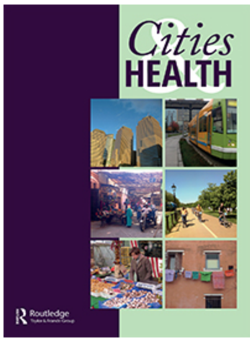

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ORIGINAL SCHOLARSHIP

Biomedical waste management in Dakar, Senegal: legal framework, health and environment issues; policy and program options

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ABSTRACT
Increases in population and the number of health-care facilities in Dakar has led to considerable increase in biomedical waste (BMW) generation, posing a huge challenge to the already burdened city's waste management system. Following the special treatment required for BMW due to associated population health and environmental risks, the gap in infrastructural development and the search for pathways to address the challenge, this position paper, examines the evolution of legal framework for biomedical wastes management, related health and environmental issues and policy and program options in the city. Historically, Senegal has ratified many international treaties, including Basel, Stockholm, and Bamako Conventions; however, the paper demonstrates a lack of an efficient chain for BMW disposal in the city. The triangulation of secondary data sources, including implementation evidence, and recent qualitative and quantitative study highlights the disconnections between multiple legal and policy commitments and their efficient implementation, with major barriers attributed to lack of financial resources and weak law enforcement, not only for BMW but solid waste in general. The evidence calls for significant investments for an effective BMW management to address environmental contamination, human exposure and associated loss to health in Dakar and implementation lessons for other Global South municipal actors.

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Biomedical Waste; legal Framework; policy; health; environment; Dakar

Introduction

In many developing countries, the number of health-care facilities has rapidly increased to better serve the increasing populations resulting from a rapid population growth (Perrott and Holland 2005, Mbongwe *et al.* 2008). While health-care facilities are important for preventative and curative care, they increasingly generate a significant volume of wastes (Bai *et al.* 2013), referred to as 'medical waste', 'health-care wastes', or 'biomedical wastes.' According to World Health Organization (WHO), about 80% of the waste typically produced by health-care providers are coming mostly from the administrative, kitchen and housekeeping functions at health-care facilities, are non-hazardous and comparable to domestic waste (World Health Organization (WHO) 2014). However, the rest of the wastes are about 15% of infectious wastes (e.g. wastes from cultures and stocks of infectious agents, infected patients, contaminated blood and its derivatives, discarded diagnostic samples) and anatomic wastes (recognizable body parts and carcasses of animals); and about 5% of sharps, toxic chemicals and pharmaceuticals and radioactive wastes. In practice, this composition varies across countries depending upon the advancement of biomedical waste management in the country (World Health Organization (WHO) 2014). Healthcare waste generation, improper or poor treatment and disposal, expose patients, relatives, health-care workers, scavengers, and the public to infectious pathogens, toxic chemicals, heavy metals, substances that are genotoxic, with the greatest risks being on children when they come into contact with these wastes (Abor and Bouwer 2008, Mesdaghinia *et al.* 2009, Coker *et al.* 2009, Abor 2013).

Africa is estimated to have 67, 740 health facilities and produce approximately 282, 447 tons of medical waste every year (Tulokhonova and Ulanova 2013). Previous studies have shown that municipal solid waste management in sub-Saharan African (SSA) cities are inefficient and ineffective (Laner *et al.* 2012, Komakech 2014); yet hazardous health-care wastes require some special treatment, thereby adding a new strain on the waste management systems especially in terms of cost (Bai *et al.* 2013). Medical (or biomedical) wastes pose different threats to humans and the environment and without proper segregation, non-infectious biomedical wastes can become contaminated and become infectious, posing further human and environmental threats (Udofia *et al.* 2015). In sub-Saharan African cities, the lack of proper storage,

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collection, transportation, treatment and disposal has made biomedical waste management a source of increasing public health concern (Udofia *et al.* 2015) and the search for pathways to address the challenge an imperative research, policy and action agenda.

Spread over 550 km^2 (0.3% of the national territory) and concentrating nearly 25% of the Senegalese population (Agence National de la Statistique et de la Demographie du Senegal 2014), Dakar typifies both the rapid population growth in urban areas of Africa and the critical challenges on urban planning, in general, and waste management in particular. Being the hub of almost 80% of the country's economic and industrial activities, Dakar is the main 'solid waste producer' in Senegal with about 2000 tons of solid waste per day (Diawara 2009). Notwithstanding, SWM practices in the city are yet to be aligned with such heavy production of waste. A study by the *Centre de Suivi Écologique (CSE) revealed* that less than half of the households in Dakar have access to a regular system of garbage collection (Centre de Suivi Ecologique 2010). In addition, most of the garbage collected in the city is piled at the Mbeubeuss dumpsite, the official dump site of the city since 1968 and located about 30 km from the city centre. The Mbeubeuss dumpsite was allocated a parcel of about 5 hectares in the beginning, but currently covers an area of more than 60 hectares (Diawara 2009, Journal Officiel de la Republique du Senegal 2010). Relevant to this paper is the evidence that not only diverse types of solid waste are deposited on the dumpsite, comprising stones, metals, organic material (food residues, paper, cardboard, etc.), and plastics, but also biomedical waste from health facilities (Diawara 2009). This situation has been linked to the exposure of the population and SWM practitioners to significant health and environmental risks, including contamination of ground water, exposure to heavy metals such as lead and cadmium (Cabral *et al.* 2012, Cissé 2012).

However, published and updated data on biomedical waste management in Africa remain scanty compared to the rest of the world (Udofia *et al.* 2015), with even huge gaps on the status of knowledge and practice on the subject in Francophone African countries, particularly in Anglophone literature due to language barriers. A recent review on medical waste management in Africa included only one study from Francophone countries (Udofia *et al.* 2015). Therefore, studies seeking to advance the understanding of medical waste management in Francophone Africa are of top most priority. Accordingly, this study provides a unique articulation and insight into the current status of biomedical waste management in Dakar, the capital of Senegal and a leading Francophone African city, with focus on the historic evolution of legal frameworks governing biomedical wastes management, gaps in policy provisions and implementation lags as well as related health and environmental issues in the city. This position paper which is the result of a funded Urban Africa Risk and Knowledge (UrbanARK) study and whose earlier version was submitted as a working paper at the end of the study is refined and represented in this forum to further disseminate its important implementation lessons. Moreover, beyond providing evidence to support policymaking and implementation advocacy in Dakar and Senegal, the evidence it highlighted will enable other municipal actors in the Global South and beyond to gain important lessons on implementation linked to policy, population and environmental health as well as providing examples of how key SDGs might be realized.

