



**Urban Africa**  
**Risk Knowledge**

**Working Paper #15**

**Biomedical waste management in Dakar: Legal framework, health and  
environment issues**

**December 2016**

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## **Abstract**

*A rapid growth of population in Dakar has led to an increase in the number of healthcare facilities in the city, with an immediate consequence of considerable increase in biomedical waste generation and considerable challenge to the already burdened the city's waste management system. Building on the special treatment required for biomedical wastes (BMW) due to associated health and environmental risks, this paper examines the historic evolution of legal framework for biomedical wastes management and related health and environmental issues in Dakar, Senegal. Historically, the country has ratified many international treaties, including Basle, Stockholm, and Bamako Conventions; however the paper demonstrates a lack of an efficient chain for biomedical wastes disposal in Dakar. Building on evidence from literature and the most recent qualitative and quantitative study of the city, the major barriers identified for the poor state of affairs is attributed mainly to lack of financial resources and weak law enforcement. This is not only in relation to BMW but solid waste management in general. Therefore, significant investment for an effective and proper BMW management in Dakar is of paramount importance in order to address environmental contamination, human exposure and associated loss to health. However, the same holds true for SWM generally in the city.*

## Introduction

In many developing countries, the number of healthcare facilities has rapidly increased to better serve the increasing populations resulting from a rapid population growth [1, 2]. While healthcare facilities are important for prevention and curative care, they increasingly generate a significant volume of wastes [3], referred to as “medical waste”, “healthcare wastes”, or “biomedical wastes.” According to World Health Organization (WHO), coming mostly from the administrative, kitchen and housekeeping functions at health-care facilities, which may also include packaging waste and waste generated during maintenance of health-care buildings are non-hazardous wastes comparable to domestic waste, which form about 80% of the waste typically produced by health-care providers [4]. However, the rest contains 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% made-up 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 [4]. Healthcare waste generation, treatment and disposal, expose patients, relatives, healthcare 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 wastes improperly disposed [5-8].

Africa is estimated to have 67, 740 health facilities and produce approximately 282, 447 tons of medical waste every year [9]. Previous studies indicated that municipal solid waste management in sub-Saharan African (SSA) cities are inefficient and ineffective [10, 11]; yet hazardous healthcare wastes require special treatment, adding a new strain on the waste management systems especially in terms of cost. [3]. 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 [12]. In SSA cities due to a lack of proper storage, collection, transportation, treatment and disposal, biomedical waste management (BWM) has become of increasing public concern for many [12] and has led to increased independent surveys in recent years in African countries.

Spread over 550 km<sup>2</sup> (0.3% of the national territory) and concentrating nearly 25% of the Senegalese population [13], Dakar typifies both the rapid population growth in urban areas of Africa and the critical challenges on urban planning, in particular, solid waste management. With 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 [14], without SWM practices yet to be aligned with such heavy production. 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 [15]. In addition, most of the garbage collected in the city is piled at the Mbeubeuss dumpsite, located at about 30 km from Dakar city centre. Declared as the official dumpsite of city in 1968, Mbeubeuss dumpsite was allocated a parcel of about 5 hectares in the beginning, but currently covers an area of more than 60 hectares [14, 16]. Relevant to this paper is evidence that not only diverse types of solid waste are deposited on that dumpsite, comprising stones, metals, organic material (food residues, paper, cardboard, etc.), and plastics, but also biomedical waste from health facilities [14]. This situation have 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 [17, 18].

However, published and updated data on the subject in Africa remain scanty compared to the rest of the world [12], with even huge gaps on the status of knowledge and practice on the subject in Francophone African countries, particularly in the Anglophone literature due to language barriers. A recent review on solid medical waste management in Africa included only one study from Francophone countries [12]. Therefore, studies seeking to advance the understanding of medical waste management in this part of the world are of top priority. Accordingly this study provides a unique and insight into the current status of biomedical waste management in Dakar, the capital of Senegal and a leading Francophone African city to Anglophone audience, 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.

The paper pursues three specific objectives: First, the paper undertakes an analysis of the historic evolution of the legal frameworks that guides biomedical waste management in the country and how this framework fits within the international standards. Second, the paper presents a situational analysis of biomedical waste management in Dakar (Senegal) 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 legal framework for biomedical waste management in Dakar. Section three discusses biomedical waste management chain from generation/production to disposal. Section

four presents health and environmental impacts of biomedical wastes. Section five uses new data to identify policy and practice gaps and suggests some practical recommendations to improve biomedical wastes management in Dakar.

