify and aggregate available technology, expertise, funding, and best practices to bear on SMW management. A conference which brings together waste management experts, toxicologists, public health (environmental and occupational health) experts, governments, and other stakeholders focused on SMW management in Africa would be a good starting point. Challenges faced in African countries which are not often articulated in published literature, can be shared at such gatherings. Sharing and documentation of country experiences should include a platform for improving visibility and accessibility of information from participating countries to strengthen research and evaluation. Funding mechanisms for SMW management and accessibility of funds is critical to every activity especially improving technology for waste treatment. However, priority should be given to internal funding which is self-sustaining rather than externally funded projects.

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Conflict of interests

The authors did not declare any conflict of interest.

REFERENCES

Abah SO, Ohimain EI (2011). Healthcare waste management in Nigeria: A case study. J. Public Health Epidemiol. 33:99-110.

Abd El-Salam MM (2010). Hospital waste management in El-Beheira Governorate, Egypt. J Environ Manage. 91(3):618-629.

Abor PA (2007). Medical Waste Management Practices in a Southern African Hospital. J. Appl. Sci. Environ. Manage. 11(3):91-96.

Abor PA (2013). Managing healthcare waste in Ghana: a comparative study of public and private hospitals. Int. J. Health Care Qual. Assur. 26(4):375-386.

AGENDA for Environment and Responsible Development (2009). Needs Assessment for Hospitals in African Countries in Relation to Infectious Waste Treatment Final Report - Demonstrating and Promoting Best Techniques and Practices for Reducing Health Care Waste to Avoid Environmental Releases of Dioxins and Mercury. Dar es Salaam, Tanzania.

Ajimotokan HA, Aremu SA (2009). Case Study Evaluation of Health-Care Waste Challenges in Hospitals within Ilorin Metropolis. Civil Engineering Impact on National Development: 1st Annual Civil Engineering Conference, University of Ilorin, Nigeria, 26-28 August, 2009. pp. 130-134.

Bassey BE, Benka-Coker MO, Aluyi HSA (2006). Characterization and management of solid medical wastes in the Federal Capital Territory, Abuja Nigeria. Afr. Health Sci. 6(1):58-63.

Beghdadli B, Ghomari O, Taleb M, Kandouci BA, Fanello S(2010). Implementation of WHO healthcare waste management (HCWM) approach in an Algerian hospital. Waste Manag. 30 (1): 162-164.

Bendjoudi Z, Taleb T, Abdelmalek F, Addou A (2009).Healthcare waste management in Algeria and Mostganem department. Waste Manag. 29(4):1383-1387.

Blenkharn JI (2007). Standards of clinical waste management in hospitals - A second look. Public Health 121(7):540-545.

Coker A, Sangodoyin A, Sridhar M, Booth MC, Olomolaiye P, Hammond F (2009). Medical waste management in Ibadan, Nigeria: Obstacles and prospects. Waste Manag. 29(2):804-811.

Debere MK, Gelaye KA, Alamdo AG, Trifa ZM (2013). Assessment of the health care waste generation rates and its management system in hospitals of Addis Ababa, Ethiopia, 2011. BMC Public Health 13:28.

Fadipe OO, Oladepo KT, Jeje JO, Ogedengbe MO (2011). Characterization and analysis of medical solid waste in Osun State, Nigeria. Afr. J. Environ. Sci. Technol. 5(12):1027-1038.

Haylamicheal ID, Mohamed AD, Yirsaw BD, Zegeye HA (2011). Assessing the management of healthcare waste in Hawassa City, Ethiopia. Waste Manag. Res. 29(8):854-862.

Hossain MS, Santhanam A, Norulani NAN, Omar AKM (2011). Clinical solid waste management practices and its impact on human health and environment – A review. Waste Manag. 31 (4): 754-766.

Jerie S (2006). Analysis of Institutional Solid Waste Management in Gweru, Zimbabwe. East. Afr. Soc. Sci. Res. Rev. 22(1): 103-125.