The study pursues three specific objectives: First, the paper undertakes an analysis of the historic evolution of the legal frameworks that guides biomedical waste management in Senegal and how this framework fits within international standards. Second, the paper presents a situational analysis of biomedical waste management in Dakar and its health and environmental impacts. Third, building on policy and program gaps identified, the paper proposes policy and program options towards improving biomedical waste management in Dakar and Senegal. The rest of the paper is organized as follows. Section two describes the materials and Methods employed in the study. Section three examines the legal framework for biomedical waste management in Dakar. Section four discusses biomedical waste management chain from generation/production to disposal. Section five presents health and environmental impacts of biomedical wastes in the local context. Section six uses new data to identify policy and practice gaps and suggests some practical recommendations to improve biomedical wastes management in Dakar.

Materials and methods

Study setting

Dakar the Capital city of Senegal has a population of approximately 3 million people with an annual population growth rate of 5.8% and a population density of 5,404 inhabitants per kilometer square (Agence nationale de la Statistique et de la Démographie (ANSD) 2014). Senegal has a total of 50 sanitary districts (SDs) in 2009, including 10 SDs in Dakar region comprising 12 hospitals, 19 health centres, 122 dispensaries, 41 health units, 524 pharmacies and 692 private clinics (Agence nationale de la Statistique et de la Démographie (ANSD)/Service Régional de la Statistique et de la Démographie de Dakar 2015). This huge number of health-care facilities provides an indication of the volume of biomedical wastes (BMW) generated, and potential threats to human health and the environment it constitutes if managed improperly, raising intricate policy and program questions to address the challenge.

Data collection

This paper employs document analysis of the existing literature on BMW in Senegal and Dakar, including specifically government reports on laws and regulations, academic works (Masters and PhD theses), and international reports about proper BMW management systems needed to protect both humans and environment. We also conducted a scoping search of grey literature on BMW in Dakar using biomedical waste, hazardous wastes, healthcare waste, Africa, Dakar, Senegal as key search words. We build further evidence on policy and practice gaps from our analysis of the most recent qualitative and quantitative data collected in Dakar between March and June 2016, under the Urban Africa Risks and Knowledge (Urban ARK) Research Programme.[1] The overarching aim of the Urban ARK program among other objectives is to generate evidence on the nature and distribution of urban risks, good practices in urban planning and governance, and the institutional arrangements at the local government levels that are required to reduce risk and build resilience to multiple hazards in specifically African urban contexts (Adelekan *et al.* 2015). The solid waste management (SWM) project, which is an integral part of the Urban ARK program, focuses on assessing different risks arising from exposure to poor SWM practices and the capacity of authorities and communities to deal with these risks.

The Dakar study implemented between March – June 2016 employed a mixed-methods approach (quantitative and qualitative). The quantitative arm entailed a cross-sectional population-based representative household survey. The qualitative data collection component included Key Informant Interviews (KIIs), Focus Group Discussions (FGDs) and in-depth Interviews (IDIs), implemented across a wide spectrum of SWM stakeholders. The study covered three specific sites in Dakar: Keur Massar and Malika settlements (primarily exposed sites located astride the Mbeubeuss dumpsite); Thiaroye Djiddah Kao (the secondarily exposed site, known for facing frequent flooding linked to poor SWM); and Medina and Patte d'Oie (non-slum comparison study sites). The quantitative component of this study used a two-stage sampling approach to select households in each site. At the first stage, enumeration areas (EAs) were selected with Probability Proportional to Size (PPS) using the Senegalese National Census 2013 database. Then, building on the demographic and health survey practices (Aliaga and Ren 2006, ICF International 2012), twenty households were randomly selected in each EA. The sample was drawn to be representative at the level of each site and also enable comparison of risk among the three communities. The sampled number of households per site was: 424 households in Keur Massar/Malika, 424 households in Thiaroye Djiddah Kao, and 442 households in Medina/Patte d'Oie. A total of 1282 households were selected in the three study sites, of which 1178 were successfully interviewed, yielding a response rate of 91.9%.

For the qualitative component, study participants were identified purposively to participate in the KIIs, IDIs and FGDs. To be able to understand the SWM policy architecture and associated risks, the qualitative participants were selected from a large list of stakeholders who are involved in SWM activities in the study sites. In addition, governmental authorities in charge of SWM were interviewed. In total, 4 FGDs, 15 IDIs and 15 KIIs were conducted.

Data analyses

Beyond the scoping search and document analysis of the existing literature on BMW in Senegal and Dakar, further evidence on policy and practice gaps came from our analysis of the most recent qualitative and quantitative data collected in Dakar between March and June 2016, under the Urban Africa Risks and Knowledge (Urban ARK) as described above. The quantitative data were exported into STATA 14.0 for cleaning and analysis, which entailed generating weighted descriptive statistics (means and percentages) using Svy command in Stata to control for the clustered nature of the data. The qualitative data were coded using NVivo 10, and synthesized using thematic analyses and triangulated with quantitative analysis results to provide a nuanced picture of stakeholders' knowledge and perceptions on SWM and associated health-related risks. This study is relevant to this paper because waste separation at source remains unaddressed in Senegal leading to both municipal waste and biomedical waste often ending up in the same dumpsites across the country against global conventions and best practices.

Ethics statement

Ethical considerations informed the quantitative and qualitative interviews that generated primary data utilized for this paper. The research team was trained to adhere to strict ethical standards and study participants were adequately informed about the purpose and methods of the study, the right to abstain from participating in the study, or to withdraw from it at any time without reprisal; and measures to ensure confidentiality of information were provided. All participants provided written informed consent and permission was sought from participants before interviews were recorded. To ensure the safety of field teams especially when working in areas on or close to the dump sites, gumboots and face masks were provided. To protect the data while in the field, the tablets used for data collection were password protected and data were cleaned out of the devices automatically as they were uploaded on a daily basis. Ethical clearance to conduct this study was obtained from the Senegalese National Ethics Committee for Health Research (Ref: SEN16/13). For this paper, we present particularly the results relevant to biomedical waste management.