## **Methodology**

### ***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 [19]. 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 [20]. This huge number of healthcare facilities provides an indication of the volume of biomedical wastes (BMW) generated, and potential threats to human health and the environment.

### ***Methods***

This paper primarily builds on a critical review of the existing documents about BMW in Senegal and Dakar including specifically government reports on laws and regulations, academic works (Masters and PhD theses), and international reports about the standards to meet for a proper BMW management systems to protect both humans and environment. We also conducted a search of grey literature on BMW in Dakar using biomedical waste, hazardous wastes, healthcare waste, Africa, Dakar, Senegal as key 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 Program<sup>1</sup>.

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

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<sup>1</sup> The details of the general Urban ARK Research Program is provided in Adelekan et al. (2015).

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 [21, 22], 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 total number of sampled households per site was calculated using the Cochran’s formula below for estimating a proportion [23].

$$n_i = \frac{z_{\alpha}^2 p_i(1 - p_i)}{d^2}$$

Where:

- $n_i$  = the number of households to be interviewed in the site  $i$
- $p_i$  = the value of the known value of a key outcome in site  $i$ . The outcome used to calculate the sample size in this study was the “*percentage of households where solid waste is regularly collected*”. Based on previous studies conducted in Dakar, the value of the outcome was:  $p=0.0$  in Keur Massar/Malika and Thiaroye Djiddah Kao; and  $p=0.50$  for Medina and Patte d’Oie [14].
- $z_{\alpha} = 1.96$  for  $\alpha = 0.05$ ;
- $d = 0.05$

Using the above formula and considering an estimated household non-response rate of 15% in Dakar [24], 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.

For the qualitative component, study participants were identified purposively to participate to 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 planned in this study. The qualitative data was 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. Quality assurance activities took place at both field and office level. In sum 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%.

Ethical considerations informed the quantitative and qualitative interviews. 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 dumpsites, gumboots and face masks were provided. To protect the data while in the field, the tablets 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. Therefore a thorough understanding of BMW management system in Senegal should look into international conventions and national laws and regulations. However, given that international conventions provide general guidelines, this paper primarily focused on national laws and regulations, which are a practical guide to what is happening in the country regarding BMW.

#### **International conventions**

***Basel Convention.*** Senegal ratified the Basel Convention in May 1992; this convention signed by more than 100 countries concerns trans-boundary movements of hazardous wastes. It is an international treaty that was designed to reduce the movements of hazardous wastes between nations, and more specifically prevent transfer of hazardous wastes from developed countries to less developed countries.



**Bamako Convention.** The main goal of this African treaty that Senegal ratified in March 1996 is 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.

**Stockholm Convention.** Senegal has also ratified the Stockholm Convention, adopted in 2001 [25]. The treaty aims 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 strongly restrict the use of dichlorodiphenyltrichloroethane (DDT), which has been shown to be dangerous for wildlife and the environment [26-29]. The Convention has been criticized. For instance, while the convention restricts 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 [30].

Although Senegal has ratified these international conventions which should guarantee a proper BMW management in the country, in practice the lack of material and human resources and capacity building in public service has strongly limited the effective implementation of these agreements at national and local levels. Yet effective implementation would have been translated into a strong BMW management system. In the next section, the paper addresses the current state of the legal national framework of BMW.

### **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, healthcare facilities must incinerate anatomic and infectious wastes. Likewise, the 1974 decree prohibits to “*mix anatomic, pharmaceutical, or toxic wastes generated by healthcare facilities and slaughterhouse wastes with domestic wastes*”. Public and private healthcare 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 about 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, such 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 has 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 healthcare facilities conform to law and regulations, and toxic BMW still are treated and disposed of like domestic wastes despite the legal provisions [31]. The best case scenario is that some healthcare facilities have rudimentary incinerators dug in the ground [32] 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 healthcare 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, PRONALIN programme 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. A deep analysis indicated that BWM management in Dakar remain 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 [33]. 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 [31]. Furthermore, ill-functioning incinerators release dioxins into the air therefore exposing vulnerable populations to threats of cancers, especially lung cancer [34]. We further examine this theme in terms of challenges of implementing national legal provisions in relation to BMW in the subsequent sections of the paper, building on the analysis of the latest data from our 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 [35]. This section describes BMW management in Dakar, Senegal.

