Biomedical waste management at a regional hospital in Belgaum, Karnataka, India.

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Abstract

The study investigated the existing practices of biomedical waste management by focusing on the methods of waste separation, quantification, transportation and disposal in a hospital in Karnataka state of India. Data was collected from the waste management department of the hospital including the hospital staff members in order to identify the factors that facilitate and constrain the existing practices of biomedical waste management with the end goal of identifying sustainable measures that could be taken to improve the existing practices of waste management in the hospital. The results showed that solid waste (blood contaminated items) is generated in high quantities (207 kg/day) whereas discarded medicines and cytotoxic drugs contributed the least quantity of 3.5 kg/day. Colour coded polyethylene waste bags are provided at the point of waste generation to avoid waste mixing while also ensuring that the different waste types are disposed properly. Furthermore, the hospital staff members responsible for waste generation and handling adhere to the prescribed waste management protocol and receive training in that regard. According to the participants, the training that is provided is not monitored and as possible problems of mixing of hazardous waste with general waste were identified. This act not only poses a threat to the waste handlers but to the patients as well because when the waste is being transported, trolleys usually pass in between the wards. The hospital has an incinerator to disinfect contaminated hazardous waste and the ash after incineration ends up in the landfill site which is managed by the municipality. To conclude, the findings show that there is some degree of management of biomedical waste in the hospital however, training of the staff responsible for waste handling needs to be monitored and evaluated frequently. The hospital could consider owning and operating its landfill site to reduce the carbon foot print caused by fuel consumption during transporting of waste to the landfill sites including the costs involved.

Key words: Biomedical waste, management, waste management, health care waste

Introduction

In the 21st century, quality of healthcare around world has been improving as demonstrated by increasing access to the general practitioners' care and the optimized performance of healthcare systems [1,2]. Rapid growth of the healthcare sector is evident from the increasing number of specialized procedures such as surgeries of the knee and hip replacements in developed countries [2]. Developing countries such as India still face problems in the healthcare sector which include the shortage of infrastructure and unequal distribution of resources across the country and economic strata of the population [3-4].

Population growth compels healthcare systems to deal with the increasing number of patients, their varying health needs, the diagnoses and treatment of new conditions. Most of the healthcare provision is carried out in hospitals which are multidisciplinary organizations. Hospitals consume enormous quantities of resources in their daily activities because of increased patients' needs and complexity of the healthcare provision. This in turn leads to increasing production of waste which will be designated as biomedical waste (BMW) in further text. BMW generated in hospitals needs to be managed carefully as it can have negative implications on human and environmental health [2]. Although the majority of this waste can be put in the same category as general waste, small quantities of hazardous waste are also generated which could have detrimental environmental and health effects if not handled with care [5]. Approximately 75-90% of the waste generated in healthcare facilities is general non-infectious waste whereas the remaining 10-25% is the infectious waste [6].

The hazardous BMW includes waste generated during diagnosis, treatment and immunization of human beings or through research activities that involve the testing or production of biological substances [7]. Sources of hazards in the BMW include the following [5]: consumables, chemicals and equipment which are as a whole or in part composed of radionuclides or infectious particles, and/or any medical equipment or consumables that have medical sharps and dangerous chemical compounds as components [8]. Definition of risk from disaster management as summarized by Tandlich and colleagues can be applied to collection, processing and treatment of hazardous waste [9]. Important for an efficient waste management system is the hazards register and the inventory of the volumes/masses of the medical wastes produced [5]. The weight of waste that is generated depends on the number of patients, types of procedures performed, etc. [5]. If quantitative assessment of the mass/volume of the different types of waste produced cannot be obtained accurately through measurement and observation, questionnaires and interviews with operators of the medical waste facilities can be used to estimate of the quantities of waste from different categories [5]. Rates of waste generation are calculated as the number of kilogram of waste per patient/hospital bed and staff per month [10].

In 2008, the BMW production statistics for India showed that 2.73 million metric tons of BMW waste was produced to be disposed in landfills with the available capacity standing at 1.50 million metric tons [11]. In the same year, India produced 416000 metric tons of incurable hazardous waste, which include BMW, but the total incinerator capacity stood only at 328000 metric tons [11]. Rajor and colleagues reported that only 6.67 % of the produced amount of hazardous waste could be incinerated, even though this method is the most efficient in elimination of pathogens and reducing the mass of total waste produced by 75 % [12]. From the policy point of view, the process of medical waste management is started by the drafting, gazetting and implementation of the national medical waste policy [5]. Rule number 4 from the Biomedical Waste Regulations of the Indian Ministry Environment and Forest states that it is the duty of every institution generating BMW to ensure that the waste is handled in a manner that does not pose adverse effects on the human health and the environment [13]. This however does not mean that such institution should have BWM treatment facilities on-site except hospitals that have more than 50 beds that are mandated to have an on-site incinerator [13].