Findings: legal framework of biomedical waste in Dakar

Like many countries around the world, Senegal has ratified most international agreements, aimed at protecting human populations and the environment to regulate hazardous wastes. The country has also crafted and implemented national laws and regulations for the same purpose at national and local levels. We present our findings in this section.

International conventions

In May 1992, Senegal joined the rank of more than 100 countries that ratified the Basel Convention, which was designed to reduce the movements of hazardous wastes between nations, and more specifically prevent transfer of hazardous wastes from developed to less developed countries. In March 1996 the country ratified the *Bamako Convention, which is an* African treaty to protect the fragile states in Africa against hazardous wastes and trans-boundary movements of hazardous waste, including radioactive wastes from developed countries, especially those which have not ratified the Basel Convention. The convention was negotiated in 1991 in Bamako (Mali) and came into force in 1998. In 2001, Senegal also ratified the Stockholm Convention, adopted in 2001 (Karlaganis *et al.* 2001) and aimed at protecting human health and the environment against particular toxic and persistent pollutants such as Aldrin, Chlordane, Dieldrin, Endrin, Heptachlor, Hexachlorobenzene, Mirex, Toxaphene, Polychlorinated Biphenyls (PCB), and to strongly restrict the use of dichlorodiphenyltrichloroethane (DDT), which has been shown to be dangerous for wildlife and the environment (Harman *et al.* 2013, Wang *et al.* 2013, Hung *et al.* 2016, Magulova and Priceputu 2016). The Convention has been criticized, particularly in relation to its restriction on the use of DDT. Some scholars posit that indoor sprayings of DDT decrease the impact of malaria in sub-Saharan Africa; therefore increasing the standards of living for millions while causing minimal environmental impact (Zelson 2014). In principle, these treaties should guarantee a proper BMW management in the country, but in practice, we find lag in their effective implementation at national and local levels, linked to the lack of material and human resources and limited capacity building in the public service. Consequently, these conventions have not been translated into a strong BMW management system in the country.

National laws and regulations

A 1974 decree is governing the disposal of both household and general wastes, including biomedical wastes in Senegal. According to the decree, health-care facilities must incinerate anatomic and infectious wastes. Similarly, the 1974 decree prohibits to '*mix anatomic, pharmaceutic, or toxic wastes generated by healthcare facilities and slaughterhouse wastes with domestic wastes*'. Public and private health-care facilities are obliged to incinerate this kind of wastes. Although incineration is one of the recommended processes to dispose of BMW, the decree is silent on the standards to be met during the incineration process. This obligation to incinerate was refined in the Code of Hygiene in 1983, with the following improvement: 'the burning fires, incinerators, and combustion plants should not generate dust or smoke likely to pollute the atmosphere'. In 2001, the Code of the Environment made further refinement stating that all kinds of wastes, including BMW, should be disposed of or recycled in an environmentally sound way, so as to remove their harmful effects on human health, natural resources, flora and fauna, and the quality of environment.

The legal provisions on solid waste management (SWM) in Senegal have evolved over time; however, a closer analysis indicates that the context of BMW management in the country still suffers from technical deficiencies as to a clear definition of wastes, the identification of the structures generating BMW, the specific treatment for each type of wastes, and more importantly law enforcement for proper disposal. Consequently, only a few health-care facilities conform to law and regulations, and toxic BMW are still treated and disposed of like domestic wastes despite the legal provisions (Ndoye and Massenet 2008). The best case scenario is that some health-care facilities have rudimental incinerators dug in the ground (Sy 2006) which are often inefficient and generate smoke and dust that pollute the environment. Besides, there is lack of standard operating procedures (SOPs) and appropriate equipment to better guide BMW management in health-care facilities; health workers are ill-trained; and at the same time, patients and caretakers are not informed about the danger of inadequate BMW management. To fill the training gap, The Programme National de Lutte contre les Infections Nosocomiales (PRONALIN), which has implemented a national program to fight health-care-associated infections in Senegal (Thiam 2013) has led to elaboration of technical standards which were used to draft a decree on BMW management in Senegal that was adopted in 2008. The decree identifies the structures generating BMW in the country and under polluter pays principle, the decree states that these structures are legally and financially responsible for the safe and environmentally sound disposal of the waste they produce. Practically, waste producers (health, pharmaceutical, veterinary facilities) are obligated to have adequate equipment for waste management or recycling. The decree also fixed the standards for transportation and treatment for different types of BMW, and determines the sanctions for non-compliance. Finally, waste producers are obliged to train the staff and provide them with appropriate materials for their work, in addition to vaccination of their personnel against certain illnesses when necessary.

Obviously, the decree advances the previous legal framework governing BMW management in Senegal in line with the Constitution, which guarantees all citizens the rights to health and a clean environment. Title II, Article 8 of the Senegalese Constitution 2001 (revised 2009), states that the Republic of Senegal guarantees to all citizens the fundamental individual freedoms, the economic and social rights as well as the collective rights. These freedoms and rights are notably: … right to a healthy [sain] environment. These freedoms and these rights are exercised within the conditions provided for by the law (African Legal Center 2015)

A deep analysis indicated that BWM management in Dakar remains a challenge because the public wastes collection systems in place do not include BMW, which are supposed to be incinerated. To achieve this goal, it is assumed that biomedical wastes producers are equipped with a performant and functioning incinerators, which is not necessarily the case for many of them (Ndiaye 2005). Ndoye reported that most incinerators do not comply with the international and national standards, are ill-functioning, therefore producing dust and smoke, and putting workers and populations in danger (Ndoye and Massenet 2008). Furthermore, ill-functioning incinerators release dioxins into the air therefore exposing vulnerable populations to threats of cancers, especially lung cancer (Ministère de l'Ecologie et du Développement Durable (MEDD, F.) 2002).

We further examine this theme in terms of challenges of implementing national legal provisions in relation to BWM in the subsequent sections of the paper, building on the analysis of the latest data from our primary field interviews between March and June 2016.