#### **Generation**

The World Health Organization (WHO) classified BMW into two broad categories [4]; 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 [36], 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 [37]. 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-99m, 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 [38]. These estimations are even more difficult due a lack of sorting; indeed hazardous are mixed with non-hazardous wastes [39, 40]. Rough estimates for Dakar can be found elsewhere. For instance, a health center produces between 0.05—0.2 kg per bed per day; the corresponding figures for a university hospital vary between 4.1—8.7 kgs. Table 1 below provides daily BMW estimations at national level.

----- Table 1 about here -----

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

----- Table 2 about here -----

Based on these figures, Dakar roughly produces one-fifth of the BMW from public healthcare facilities in the country. Given the concentration of the population in the capital city and the increasing number of private healthcare facilities, these figures may have underestimated the real production level, and the exact percentage is definitely higher than reported.

## **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 [4]. 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 [41, 42]. These requirements are scrutinized in the context of Dakar, Senegal.

**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 [38]. Best practices at this step will allow the reduction of the volume of hazardous wastes for which the costs 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 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 to 75% in Abass Ndao. In-situ observations led to the conclusion that sharp wastes and blood wastes were mixed with non-hazardous wastes [43]. Furthermore, among 75 healthcare facilities visited, pharmaceutical wastes were mixed with non-hazardous wastes in 66 healthcare facilities; infectious wastes were mixed with other wastes in 49 healthcare facilities; anatomical wastes were mixed with other wastes in 11 healthcare 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 [38].

**Packing.** To ease BMW management, different colors (see Table 3) were assigned to various wastes for effective segregation. 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 healthcare facilities surveyed (83%); however they were effectively in only 51% [43]. 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 [38]. 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 healthcare facilities have a secure central waste storage; however adequate use of the central waste storage was found only in the main hospital of Dakar [43]. 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 [38]; yet it is well known that improper management of wastes and lack of protection of medical staff are responsible for HIV infections [43]. It is also recommended that BMW should be evacuated on a daily basis. In Dakar, most healthcare facilities surveyed complied with the recommendation, except the hospital of Grand Yoff where wastes were evacuated biweekly.

----- Table 3 about here -----

**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 pathogen agents. 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) [43]. 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 [44]. There is almost no indication about external transportation of BMW in Dakar. Yet it is recommended that the transportation of BMW outside of the healthcare facilities must be done ideally with specific vehicles for this task and designed with an easy unloading, cleaning and disinfection system [38], and fully enclosed to prevent any spillage on the entire transportation circuit [36].

**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 require special attention. Specific treatment are required for hazardous wastes. There are many treatment techniques which are processes designed to change the biological character or composition of the waste [41].

### **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 [38]. A study in five hospitals in Dakar showed that all of them re-use glass slides after autoclaving [43]. Scalding is a variant of this technique used when the healthcare 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 50-80% of weight of the wastes can be reduced [38]. 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<sub>2</sub>, 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. [43] 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 healthcare facilities in Dakar, which do not have a functioning incinerator; therefore exposing populations, especially children in search of toys among unburned materials [37]. Additionally, lower temperatures in the incinerators increase the persistence of infectious risks, pollution risks for earth and water, and the generation of secondary wastes [45]; and the emanations of highly toxic and carcinogenic substances [44]. These toxic gases are dioxins, furans, polychlorinated biphenyls (PCBs), nitrogen oxides, and sulfur particles [45]. Finally, although of low intensity, these toxic substances lead to a number of diseases and cancers when exposed for a long period. They include disturbances of liver function, skin lesions, disruption of immune, nervous, endocrine and reproductive systems [45].

## **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 healthcare 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 [37]. Due to financial constraints in many healthcare facilities in Dakar, some scholars have recommended this practice although they recognize the risks for human populations and animals [44], and the environment [38].

This section has shown that treatment techniques for BMW are numerous and require technology and are costly. 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 current state, these techniques are detrimental for populations and sources of pollution for the environment. Table 4 summarizes the most appropriate modes of disposal for each type of BMW.