BMW management has been shown to be problematic in nursing homes with less than 50 beds in Bangalore [14]. This is supported by the general lack of awareness of the BMW management among dental professionals in India [15]. Even qualified dentists did not follow the regulatory and legislative requirements for BMW disposal. This is based on the national survey of the BMW processing by local dentists which has shown that 70.6 % of them only applied boiling water to sterilise the biomedical waste on-site of their practices [16]. The authors in the same study also found that 68.6 % of dentists disposed of the boiling-water sterilised waste in the municipal refuse collection bins [16]. The situation is further complicated by the fact that private facilities in rural areas often provide a significant part of healthcare, but they are operated by untrained staff who disposed of the BMW on municipal solid waste landfills [17]. This could meet the minimum standard of safe disposal if more stringent sterilisation procedures are implemented which could be achieved through the application of the solar autoclave as described Dravid and colleagues or other relevant technologies as described by Thakur and Katoch [18- 19].

A study of private nursing homes in Delhi showed that BMW management protocols and practices were of a very low standard, while between 25 and 41.7 % of the nursing staff did not possess any knowledge of BMW generation [20]. This would likely attract punitive action from the State Pollution Control Board or Committee exercises the punishment of the biomedical waste handling rule violators [13]. Education and awareness campaigns about the BMW management should be run among the staff of the healthcare facilities to improve BMW management. They are likely to be successful as 95 to 98.2 % of the nursing staff considered effective

BMW management important in the disease prevention and elimination of the transmission of infectious diseases [20]. Dumping of biomedical waste on municipal landfills has been reported by Choudhary and colleagues [21].

Leaching of contaminants from BMW that is disposed into landfills has been shown to contaminate water resources in India [22]. Needle stick injuries can occur during recapping of the used needles, opening of the biohazard disposal containers and recent studies have shown that the cleaning staff and nurses are at the highest risk of needle stick injuries [23-25]. This is a problem in India as recent studies from the Karnataka state indicate that 67 % of nurses and up to 83 % of medical facility technicians are involved in it [26]. Survival of disease-causing agents varies and not known to the same extent for prions, viruses and bacteria [27-28]. As a result of several factors, the volume and masses of medical waste is growing globally and this puts the public health of about 50 % of the world's population at risk from medical waste [29]. Epidemiological studies on the issue of medical waste are needed to better understand the public health risks and hazards from medical waste [5].The aim of this study was to investigate existing practices of BMW management in a hospital situated in Karnataka state of India by focusing on the methods of waste separation, quantification, transportation and disposal. The objectives included identifying the factors that facilitate and constrain the existing practices of BMW management in the hospital, with the end goal of identifying sustainable measures that could be taken to improve BMW management.

Methodology

The background information of the study site

Founded in 1996, the hospital used in this study is situated in the fringes of Belguam city in India [30]. The hospital is equipped with modern health care facilities, health care specialists and offers all basic specialities thereby making it one of the best hospitals in North Karnataka. Similar to other health care facilities that are found in India, this hospital manages its BMW on site and has a sanitary inspector who is responsible for overseeing the safe management of waste and keeps records of the different waste types including quantities. Generators of BMW waste which are primarily doctors and nurses are responsible for separating different waste types at the site of generation and then waste handlers transport the waste to either treatment facilities or disposal sites. The hospital has an incinerator which is used to disinfect infectious waste and a wastewater treatment plant for dealing with liquid waste. Ash from the incinerator is transported to a designated landfill site for disposal.

Data collection

All site access was obtained by the first author after following all the necessary procedures that are required. Data was collected from the official records of the waste management department of the hospital including the hospital staff members to identify the factors that facilitate and constrain the existing practices of BMW management, with the end goal of identifying sustainable measures that could be taken to improve the existing practices of waste management in the hospital. The collected data included the amount and types of waste that are produced in the hospital, method of waste collection, storage, transportation, treatment, disposal and the number of beds with the exception of personal data.

Results

Knowledge of the types of BMW that are produced and their respective quantities is crucial in the planning and implementation of effective waste management strategies. The data on the types and quantities of BMW produced in the hospital suggested that solid waste (blood contaminated items) is produced in large quantities per day (207 kg/day) while discarded medicines and cytotoxic drugs (3.5 kg/day) contributed less to the total BMW (refer to Table I). Information on the quantities of animal, microbiological and biotechnological waste that is produced within the hospital was not available.

Table I: the type and quantities of BMW produced in a hospital situated at the Karnataka state of India.