Biomedical wastes: generation, transportation, and treatment

Management of the medical wastes produced in healthcare facilities has raised concerns related to public health, occupational safety, and the environment (Zhao *et al.* 2009). This section describes BMW management in Dakar, Senegal.

Generation

The World Health Organization (WHO) classified BMW into two broad categories (World Health Organization (WHO) 2014); WHO also provides a more detailed classification of BMW into five categories emphasizing the level of BMW-related risks, from a low to high levels (World Health Organization (WHO) and Programme des Nations Unies pour l'Environnement/SCB 2005), as follows:

- Category A: Non-hazardous wastes (office wastes, packaging, leftover food);
- Category B: BMW requiring special attention including anatomical, sharps, pharmaceutical, blood, and fluid wastes;
- Category C: Infectious wastes from laboratories and microbiological cultures;
- Category D: Other hazardous wastes such as chemicals, gases, liquids or products with higher concentration of metals (e.g. mercury);
- Category E: Radioactive wastes (e.g. cobalt, technetium, iridium).

Other scholars used different characteristics to classify BMW. For instance, Faye adopted a classification according to the nature (liquid or solid) of the wastes (Faye 2007). According to this classification, liquid BMW usually are produced in low quantities; however, they require special attention because they are sometimes toxic and include blood residues, liquid chemicals, medical fluids (e.g. gastric washings, pleural and cardiac punctures, liquids from post-surgery drains). Biomedical wastes are essentially anatomic wastes (organ tissues, fetuses, placentas, biological samples, rests from amputation), toxic wastes (chemicals, X-Ray films), sharp wastes (saw blades, needles, syringes, scalpels, probes, tubes, etc.), bandage residues, and pharmaceutical wastes. Chardon adopted a classification close to WHO, distinguishing between non-hazardous wastes, and infectious (contain bacteria, viruses, parasites, fungi), chemical and toxic (laboratory wastes, unused drugs, medical imaging wastes, effluents from laundry and morgue), and radioactive wastes (unsealed containers for applications in vivo, diagnostic – technetium-99 m, iodine-123, therapeutic – iodine 131, strontium 89, and for radio-vitro assays – iodine 125, sulfur-35).

The commonalities of all these classifications are the levels of risks related to either human populations or environment, or both. In SSA however, the estimates of BMW are still unknown due to a lack of systematic weighting of wastes in health facilities (Aroga 2012). These estimations are even more difficult due to a lack of sorting; indeed, hazardous are mixed with non-hazardous wastes (Mbodji 2008, Ndié and Yongsi 2016). Rough estimates for Dakar can be

Table 1. Estimated volume of biomedical wastes in public health facilities in Senegal.

Type of health facilities	Number of health facilities	Quantity (liter/day)	Quantity (1000 liters/day)
Hospitals	34	1200	40.8
Health centres	89	300	26.7
Health posts	1240	30	37.2
DPC	76	30	2.3
Health cases	1722	10	17.2
Total			124.2

Source: Programme de Renforcement des Systèmes Régionaux de Surveillance de Maladies/Sénégal (PRSRSM) (2016).

found elsewhere. For instance, a health centre produces between 0.05 and 0.2 kg per bed per day; the corresponding figures for a university hospital vary between 4.1 and 8.7 kg. Table 1 provides what available evidence suggests are daily BMW estimations at national level.

Figures in Table 1 indicate that overall, public health-care facilities produce on a daily basis 124 meter cubes of wastes. Hospitals, health centres and health posts produce 92% of BMW. However, these figures provide only a partial snapshot of the reality because they do not include private health-care facilities and other facilities such as veterinary, training, and pharmaceutical facilities. Furthermore, there are no standards of wastes weighting in most health-care facilities therefore hindering any reliable comparisons. Table 2 presents specific situation of Dakar.

Based on these figures, Dakar roughly produces one-fifth of the BMW from public health-care facilities in the country. Given the concentration of the population in the capital city and the increasing number of private health-care facilities, these figures may have underestimated the real production level, and the exact percentage is definitely higher than reported. These findings underscore the gap in up-to-date data that needs to be filled to inform evidence-based advocacy for policy change and program interventions.

Management of biomedical wastes

The ultimate goal of each BMW management is to provide human populations and the environment with timely and adequate protection against the threats posed by hazardous wastes while ensuring a proper disposal of non-hazardous wastes (World Health Organization (WHO) 2014). Developing countries usually lack proper BMW management; however, WHO has identified the following steps to guarantee proper BMW management systems, including (*i*) identification of waste; (*ii*) segregation and packing; (*iii*) labeling and documentation; (*iv*) internal and external transportation; (*v*) temporary storage; (*vi*) treatment technique; (*vii*) disposal of treated clinical waste; (*viii*) landfill/dumps (Pruss *et al.* 1999, Marinkovic *et al.* 2008). The implementation of these requirements is scrutinized in the context of the city of Dakar, building on available secondary evidence gleaned from relevant literature.

Table 2. Estimated volume of biomedical wastes in public health facilities in Dakar, Senegal.

Type of health facilities	Number of health facilities	Quantity (liter/day)	Quantity (1000 liters/day)
Hospitals	12	1200	14.4
Health centres	19	300	5.7
Health posts	122	30	3.7
Health cases	41	10	0.4
Total			24.2

Source: Programme de Renforcement des Systèmes Régionaux de Surveillance de Maladies/Sénégal (PRSRSM) (2016).

Identification and segregation

This step is pivotal to identify and isolate non-hazardous BMW, which can be eliminated in the regular chain of solid waste management, from hazardous wastes, which requires a special treatment technique for disposal (Aroga 2012). Best practices at this step will allow the reduction of the volume of hazardous wastes for which the cost of disposal is higher than non-hazardous wastes. In contrast, it may compromise subsequent steps if not well managed.