Majara M, Leduka RC (2009). Health-Care Waste Practices in Selected Health-Care Facilities in Maseru. Rev. South. Afr. Stud. 12(1):1-29.

Manga VE, Morton OT, Mofor LA, Woodard R (2011). Health care waste management in Cameroon: A case study from the Southwestern

Region. Resour. Conserv. Recycl. 57:108-116.
Manyele SV, Anicetus H (2006). Management of medical waste in Tanzanian hospitals. Tanzan. Health Res. Bull. 8(3):177-182.
Mbongwe B, Mmereki BT, Magashula A (2008). Healthcare waste management: current practices in selected healthcare facilities, Botswana. Waste Manag. 28(1):226-233.
Mesdaghinia A, Naddafi K, Mahvi AH, Saeedi R (2009). Waste management in primary healthcare centres of Iran. Waste Manage. Res 27(4):354-361.
Muluken A, Haimot G, Mesafint M (2013). Healthcare waste management practices among healthcare workers in health care facilitiesof Gondar town, Northwest Ethiopia. Health Sci. J. 7(3): 315-326.
Ndiaye M, El Metghari L, Soumah MM, Sow ML (2012). [Biomedical waste management in five hospitals in Dakar, Senegal]. Bull. Soc. Pathol. Exot. 105(4):296-304.
Nemathaga F, Maringa S, Chimuka L (2008). Hospital solid waste management practices in Limpopo Province, South Africa: a case study of two hospitals. Waste Manage. 28(7):1236-1245.
Nkhuwa DCW, Kafula T, Ahmed AH 2008.Preliminary Inventory of Hazardous Medical Waste Disposal Systems and their influence on Groundwater Quality in Lusaka. Med. J. Zamb. 35(4):129-138.
Patwary MA, O'Hare WT, Sarker MH (2011). Assessment of occupational and environmental safety associated with medical waste disposal in developing countries: A qualitative approach. Saf. Sci. 49(8-9):1200-1207.
Pruss A, Giroult E, Rushbrook P (1999). Safe management of wastes from health-care activitiesGeneva, Switzerland: World Health Organization. pp. 1-30.
Rao PH (2008). Report: Hospital waste management – awareness and practices: a study of three states in India. Waste Manage. Res. 26:297-303.
Saad SA (2013). Management of hospitals solid waste in Khartoum State. Environ. Monit. Assess. 185 (10): 8567 -8582.
Sabour MR, Mohamedifard A, Kamalan H (2007). A mathematical model to predict the composition and generation of hospital wastes in Iran. Waste Manage. 27(4):584-587.
Sawalem M, Selic E, Herbell J-D (2009). Hospital waste management in Libya: A case study. Waste Manage. 29(4):1370-1375.
Singh S, Prakash V (2007). Toxic Environmental Releases from Medical Waste Incineration: A Review. Environ. Monit Assess. 132:67-81.
Taru P, Kuvarega AT (2005). Solid medical management – the case of Parirenyatwa Hospital, Zimbabwe. Rev. Biomed. 16:153-158.
Tudor TL, Townend WK, Cheeseman CR, Edgar JE (2009). An overview of arisings and large-scake treatment technologies for healthcare waste in the United Kingdom. Waste Manage. Res. 27:374-383.
U. S. Congress Office of Technology Assessment (1988). Issues in Medical Waste Management: Background Paper, OTA-BP-O-49. Washington D.C: United States Government Printing Office, 1988.
Udofia EA, Nriagu J (2013). Health-care Waste in Africa: A silent crisis? Glob. Health Perspect. 1(1):3-10.
Walkinshaw E (2011). Medical waste-management practices vary across Canada. CMAJ 183(18):1307-1308.
WHO (2004). Review of Health Impacts from Microbiological Hazards in Healthcare Wastes. Department of Blood Safety and Clinical Technology and Department of Protection of the Human Environment, World Health Organization, pp. 12-13.
WHO (2014). Safe management of wastes from healthcare activities (2nd edn). Geneva, Switzerland: WHO Press, pp. 102, 136-138, 181-190.