Waste category	Description	Quantity (kg/day)
Category 1	Human anatomical waste	40
Category 2	Animal waste	n/a
Category 3	Microbiology and biotechnology waste	n/a
Category 4	Waste sharps	14
Category 5	Discarded medicines and cytotoxic drugs	3.5
Category 6	Solid waste (blood contaminated items)	207
Category 7	Solid waste (other types of disposable waste excluding sharps)	38
Category 8	Liquid waste	16 500 m^3/month
Category 9	Incineration ash	14.5 kg/month
Category 10	Chemical waste	Included in category 8

n/a- data not available

At the point of BMW generation, colour coded polyethylene waste bags are provided to store different waste types discretely (refer to Table II). Three colour coded bins with the bags that correspond to the colour are placed so that the waste generators, which are mainly doctors and nurses, can separate the waste accordingly. Thus colour coding ensures that the infectious and non-infectious waste is separated to avoid waste mixing and to also ensure that different waste types are disposed properly. For safety purposes doctors, nurses and waste handlers are trained on how to manage BMW to minimize the health and environmental risks that are associated with the handling of waste. For doctors and nurses, the training mainly focuses on separating the waste at the site of generation using the prescribed colour coding method while the waste handlers training also includes collection, transportation and the disposal of waste. Although the training on how to manage BMW is provided in the hospital, regular assessment of BMW management practices is not given priority and as such mixing of hazardous and general waste was identified as a problem. Training on how to handle BMW is only given once to the newly employed staff and, there are no refresher courses that are provided to ensure that the employees are equipped with the new and updated strategies of managing BMW. Each hospital ward is responsible for providing training to its BMW handlers and there is a high awareness regarding the dangers posed by BMW to human health. However, there seem to be little awareness on the effects of BMW to the environment. The hospital lacks a platform or a forum where BMW generators and handlers to discuss waste management issues.

Table II: the storage and segregation of BMW in a hospital situated at the Karnataka state of India.

Colour coding of the waste bag	Type of the waste collected
White	General non-infectious and non- hazardous waste e.g paper, cardboard
Red	Infectious blood, body fluid and microbiological contaminated wastes excluding sharps e.g catheters, gloves, syringes
Yellow	Infectious human anatomical wastes e.g human tissues, human organs and body fluids
Blue	Waste from sharps e.g, needles, scalpels, blades

The BMW waste is collected every day in the morning and afternoons using closed trolleys and the waste handlers are responsible for that (refer to Table III). During waste collection times the waste handlers wear protective clothing which includes gloves, overalls, aprons, gumboots and masks to minimize skin contact with the BMW and are vaccinated. The non-infectious general waste such as paper is collected and transported by the waste handlers of the City Corporation of Belgaum (CCB) trucks to the landfill site. Organic waste from the kitchen is composted and used as a soil amender for the hospital lawn. Wastewater produced by the hospital is treated in the wastewater treatment plant that is within the premises of the hospital and is used for irrigation. Infectious and non-infectious plastic waste is disinfected with sodium hypochlorite, shredded and then sold for reuse. The hospital has an incinerator that is used for the burning of human anatomical waste and the ash is transported to the landfill site by the CCB trucks. The incinerator has a primary and a secondary chamber with a disposal chute into the primary chamber. The primary chamber burns at 750-850 degrees Celsius while the secondary chamber burns at 1000- 1100 degrees Celsius . After passing through the secondary chamber, the BMW is completely burnt to ash. The heat receiving unit (550- 750 degrees Celsius) is cooled down with cold water. Fumes are transported by water into the venture inlet where desulphurisation occurs. Caustic soda is used to remove the impurities from the fumes and the fumes are then released through the chimney into the atmosphere.

Table III: the methods of BMW collection, frequency of collection and the disposal BMW in the in-patient department and out- patient department of the hospital situated at the Karnataka state of India.

Type of waste	Method of collection	Frequency of collection	Methods of disposal
General waste			Landfill
Sharps	Collected in trolleys with closed tops and	Twice a day- once in the early morning and once	Burnt, disinfected, shredded and incinerated
Infectious waste	transported to the	in the afternoon.	Incinerated
Plastic waste	BMWM site.		Disinfected, shredded and sold

Both the in-patient department (IPD) and out- patient department (OPD) of the hospital generate BMW of 650-700 kg/day (refer to Table IV). Generally, the OPD BMW mostly consists of general non-infectious waste as opposed to the IPD.

Table IV: BMW generation rate including the number of beds in the IPD of the hospital situated at the Karnataka state of India.