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

## **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 developing countries. 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%) disposed their toxic wastes, although some variations exist across sites (99% in Keur Massar/Malika and Djiddah Thiaroye Kao, and 94% in Medina/Patte d'Oie). The overall toxic wastes behaviours 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 communities, the levels of concern was very low, with only 3.2 percent of respondents identifying toxic waste management as a



problem, with significant variation across different sections of the city (see Table 6). However, while 14 percent of respondents in Keur Massar / Malika (the communities primarily exposed sites located astride the Mbeubeuss dumpsite) identified disposal of toxic wastes such as chemicals as a problem. Only 2.5 percent of respondents in Djiddah Thiaroye Kao and 1,9 percent of residents in Medina / Patte d'Oie identified the same as a problem.

**Table 6 About here Disposal of electronic wastes**

The electronic wastes also referred to as “e-wastes” and 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 environment in the world, especially in developing countries lacking proper SWM policies on e-wastes [46-49]. The inefficient enforcement of rules and regulations can be found in households’ behaviours 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 lack 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) [48].

----- Table 4 about here ----- Our findings identified an outcome relevant to electronic waste, not with returning electronics to manufacturers or dealers but electric/electronic materials found to be among the most objects or products that are coming from dumpsites and reused across all study communities, especially among, those primarily living adjacent to the dumpsites, where 72 percent of residents reuse them (see Table 7)

[Table 7 about here].

**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 healthcare 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 [40]. Health and environment impacts of poor BMW management has been addressed elsewhere [50-57]. Overall, previous studies reported that poor BMW management affects human health and environment. This section focuses on health and environmental impacts in Dakar, Senegal. Specifically, it describes people at-risk and addresses health and environmental impacts.

**Persons at risk.** Obviously all people are at risk of a poor and ineffective BMW management; however some are at higher than others due to frequent contact with non- and hazardous BMW, especially sharps [36]. They include medical and paramedical staff of healthcare facilities, laboratories, health research centres, morgues, centres of autopsy, blood banks, laboratories and research centres for animals, and staff tasked to manipulate the wastes generated [43]. In-patients and out-patients treated in healthcare facilities, accompanying persons and visitors are potentially at risk. In developing countries where hazardous BMW can be easily mixed with non-hazardous wastes as a consequence of poor BMW [39], staff who manipulate wastes are at higher risks. Likewise skimmers and children in search of toys on the dumpsite of Mbeubeus where untreated and unsorted wastes are dumped are also at higher risks. The general population is at risk due to improper cleaning. In fact, liquid BMW (e.g., urines, infected blood, bacteria) are dumped in the rivers and sea where they are in contact with people; therefore they become a threat for human populations. BMW stored with healthcare facilities and disposed without a specific treatment constitute a host of pathogenic micro-organisms, which infect medical and paramedical staff, patients, accompanying persons and visitors, skimmers and children in contact with these sites.

**Health and environmental impacts.** Despite all precautions, BMW management (e.g., landfills and incineration) still have indirect effects on humans and environment through the release of toxic pollutants in the air or on land. The risks are higher with a poor, improper and ineffective BMW management as is the case in many developing countries. As a result, many diseases can be contracted through BMW including microbial/bacterial diseases (e.g., tuberculosis, streptococcus, and typhoid), parasitic diseases from stool (e.g., dysentery, worms) [58]. Contaminated needles and syringes improperly handled are another threat because they are collected from the dumps by skimmers and resold on the market. WHO estimated in 2000 that 21 million hepatitis B infections, two million of

hepatitis C infections, and 260 thousands of new HIV infections in the world come from recycled syringes [59].

Open burning and inappropriate incinerators are common practices in most healthcare facilities in Dakar, Senegal. It is likely that those incinerators do not meet the standards and burn at low temperatures, generating persistent organic pollutants (POPs) like dioxins, furans, and other pollutants which are freed in the air and the environment [36]. Staff tasked with wastes burning and the surroundings of healthcare facilities are particularly vulnerable because of a longer exposure to dioxins and furans can affect immune, endocrine, nervous, and reproductive systems [59]. BMW containing lead constitutes another threat for human populations and the environment. Materials such as rectal and buccal thermometers contains important quantity of lead; yet evidence showed that medical and dental cabinets dispose of these material in an inappropriate manner. Indeed 93% of medical/dental cabinets throw BMW with lead in the spittoon or in the trash [60]; yet lead has consequences for human health it may diffuse in the body to reach the brain, liver, kidney and bones. It is estimated that lead is responsible of 600,000 new cases of intellectual deficiency among children, and 143,000 deaths per year mainly in developing countries [61].