A cross-sectional study in five hospitals in Dakar showed that most of the hospitals were doing inappropriate sorting of BMW. The proportion of medical staff who reported inappropriate practices to handle BWM ranged from 58% in CHNU Le Dantec Dakar to 75% in Centre Hospitalier Abass Ndao, Dakar. In-situ observations led to the conclusion that sharp wastes and blood wastes were mixed with non-hazardous wastes (Ndiaye *et al.* 2012). Furthermore, among 75 health-care facilities visited, pharmaceutical wastes were mixed with non-hazardous wastes in 66 health-care facilities; infectious wastes were mixed with other wastes in 49 health-care facilities; anatomical wastes were mixed with other wastes in 11 health-care facilities. These practices were also found in another study conducted in the main hospital of Dakar, which reported that 91% of wards did not use appropriate sorting to separate hazardous and non-hazardous wastes (Aroga 2012).

Packing

To ease BMW management, different colors (see Table 3) were assigned to various wastes for effective segregation.

Table 3. Colour coding and types of containers for disposal of biomedical wastes.

Categories of wastes	Colors
Non-hazardous wastes	Black (bins or bags)
Hazardous wastes with sharps	Red (bins or bags)
Hazardous wastes without sharps	Blue (bins or bags)
Hazardous radioactive wastes	Yellow (safety boxes)
Hazardous wastes with chemicals (e.g. mercury, cadmium)	Green (bags or bags)

It is recommended that this packing is done on a daily basis and transferred to the central waste storage. In Dakar, Ndiaye reported that safety boxes were available in most of health-care facilities surveyed (83%); however, they were effectively used in only 51% (Ndiaye *et al.* 2012). Aroga reported a lack of specific management system for sharp objects and appropriate bags to store anatomical wastes in all wards at the main hospital of Dakar (Aroga 2012). In relation to WHO recommendation, once the wastes are packed, they are transferred to a central waste storage which is secure and inaccessible to the public. In Dakar, 71% of wards in the health-care facilities have a secure central waste storage; however, adequate use of the central waste storage was found only in the main hospital of Dakar (Ndiaye *et al.* 2012). Another WHO recommendation is to protect medical staff manipulating (hazardous) wastes. Studies in Dakar indicated that staff in the main hospital of Dakar were not protected; they were working without appropriate gloves and security boots (Aroga 2012); yet it is well known that improper management of wastes and lack of protection of medical staff are responsible for HIV infections (Ndiaye *et al.* 2012). It is also recommended that BMW should be evacuated on a daily basis. In Dakar, most health-care facilities surveyed complied with the recommendation, except the hospital of Grand Yoff where wastes were evacuated biweekly.

Transportation

The underlying principle for wastes transportation internally or externally is to ensure the best conditions for safety; it is important that wastes are properly stored to avoid their scattering and release of toxic substances or pathogens. Also, appropriate materials (e.g. adjustable trolleys) should be used during the transportation of BMW for easy loading and cleaning. Internally, the transportation of BMW should follow a predefined itinerary to protect patients and visitors while ensuring that staff dedicated to waste management are well protected. Ndiaye and colleagues opined that risks are high in internal transportation because it is done manually in 56% of wards, utilizes the carts and trolleys used for patients in 67% of wards, or wheelbarrows (34% of services) (Ndiaye *et al.* 2012). With these practices, it is clear that the transportation of BMW is associated with high risks such as occupational injuries, and the risks of infections for both patients and visitors. The same practices were observed in the hospital of Ziguinchor where the staff carry the wastes manually or simply use the trolleys used in the morgue (Ndiaye *et al.* 2003). There is almost no indication about external transportation of BMW in Dakar. Yet it is recommended that the transportation of BMW outside of the health-care facilities must be done ideally with specific vehicles for this task and designed with an easy unloading, cleaning and disinfection system (Aroga 2012), and fully enclosed to prevent any spillage on the entire transportation circuit (World Health Organization (WHO) and Programme des Nations Unies pour l'Environnement/SCB 2005).

Treatment and disposal

Toxic and infectious wastes are of much concern because they are dangerous for human populations and the environment; therefore, the disposal of these wastes requires special attention. Specific treatment is required for hazardous wastes. There are many treatment techniques which are process-designed to change the biological character or composition of the waste (Marinkovic *et al.* 2008).

Steam autoclave sterilization

This technique uses thermal decontamination for non-anatomical wastes, and is more appropriate for towels and bed linen. Previous studies showed that due to their pathogenic nature, priority should be given to laboratory wastes (Aroga 2012). A study in five hospitals in Dakar showed that all of them re-use glass slides after autoclaving (Ndiaye *et al.* 2012). Scalding is a variant of this technique used when the health-care facility does not have an autoclave.

Incineration

While developed countries are phasing out incinerators as the preferred treatment technique for BMW because of human health and environmental issues, incineration is the most popular and the most used technique for the elimination of BMW in Dakar. It is used for anatomical wastes, sharp wastes, and mixed wastes (non-anatomical infectious and radioactive wastes). With incineration, 80–95% of volume and between 50% and 80% of weight of the wastes can be reduced (Aroga 2012). The incinerator should meet some standards. For instance, first and second chambers should reach 760 and 860 degrees Celsius for an incinerator with double chambers, respectively, because incomplete combustion of wastes produces CO_2, volatile gases or other dangerous particles. Chemical or radioactive wastes, pressured containers, and human parts cannot be incinerated; they are burned in a crematorium.

In Dakar, Ndiaye et al. (2012) showed that BMW was disposed of in old and outdated models of incinerators or in artisanal ovens, therefore emitting huge smoke with heavy metals, chlorinated organic particles and harmful gases that pollute the air and cause risks of environmental degradation, soil and water contamination and poisoning of people and animals. Ineffective and improper incineration is comparable to an open burning mostly practiced in many health-care facilities

Table 4. Treatment techniques for different types of BMW.