Appendix. List of references for the reviewed articles.

Country	Number of articles reviewed	References
Algeria	2	Bendjoudi Z, Taleb T, Abdelmalek F, Addou A (2009). Healthcare waste management in Algeria and Mostganem department. Waste Manag. 29(4): 1383-1387. Beghdadli B, Ghomari O, Taleb M, Kandouci BA, Fanello S (2010). Implementation of WHO healthcare waste management (HCWM) approach in an Algerian hospital. Waste Manag. 30 (1): 162-164.
Botswana	1	Mbongwe B, Mmereki BT, Magashula A (2008). Healthcare waste management: current practices in selected healthcare facilities, Botswana. Waste Manag. 28(1): 226–233.
Cameroun	1	Manga VE, Morton OT, Mofor LA, Woodard R (2011). Health care waste management in Cameroon: A case study from the Southwestern Region. Resources, Conservation and Recycling 57:108–116.
Egypt	2	Soliman SM, Ahmed AI (2006). Overview of biomedical waste management in selected governorates in Egypt: A pilot study. Waste Manag. 27(12): 1920-1923. Abd El-Salam MM (2010). Hospital waste management in El-Beheira Governorate, Egypt. J Environ Manage. 91 (3): 618-629.
Ethiopia	4	Azage M, Kumie A (2010). Healthcare waste generation and its management system: the case of health centers in West Gojjam Zone, Amhara Region, Ethiopia. Ethiop. J. Health Dev. 24(2): 119 – 126. Haylamicheal ID, Mohamed AD, Yirsaw BD, Zegeye HA (2011). Assessing the management of healthcare waste in Hawassa City, Ethiopia. Waste Manag Res 29(8): 854-862. Debere MK, Gelaye KA, Alamdo AG, Trifa ZM (2013). Assessment of the health care waste generation rates and its management system in hospitals of Addis Ababa, Ethiopia, 2011. BMC Public Health 13: 28. Muluken A, Haimot G, Mesafint M (2013). Healthcare waste management practices among healthcare workers in health care facilities of Gondar town, Northwest Ethiopia. Health Science Journal 7(3): 315-326.
Ghana	4	Squire (2013). Biomedical Pollutants in the Urban Environment and Implications for Public Health: A Case Study. ISRN Public Health vol. 2013, Article ID 497490, 5 pages. Abor PA (2013). Managing healthcare waste in Ghana: a comparative study of public and private hospitals. Int J Health Care Qual Assur. 26(4): 375-386. Asante OB, Yanful E, Yaokumah EB (2014). Healthcare Waste Management; Its Impact: A Case Study Of The Greater Accra Region, Ghana. International Journal of Scientifiic and Technology Research 3(3): 106 -112. Akum FA (2014). An Assessment of Medical Waste Management in Bawku Presbyterian Hospital of the Upper East Region of Ghana. Merit Res. J. Environ. Toxicol. 2(2): 27 – 38.
Kenya	1	Mazrui N (2010). Medical Waste Management in Kenya: Opportunities for improvement. Tropical Resources Bulletin of the Yale Tropical Resources Institute 29: 66-70.
Lesotho	1	Majara M, Leduka RC (2009). Health-Care Waste Practices in Selected Health-Care Facilities in Maseru. Review of Southern African Studies 12(1): 1-29.
Libya	1	Sawalem M, Selic E, Herbell J-D (2009). Hospital waste management in Libya: A case study. Waste Manag. 29(4): 1370 - 1375.
Madagascar	1	Odette RH, Masika J, Venance T, Soatiana JE, Christane NA, Lamine CM, Bin L (2014). Assessment of healthcare waste generation and its management systems: A prevalence survey of the healthcare facilities in Madagascar.IOSR-JESTFT 8(7 ver. III): 20 -29.

Appendix. Contd.