It is also common in Dakar that BMW are disposed using the regular circuit of municipal solid waste management; therefore threatening human populations and damaging the environment. Like open storage of BMW widely practiced in healthcare facilities in Dakar, unprotected staff in contact with BMW, skimmers and children in the dumpsite of Mbeubeus are at risk of bacterial infections or inhalation of dangerous substances. Heavy metals and persistent organic pollutants (POPs) released during the destruction of organic substances (e.g., combustion, anaerobic digestion) contaminate soils and atmosphere. Winds can easily move these substances to surrounding homes or the groundwater where they constitute a threat for human health. Moreover, unprotected landfills and dumpsites are favorite places for pests (rats, dogs) for food while hosting a lot of vectors such as flies and mosquitoes. When in contact with surrounding homes, these pests become passive vectors of pathogen organisms; therefore they widely spread many diseases. Table 5 summarizes the diseases as a result of exposure to BMW during the handling of the pathological agents, and their transmission modes. Previous research has established the presence of pathogenic bacteria in biomedical waste [62, 63].-----

----- Table 5 about here -----

Data from the field study found high levels of knowledge of the *potential effects of poor solid waste management for health*. However, respondents also presented the dumpsite 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. Notwithstanding, people living closest to the dumpsite recognize that it brings a lot of health problems. As mentioned earlier, 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 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, 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 was not sustained after the project and many health facilities in the country still lack adequate and efficient systems for good biomedical waste management and biomedical wastes are still stored and transported with other types of wastes as confirmed in the literature [64] and through the results of our most recent field study. However there are a number of lessons learnt from this long experience of handling biomedical waste in Dakar which can lead, if embraced by all stakeholders, to foresee better prospects in this field. Better health and better planet cannot be envisioned without best practices to manage hazardous biomedical wastes and in the next section of the paper we discuss some avenues to improve biomedical waste management in the city.

**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 issue rather than a technical issue [36]. 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 are of top 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 wastes, epidemiological studies on at-risk 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 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 has insufficient knowledge about best practices of biomedical wastes management [43, 65]. The unawareness of the threats posed by BMW can partly explain why healthcare 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 healthcare facilities [43].

Besides the information, training is needed for effective BMW management system in healthcare 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 healthcare facilities is either lacking or outdated [43, 44, 65]; therefore a proper management system of BMW is not feasible. The reliable equipment is often costly and many healthcare 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. Healthcare 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 healthcare facilities lack financial resources to implement an effective BMW management system. Without public and private investments, the system will not be as effective as expected, which requires an urgent and big shifts. We propose the creation of “*geographical zones of BMW generation*” consisting of clustering of healthcare facilities in a specific geographic area. Each zone will be defined depending upon the density of healthcare facilities and inherent conditions. Thereafter, a BMW management plan will be established taking into account the specificities of each healthcare 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 healthcare facilities in the specific zone.

Policymakers and high-level managers in healthcare 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. Most of the barriers identified at policy levels include lack of government support (46%), lack of leadership (59%), lack of land tenure (59%) are the main barriers identified at policy levels. 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 are almost no indication of law enforcement regarding BMW in healthcare facilities. Managers of healthcare facilities need to have clear financial plans to ensure an effective BMW management in their healthcare facilities. Evidence indicate that either financial resources are insufficient or they do not allocate resources for BMW in their respective healthcare facilities. Unions may also be more involved to obligate healthcare managers to implement appropriate mechanisms to ensure that BMW chains in their healthcare 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 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 data from the quantitative and qualitative interviews conducted in the city between March and June 2-16. 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 remain 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 [57], most studies have investigated health impacts of old incinerators, very little data exists on direct human exposure to BMW, but 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, 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 [66] and therefore proximity to the dumpsite is linked to these dangers. Consequently, significant investment for an effective and proper BMW management in Dakar is of paramount importance given the associated health and environmental risks. 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 policy makers and stakeholders to influence policy making and action, have been identified as of utmost paramount.

**Acknowledgements**

We wish to thank the Economic and Social Research Council (ESRC) and the UK Department for International Development (DFID) for providing funding for the study. Our profound gratitude also goes to Professor Mark Pelling, the Principal Investigator of the Urban ARK project for his guidance and support.