Category	Type of BMW	Sources	Treatment technique
Non-hazardous and hazardous anatomical wastes	• Body parts • Organs, tissues (blood) • Rests of conception	• Autopsy and pathology analyses • Surgery, maternity, gynecology	• Cremation • Incineration • Landfill
Hazardous non-anatomical wastes	• Biological fluids (blood, serum, plasma, urine, sperm, expectoration) • Cottons, compresses, bandages, etc. • Gloves, materials for tests, laboratory • Vaccines and cultures of infectious agents	• Care in isolation • Dialysis • Microbiology analyses, biochemistry, hematology, pathology	• Incineration
Infectious materials	• Sharps: needles, scalpels, syringes, forceps, test tubes, etc.	• Laboratory, pathologies	• Incineration
At risk chemical BMW	• Non- and halogenic solvents • Inorganic solvents (reagents, dyes …)	• Laboratory • Radiology • Development of films	• Recycling • Liquids: neutralization and throw in sewage
Pharmaceutical	• Drugs and pharmaceutical chemicals (expired, altered, or residual drugs, toxic salt, expired vaccines, serum, toxoids) • Cytotoxic drugs and chemicals: neoplastic drugs and residues …	• Preparation and distribution of drugs • Chemotherapy	• Incineration (minimum 1000 degrees Celsius) • Landfill after crushing
Radioactive	• Contaminated wastes, biologic fluids: lingerie, bedding • Contaminated hardware, unused material for preparation, contaminated solvent, scintillation liquids …	• Residues of radioactive products • Medical analyses and research • Radio-diagnosis and treatment	• Landfills

Source: Doucouré (2004).

in Dakar, which do not have a functioning incinerator, thereby exposing populations, especially children in search of toys among unburned materials to health risks (Faye 2007). Additionally, lower temperatures in the incinerators increase the persistence of infectious risks, pollution risks for earth and water, and the generation of secondary wastes (Chardon 2008); and the emanations of highly toxic and carcinogenic substances (Ndiaye *et al.* 2003). These toxic gases are dioxins, furans, polychlorinated biphenyls (PCBs), nitrogen oxides, and sulfur particles (Chardon 2008). Although of low intensity, these toxic substances lead to a number of diseases and cancers when exposed to for a long period. They include disturbances of liver function, skin lesions, disruption of immune, nervous, endocrine and reproductive systems (Chardon 2008).

Landfills

Treated wastes can be disposed of on the land, using a sanitary landfill or any other environmentally acceptable method of final storage appropriate to local conditions. Landfills are a common practice in Dakar or even in the country, especially in health-care facilities without an incinerator. They are usually holes dug into the ground without any safety precaution; and supplied with BMW until they are filled up, and finally buried (Faye 2007). Due to financial constraints in many health-care facilities in Dakar, some scholars have recommended this practice although they recognize the risks for human populations and animals (Ndiaye *et al.* 2003), and the environment (Aroga 2012).

This section has shown that treatment techniques for BMW are numerous and the required technology is available. In the context of Dakar, professionals in BMW management have recommended incineration and proper landfills as the preferred techniques for proper disposal of BMW. However, analyses also showed that in the current state, these techniques are detrimental to population health and sources of pollution for the environment. Table 4 summarizes the most appropriate modes of disposal for each type of BMW.

Further evidence from the most recent quantitative and qualitative data collection in Dakar, Senegal are discussed under the following sub-headings.

Findings: Quantitative and qualitative primary data.

Disposal of toxic wastes

Although all countries around the world face challenges for toxic wastes management, developing countries are more affected due to ineffective and inefficient systems of solid waste management generated through a rapid urbanization and poor planning in most cities. In this study, households' respondents were asked how they usually dispose toxic wastes including painting, batteries, and radios (see Table 5). Unsurprisingly, almost all households (96%) in our 2016 primary study disposed their toxic wastes together with other trash without separation, although some variations exist across study sites (99% in Keur Massar/Malika and Djiddah Thiaroye Kao, and 94% in Medina/Patte d'Oie). The overall toxic wastes behaviors across the city can be characterized as lacking clear rules and regulations in relation to sorting and recycling despite the known toxicity of wastes contained in radios, batteries, and painting. Notwithstanding, while toxic waste management was identified among the waste-related problems faced by residents across all

Table 5. Solid waste management practices in the communities.

	Keur Massar/Malika	Djiddah Thiaroye Kao	Medina/Patte d'Oie	Total
Disposal of toxic wastes with other trash	99.4	99.1	94.3	96.1
Burning of trash at dumpsite	59.7	9.5	3.5	10.8
Disposing toxic waste, e.g. chemicals	13.6	2.5	1.9	3.2
Illegal dumping of trash	35.4	19.2	7.1	13.2
Littering the community	38.4	9.2	18.4	17.9
People dumping trash in others' plots	49.0	12.4	6.0	12.1
Consuming food grown near dump	8.2	0.7	0.8	1.5
Other	0.8	0.0	2.5	1.7
N	**382**	**392**	**402**	**1176**

communities, the levels of concern were very low, with only 3.2% of respondents identifying toxic waste management as a problem, with significant variation across different sections of the city (see Table 5). However, while 14% of respondents in Keur Massar/Malika (the communities primarily exposed to the Mbeubeuss dumpsite) identified disposal of toxic wastes such as chemicals as a problem, only 2.5% of respondents in Djiddah Thiaroye Kao and 1.9% of residents in Medina/Patte d'Oie identified the same as a problem.

Disposal of electronic wastes

The electronic wastes also referred to as 'e-wastes' are generated from the new information and telecommunication technologies (ICT) such as computers, printers, fax machines, mobile phones, tablets and netbooks, personal digital assistants (PDAs), radios and TVs. E-wastes are also defined as end-of-use or end-life of electronic products, components and peripherals. Recycling e-wastes has been suggested as the more promising way to protect the environment in the world, especially in developing countries lacking proper SWM policies on e-wastes (Osibanjo and Nnorom 2007, Nnorom and Osibanjo 2008a, 2008b, Olowu 2012). The inefficient enforcement of rules and regulations can be found in households' behaviors about e-waste disposal in Dakar. In fact, 64% of households treat and dispose e-wastes like any other wastes despite that e-wastes constitute a serious threat for populations and environment. The situation is even worst in Djiddah Thiaroye Kao where 98% of households dispose e-wastes with other trash compared with 76% and 48% in Keur Massar/Malika and Medina/Patte d'Oie, respectively. Like most SSA cities, Dakar lacks clear rules and regulations about e-wastes. Yet most developed countries have in place legislation mandating manufacturers and importers to take-back used electronic devices at the end-of-their life (EoL) based on the principle of extended producer responsibility (EPR) (Nnorom and Osibanjo 2008a).