Country	No. of articles reviewed	Reference(s)
Mauritius	1	Mohee R (2005). Medical wastes characterization in healthcare institutions in Mauritius. Waste Manag. 25(6): 575 -581.
Morocco	1	Mbarki A, Kabbachi B, Ezaidi A, Benssaou M (2013). Medical Waste Management: A Case Study of the Souss-Massa-Draa Region, Morocco. JEP 4: 914-919.
Nigeria	23	Bassey BE, Benka-Coker MO, Aluyi HSA (2006). Characterization and management of solid medical wastes in the Federal Capital Territory, Abuja Nigeria. Afr Health Sci. 6(1):58-63. Longe EO, Williams A (2006). A Preliminary Study of Medical Waste Management in Lagos Metropolis, Nigeria. Iran. J. Environ. Health. Sci. Eng. 3(2): 133-139. Babatola JO, 2008. A Study of Hospital Waste Generation and Management Practice in Akure, Nigeria. African Research Review 2(3): 292-305. Oke IA (2008). Management of immunization solid wastes in Kano State, Nigeria. Waste Manag. 28(12): 2512-2521. Ngwuluka N, Ochekpe N, Odumosu P, John SA (2009). Waste management in healthcare establishments within Jos metropolis, Nigeria. Afr. Sci. Environ. Sci. Technol. 3 (12):459 – 465. Odigie JO, Siminialayi IM (2009). Medical waste management at the University of Port Harcourt Teaching Hospital. Port Harcourt Medical Journal 4: 23 – 28. Coker A, Sangodoyin A, Sridhar M, Booth MC, Olomolaiye P, Hammond F (2009). Medical waste management in Ibadan, Nigeria: Obstacles and prospects. Waste Manag. 29 (2): 804-811. Ajimotokan HA, Aremu SA (2009). Case Study Evaluation of Health-Care Waste Challenges in Hospitals within Ilorin Metropolis. Civil Engineering Impact on National Development: 1st Annual Civil Engineering Conference, University of Ilorin, Nigeria, 26-28 August, 2009, pp. 130-134. Ngouakam H, Aniekan UU, Onojeta AF (2010). Management of solid clinical wastes in some hospitals in Akwa Ibom State, Nigeria. International Journal of Natural and Applied Sciences 6(1): 92-100. Adedigba MA, Nwhator SO, Afon A, Abegunde AA, Bamise CT (2010). Assessment of dental waste management in a Nigerian tertiary hospital. Waste Manag Res. 28(7): 769 – 777. Samuel SO, Aderibigbe SA, Nwigwe CG, Nyamngee A (2011). Opinion of Health Workers On, And Their Safety Practices In Connection With The Handling Of Medical Wastes At A University Hospital in South East Nigeria. EMJ 10(1): 75 – 78. Johnson O (2011). Statistical Analysis of Medical Waste Generation, Management and Health Implications in Enugu Metropolis, Enugu State, Nigeria. Environment and Ecology 29(1A): 301 – 305. Fadipe OO, Oladepo KT, Jeje JO, Ogedengbe MO (2011). Characterization and analysis of medical solid waste in Osun State, Nigeria. Afr. J. Environ. Sci Technol. 5(12): 1027-1038. Chima GN, Ezekwe IC, Digha NO (2011). An assessment of medical waste management in health institutions in Yenagoa, South-South, Nigeria.World Review of Science, Technology and Sust. Development 8(2/3/4): 224-233. Morenikeji OA (2011). An investigation of the disposal of dental clinical waste in Ibadan City, south-west Nigeria. Waste Manag Res. 29(3): 318 – 322. Abah SO, Ohimain EI (2011). Healthcare waste management in Nigeria: A case study. J. Public Health Epidemiol. 33: 99-110. Jiburum BC, Jiburum U (2012). An appraisal of medical waste management in four tertiary hospitals in Enugu, Nigeria. Port Harcourt Medical Journal 6: 192 – 197. Ogbonna DN, Chindah A, Ubani N (2012). Waste management options for health care wastes in Nigeria: A case study of Port Harcourt hospitals. J Public Health Epidemiol. 4(6): 156-169. Oruonye ED (2012). An Assessment of Medical Waste Disposal Methods in Jalingo Metropolis, Taraba State Nigeria. I. J. A. B. R. 2(1): 67-71. Longe EO (2012). Healthcare waste management status in Lagos State, Nigeria: a case study from selected healthcare facilities in Ikorodu and Lagos Metropolis. Waste Manag Res 30 (6): 562-571.