**Conflict of interest**

None declared



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## Tables

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 (1,000 liters/day)
Hospitals	34	1,200	40.8
Health centers	89	300	26.7
Health posts	1,240	30	37.2
DPC	76	30	2.3
Health cases	1,722	10	17.2
Total			124.2

Source: [64]

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

<b>Type of health facilities</b>	<b>Number of health facilities</b>	<b>Quantity (liter/day)</b>	<b>Quantity (1,000 liters/day)</b>
Hospitals	12	1,200	14.4
Health centers	19	300	5.7
Health posts	122	30	3.7
Health cases	41	10	0.4
<b>Total</b>			<b>24.2</b>

Source: [64]

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 bins)



Table 4: Treatment techniques for different types of BMW

<b>Category</b>	<b>Type of BMW</b>	<b>Sources</b>	<b>Treatment technique</b>
<b>Non-hazardous and hazardous anatomical wastes</b>	<ul style="list-style-type: none"> <li>• Body parts</li> <li>• Organs, tissues (blood)</li> <li>• Rests of conception</li> </ul>	<ul style="list-style-type: none"> <li>• Autopsy and pathology analyses</li> <li>• Surgery, maternity, gynecology</li> </ul>	<ul style="list-style-type: none"> <li>• Cremation</li> <li>• Incineration</li> <li>• Landfill</li> </ul>
<b>Hazardous non-anatomical wastes</b>	<ul style="list-style-type: none"> <li>• Biological fluids (blood, serum, plasma, urine, sperm, expectoration)</li> <li>• Cottons, compresses, bandages, etc.</li> <li>• Gloves, materials for tests, laboratory</li> <li>• Vaccines and cultures of infectious agents</li> </ul>	<ul style="list-style-type: none"> <li>• Care in isolation</li> <li>• Dialysis</li> <li>• Microbiology analyses, biochemistry, hematology, pathology</li> </ul>	<ul style="list-style-type: none"> <li>• Incineration</li> </ul>
<b>Infectious materials</b>	<ul style="list-style-type: none"> <li>• Sharps: needles, scalpels, syringes, forceps, test tubes, etc.</li> </ul>	<ul style="list-style-type: none"> <li>• Laboratory, pathologies</li> </ul>	<ul style="list-style-type: none"> <li>• Incineration</li> </ul>
<b>At risk chemical BMW</b>	<ul style="list-style-type: none"> <li>• Non- and halogenic solvents</li> <li>• Inorganic solvents (reagents, dyes...)</li> </ul>	<ul style="list-style-type: none"> <li>• Laboratory</li> <li>• Radiology</li> <li>• Development of films</li> </ul>	<ul style="list-style-type: none"> <li>• Recycling</li> <li>• Liquids: neutralization and throw in sewage</li> </ul>
<b>Pharmaceutical</b>	<ul style="list-style-type: none"> <li>• Drugs and pharmaceutical chemicals (expired, altered, or residual drugs, toxic salt, expired vaccines, serum, toxoids)</li> <li>• Cytotoxic drugs and chemicals: neoplastic drugs and residues ...</li> </ul>	<ul style="list-style-type: none"> <li>• Preparation and distribution of drugs</li> <li>• Chemotherapy</li> </ul>	<ul style="list-style-type: none"> <li>• Incineration (minimum 1000 degrees Celsius)</li> <li>• Landfill after crushing</li> </ul>
<b>Radioactive</b>	<ul style="list-style-type: none"> <li>• Contaminated wastes, biologic fluids: lingerie, bedding</li> <li>• Contaminated hardware, unused material for preparation, contaminated solvent, scintillation liquids...</li> </ul>	<ul style="list-style-type: none"> <li>• Residues of radioactive products</li> <li>• Medical analyses and research</li> <li>• Radio-diagnosis and treatment</li> </ul>	<ul style="list-style-type: none"> <li>• Landfills</li> </ul>

Source: [67]

Table 5: 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 gonorrhoea 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: [60]

Table 6: Solid waste management in the communities

	Keur Massar / Malika	Djiddah Thiaroye Kao	Medina / Patte d'Oie	Total
<b>Waste-related problems people in this community face *</b>				
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
<b>N</b>	<b>382</b>	<b>392</b>	<b>402</b>	<b>1176</b>

\*: Multiple responses

Table 7 Types of objects or products coming from dumpsites and reused by the community\*

Paper	Keur Massar/ Malika 30.2	Djiddah Thiaroye Kao 22.5	Medina/Patte d'Oie 0.0	Total 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



The contents of this Working Paper reflect the views of the author only and not those of the UK Department for International Development or the Economic and Social Research Council.