Our findings identified electric/electronic materials are among the products that are coming from dumpsites and mostly being reused across all study communities, especially among those primarily living adjacent to the Mbeubeuss dumpsite, where 72% of residents reuse these items (see Table 6)

Findings: Health and environmental impacts of biomedical wastes

One major concern in literature is the health and environmental impacts of biomedical wastes. WHO estimated in early 90s that 18–64% of health-care facilities in the world do not properly dispose of BMW, and the highest proportion of them are in developing countries. Many factors including a lack of BMW management plan, lack of equipment, financial constraints, and the lack of adequate training, explain among others the absence of proper BMW management chain in developing countries (Ndié and Yongsi 2016). Health and environment impacts of poor BMW management have been addressed elsewhere (Briggs 2008, Giusti 2009, Forastiere *et al.* 2011, Sankoh *et al.* 2013, Babanyara *et al.* 2013, Ranzi *et al.* 2014, Wiafe *et al.* 2015, Mmereki *et al.* 2017). Overall, previous studies reported that poor BMW management affects human health and environment.

In Table 7, we summarize evidence from previous studies on the linkages between biomedical waste and pathogenic bacteria (Hossain *et al.* 2011,

Table 6. Types of objects or products coming from dumpsites and re-used by the community.

	Keur Massar/Malika	Djiddah Thiaroye Kao	Medina/Patte d'Oie	Total
Paper	30.2	22.5	0.0	24.3
Plastics/Plastic bags	60.5	95.0	90.5	70.9
Glass	83.2	65.0	100.0	82.8
Electric/Electronic materials	71.9	27.5	18.9	56.4
Metal (tin, iron, etc.)	65.7	67.5	66.5	66.1
Other	1.1	5.0	0.0	1.6
N	**196**	**20**	**6**	**222**

Source: Primary quantitative data from the 2016 Urban ARK field survey in Dakar by Study Team.

Table 7. Diseases from hazardous biomedical waste.

Diseases	Pathogen agent	Transmission modes
Gastroenteritis	Enterobacteriaceae: salmonella, schigella; Vibrio cholerae;	Faeces and vomiting
Respiratory infections	bacillus tuberculosis, measles virus, streptococcus pneumonia	Breathing, secretions air, saliva
Eye infections	Herpes virus Eye secretions	Eye tears
Genital infections	Neisseria gonorrhea herpes virus	Genital secretions
Anthrax	Bacillus anthracis	Respiratory dermal secretions Respiratory droplets
Meningitidis	Meissiria Meningitis	Liquid cerebra-spinal Breathing
AIDS	AIDS virus	Infected blood, Body secretions
Ebola	Marburg virus	Infected blood Body secretions
Staphylococcus infections	Staphylococcus	Infected blood
Bacteraemia	Staphylococcus aureus, enterobacteria, enterococcus	Infected blood
Hepatitis B	Hepatitis B virus	Blood and secretions
Hepatitis C	Hepatitis C virus	Blood and secretions

Source: Boubacar (2011).

2013) as well as diseases associated with exposure to hazardous biomedical wastes (Djocgoue 2016, Organisation mondiale de la Santé (OMS) 2011, Boubacar 2011, Organisation mondiale de la Santé (OMS) 2015). Data from our primary field study found high levels of knowledge of the *potential effects of poor solid waste management for health, yet* only 3.2% of respondents identified toxic waste management as a problem, with significant variation across different sections of the city (see Table 6). While 14% of respondents in Keur Massar/ Malika (the communities primarily exposed to the Mbeubeuss dumpsite) identified disposal of toxic wastes such as chemicals as a problem, only 2.5% of respondents in Djiddah Thiaroye Kao and 1.9% of residents in Medina/Patte d'Oie identified the same as a problem. The perception of risks associated with exposure to toxic wastes is further beclouded by the view of dumpsites among respondents as income-generating places for people to work and earn money for their survival. Consequently, the study participants do not see the idea to relocate the dumpsite as a sustainable option as many households rely on the dumpsite for their economic sustenance.

However, it is important to highlight that people living closest to the dumpsites recognize more strongly that such a site brings a lot of health problems. In fact, participants in the FGDs including women and youth are all aware of negative effects associated with poor SWM; however, as one youth mentioned '*we have no choice*'. This translates into a deep vulnerability of human lives when people have to surrender to such an adverse situation even though the consequences are enormous and well known. More importantly, as there is no separation between toxic and non-toxic wastes, there was little distinction in these perceptions and perspectives between toxic waste management and non-hazardous SWM.

Biomedical waste management in Dakar: a call for action

Like many developing countries, solid waste management is of great concern in Senegal, and particularly in Dakar the Capital City as shown along the lines in this paper. The situation is even more complicated with biomedical wastes, especially hazardous wastes, which require special treatment and financial investments. There have been national efforts aimed at improving biomedical waste management in the country as we have shown across our report, including 'Programme national de lutte contre les infections nosocomiales – PRONALIN' to improve hygiene and safety in public and private hospitals in Senegal, and 'Projet de gestion des dioxins et de mercure – PROGEDIME' to regulate the techniques for the disposal of wastes containing dioxins and mercury in the country. The PROGEDIME has permitted the building of technical units (crusher, sterilizer) in the hospitals of Grand Yoff and Rufisque, and the health post of Sangalcom as part of the efforts to promote a better management of biomedical wastes. Unfortunately, these efforts were not sustained after the projects ended and many health facilities in the country still lack adequate and efficient systems for good biomedical waste management. Consequently, biomedical wastes are still stored and transported with other types of wastes as confirmed in the literature (Programme de Renforcement des Systèmes Régionaux de Surveillance de Maladies/ Sénégal (PRSRSM) 2016) and through the results of our most recent field study. Notwithstanding, there are a number of lessons learnt from this long experience of handling biomedical waste in Dakar, which if embraced by all stakeholders, portends better prospects in this field. The lessons and avenues to improve biomedical waste management in the city are discussed under the following subheadings.