Appendix. Contd.

Country	Number of articles reviewed	Reference(s)
Nigeria	23	Tobin EA, Ediagbonya TF, Asogun DA, Oteri AJ (2013). Assessment of Healthcare Waste Management practices in Primary Health Care Facilities in a Lassa Fever Endemic Local Government Area of Edo State, Nigeria. AFRIMEDIC Journal 4(2): 16-23. Idowu I, Alo B, Atherton W, Khaddar RA (2013). Profile of medical waste management in two healthcare facilities in Lagos, Nigeria: a case study. Waste Manag Res 31(5): 494-501. Uwa CU (2014). Assessment of Healthcare Waste Management Practices in Enugu Metropolis, Nigeria. IJESD 5(4): 370 – 374.
Senegal	1	Ndiaye M, El Metghari L, Soumah MM, Sow ML, 2012. [Biomedical waste management in five hospitals in Dakar, Senegal]. Bull Soc. Pathol Exot. 105(4): 296-304.
Somaliland	1	Di Bella V, Ali M, Vaccari M (2012). Constraints to healthcare waste treatment in low-income countries – a case study from Somaliland. Waste Manag Res 30 (6): 572-575.
South Africa	3	Nemathaga F, Maringa S, Chimuka L (2008). Hospital solid waste management practices in Limpopo Province, South Africa: a case study of two hospitals. Waste management 28(7): 1236–1245. Abor PA, Bouwer A (2008). Medical waste management practices in a Southern African hospital. International Journal of Healthcare Quality Assurance 21(4): 356-364. Gabela SD, Knight SE (2010). Healthcare waste management in clinics in a rural health district in KwaZulu-Natal. South Afr J Epidemiol Infect 25(1): 19-21.
Sudan	1	Saad SA (2013). Management of hospitals solid waste in Khartoum State. Environ Monit Assess. 185 (10): 8567 -8582.
Tanzania	5	Mato RRAM, Kassenga GR (1997). A study on problems of management of medical solid wastes in Dar es Salaam and their remedial measures. Resources, Conservation and Recycling 21: 1-16. Mato RRAM, Kaseva ME (1999). Critical Review of industrial and medical waste practices in Dar es Salaam City. Resources, Conservation and Recycling 25(3-4): 271-287. Manyele SV, Anicetus H (2006). Management of medical waste in Tanzanian hospitals. Tanzan Health Res Bull. 8(3):177-182. Manyele SV, Lyasenga TJ (2010). Factors affecting medical waste management in low level health facilities in Tanzania. African Journal of Environmental Science and Technology 4(5):304-318. Nilsson J, Pembe AB, Urasa M, Darj E, 2013. Safe injections and waste management among healthcare workers at a regional hospital in northern Tanzania. Tanzania Journal of Health Research 15(1): 0-7.
Uganda	1	Mugambe RK, Ssempebwa JC, Tumwesigye NM, van Vliet B, Adedimeji A, 2012. Healthcare waste management in Uganda: management and generation rates in public and private hospitals in Kampala. J Public Health 20: 245-251.
Zimbabwe	3	Taru P, Kuvarega AT (2005). Solid medical management – the case of Parirenyatwa Hospital, Zimbabwe. Rev Biomed 16: 153-158. Jerie S (2006). Analysis of Institutional Solid Waste Management in Gweru, Zimbabwe. Eastern Africa Social Science Research Review 22(1): 103-125. Mangizvo RV, Chinamasa R (2008). Solid medical waste management: The case of Kwekwe City in Midlands Province, Zimbabwe. Journal of Sustainable Development in Africa 10(3): 188-200.