Knowledge of biomedical wastes threats and awareness

An effective management system of biomedical wastes in Dakar should be a collective action. Therefore, decision-makers at national and local levels need to be made fully aware of the threats biomedical wastes represent for human health and the environment. As WHO put it, the treatment of biomedical wastes is first and foremost a management than a technical issue (World Health Organization (WHO) and Programme des Nations Unies pour l'Environnement/SCB 2005). Once decision-makers understand the importance of an effective and good management of biomedical wastes, it becomes easy to implement the appropriate treatment techniques required to safeguard human health and the environment. To achieve this goal, research addressing biomedical wastes is of topmost priority, and this paper showed that studies on this topic are rare. Instances of themes to be addressed include, but not limited to, population exposure to certain types of pollutants, evaluation studies on health and environmental impacts of poor biomedical waste management, epidemiological studies on at-risk and the most vulnerable populations, quantification and categorization of biomedical wastes, and identification and adoption of best practices of biomedical wastes management.

Information, training, and sensitization

The question to be addressed is whether the medical and paramedical staff have the required information to guide their behaviors in biomedical wastes generation, packaging, transportation, and disposal; but more importantly, whether they are aware of the risks they are exposed, and the risks for human health and the environment generally. Previous studies showed that personnel have insufficient knowledge about best practices of biomedical wastes management (Diouf 2005, Ndiaye *et al*. 2012). The unawareness of the threats posed by BMW can partly explain why health-care facilities do not allocate a budget for BMW management. It is important that medical and paramedical staff especially those tasked to collect, transport, and dispose of biomedical wastes be fully informed about the dangers of inappropriate BMW management for themselves, patients, visitors, and the environment. For instance, a department of occupation safety can be created to handle the problems related to safety and threats in health-care facilities (Ndiaye *et al*. 2012).

Besides the information, training is needed for effective BMW management system in health-care facilities in Dakar. The training component will aim to (*i*) improve sorting and packaging practices among BMW producers (e.g. doctors, nurses, lab technicians) with the ultimate objective to decrease exposure (intentional or accidental) to non- and hazardous wastes; (*ii*) sensitize other personnel tasked with cleaning and packaging to observe the requirements during the collection and transportation of biomedical wastes by implementing safety measures (e.g. helmets, gloves).

Equipment and infrastructures

An effective management system for BMW is related to quantity and quality of equipment and infrastructures. In the case of Dakar, evidence showed that, yet important, equipment in many health-care facilities is either lacking or outdated (Ndiaye *et al*. 2003, 2012, Diouf 2005), making a proper management of BMW difficult. The reliable equipment is often costly and many health-care facilities cannot afford it, creating an opening for private investment in BMW management. This solution will potentially improve safety by bringing into the process well-trained and equipped personnel. Health-care facilities will no longer invest in personnel training or in acquiring a plant for BMW management. The centralization of the BMW management chain can reduce the costs associated with BMW management and optimize the costs for the private investors. Finally, compliance with standards is easily managed at municipal level because there will be only a few firms to control.

Local biomedical waste management plans

The lack of consistency between current laws, regulations, and the local context is another bottleneck for an effective BMW management. Therefore, a better articulation between the local context and the legal framework may be helpful to address poor BMW management systems. It is clear that most health-care facilities lack financial resources to implement an effective BMW management system in Dakar. Without public and private investments, the system will not be as effective as expected, which requires urgent and big shifts. We propose the creation of '*geographical zones of BMW generation*' consisting of clustering of health-care facilities in a specific geographic area. Each zone will be defined depending upon the density of health-care facilities and inherent conditions. Thereafter, a BMW management plan will need to be established taking into account the specificities of each health-care facilities in the area (storage and collection) and necessary synergies to ensure an appropriate BMW disposal plan (transport, disposal) along with training and capacity building among health-care facilities in the specific zone.

Policymakers and high-level managers in health-care facilities also need to be sensitized because of their strategic role in effective BWM management in Dakar. Policymakers need to be mobilized to include BMW management among the priorities of the Ministry of Health (MoH). These provisions are lacking in the current strategic plans of the Ministries of Health and Environment. This situation is confirmed in our current interviews with respondents identifying challenges at individual, household, and policy levels as undermining efficient actions and practices to address health risks associated with poor solid waste management. The barriers identified at policy levels include lack of government support (46%), lack of leadership (59%), lack of land tenure (59%). As the findings showed, no effective community actions will be envisioned unless there is a big shift at policy level to boost SWM in the city.

Finally, there is almost no indication of law enforcement regarding BMW in health-care facilities. Managers of health-care facilities need to have clear financial plans to ensure an effective BMW management in their health-care facilities. Evidence indicate that either financial resources are insufficient or they do not allocate resources for BMW in their respective health-care facilities. Unions may also be more involved to obligate health-care managers to implement appropriate mechanisms to ensure that BMW chains in their health-care institutions comply with international and national standards. Personnel tasked with BMW management need to be educated for more responsibilities, given the levels of risk associated with BMW.

Conclusion

This paper presents an overview of the status of current policies and practices concerning biomedical wastes management in Dakar, Senegal. To achieve this goal, the paper analyzed the legal framework of biomedical wastes, the chain of biomedical wastes management systems in the city and triangulated data from secondary sources and primary quantitative and qualitative interviews conducted in the city between March and June 2016. Although the country has adhered to many international instruments to build its national legal framework for BMW management, it clearly appeared that the management of biomedical wastes in the capital city remains inefficient because of a lack of best practices to handle and dispose of biomedical wastes, especially hazardous wastes. Although epidemiological evidence linking poor BMW management and human health is controversial (Giusti 2009), and very little data exists on direct human exposure to BMW, yet there are plausible reasons to posit that living close to dumpsites or incinerators can jeopardize human health. The most current data from three sites in the city with different levels of exposure to the city's main dumpsite, confirm the vulnerability of those who mostly live closest to the dumpsite as more exposed to poor SWM and associated health challenges. Further, poor BMW management affects the quality of soil, water, and air (Dan *et al.* 2014) and therefore proximity to the dumpsite is logically linked to these dangers. Consequently, significant investment for an effective and proper BMW management in Dakar is of paramount importance. In this process, substantial investment in research efforts to collect data on old and new challenges, interventions that work or otherwise as well as engagement with policymakers and stakeholders to influence policymaking and action have been identified as important dimensions of the agenda.

Note

1. The full details of the general Urban ARK Research Programme is provided in Adelekan *et al.* (2015).

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