Average number of patients/day	200
Total number of beds	1713
Total bed occupancy	1000
BMW generation rate (weight/day)	650-700 kg/day (including OPD)

The carbon footprint of the CCB trucks that are responsible for transporting non-infectious general waste including the ash from the incinerator of the hospital is shown in Table V. The CCB trucks travel 17 kilometres (one way trip) to dispose the dry general waste at the municipal landfill site. The waste disposal occurs five days a week and as such 25 trips are made to the landfill site making a total number of kilometres that are travelled to be 425. Assuming that on average 5 litres of diesel is consumed per kilometre travelled by the trucks, then the average amount of diesel that is used per week would be 2125 litres which is an equivalent of 170 litres of diesel consumed per pay. Based on the assumption that 2125 litres of diesel is consumed per week by the CCB trucks, the total number of litres used was calculated to be 110 500 litres of diesel per year. Considering the price per/litre of diesel in India which is 62.48 Rs (0.96 US$), the total spending of the CCB trucks on fuel would be approximately 106 093.62 US$ per year. The total amount that the hospital pays the CCB for the transportation of waste is not reported; as such the reported price was based on the 2017 diesel prices. Using the known conversion factors to estimate the greenhouse gas emission over a period of a year, the total emissions were found to be 295 256 kg's.

Table V: the carbon footprint of the CCB trucks responsible for transporting waste to the landfill sites.

Greenhouse gas	Conversion factor	Diesel (litres/year)	Emission (kg)
CO_2	2.6413	110 500	291 863.65
CH_4	0.0015	110 500	165.75
N_2O	0.0292	110 500	3226.60
Total emission			295 256

Discussion and conclusion

The management of BMW begins at the point of generation where the waste generators are expected to separate the different waste streams based on the degree of the health hazards posed by each waste stream. This is achieved through the use of colour coded waste receptacles to ensure that non-hazardous waste is separated from the hazardous waste. In cases where the frequency of BMW collection is low, waste generating sites are expected to have temporary waste storage facilities before long distance transportation, treatment or disposal of waste [5]. Management of BMW in hospital involves numerous steps which include waste collection, separation, storage, transportation, treatment and disposal. There is an onsite BMW management site where secondary waste separation occurs prior treatment and disposal including a wastewater treatment plant and an incinerator. The aforementioned facilities play a key role in the safe management of the waste generated within the premises of the hospital. The BMW management strategy of hospital, is be effective and in line with the regulations for BMW management [13,31]. Training is provided by the hospital to the BMW generators and handlers although there seemed to be a lack of assessing and monitoring the training program. The WHO guidelines of 2014 do recommend that some form of training be provided to the waste handlers to minimize any health and environmental risks that might be the consequence of mismanagement of BMW [5]. A study conducted by Patil and Pokhrel recommended that KLE Society hospital should have meetings with the waste generators and handlers to address the issues that are linked to waste management practices after identifying that there was no forum for discussing waste management issues [31]. Extended training, practical demonstrations and the reminder on health care waste management guidelines for a period of 18 months was found to be very useful towards improving the knowledge and the skills of health and sanitary workers in teaching hospitals in Pakistan [40]. As such, implementing the same strategy in the hospital used in this study could be a possible solution.

The hospital has an inventory of the BMW types that it generates, which serves as an important factor when planning on implementing waste management strategies (refer to Table I). Solid waste (blood contaminated waste) constitutes a major portion of the waste that is generated in the hospital (207 kg/day). Patil and Pokhrel reported a waste generation rate of 327 kg/day of non-infectious waste per ward and only 63 kg/day for infectious waste [32]. Choudhary and colleagues reported production rates of 325-350 kg/day for yellow bags, 5-10 kg/day for red bags, 30-35 kg/day for blue bags and 225-250 for the black waste bags in the hospitals and clinics of Jodhpur city which had a total of 4886 beds [21]. The authors further reported that the average quantity of the total waste collected from these healthcare facilities equalled 600-650 kg/day [21]. Such data is important when deciding on the necessary and appropriate technologies that would be required to effectively manage the waste. As per the regulations of BMW management in India, the hospital uses the colour coding method for the collection and the storage of different types of waste [13,31]. The training that is provided to the doctors and nurses, the major BMW generators in the hospital, enables them to separate BMW according to the prescribed separation protocol. A study conducted by Chudasama and colleagues in PDU Government Medical College and Civil hospital reported that only doctors (98.4%) were aware of BMW separation by colour coding as stipulated in the regulations, and that there was poor awareness amongst among other health care personnel [6]. On the contrary, nurses (72.72%) were found to be more aware of the colour coding of BMW as opposed to the other health care personnel in Mangalore [33]. BMW separation using colour coding minimizes the chances of mixing general and hazardous waste ensuring that the respective waste types are treated or disposed of properly.

During waste collection times closed metal trolleys are used when transporting BMW within the passages of the wards to the BMW management site. Contact between the patients, hospital and BMW is prevented by using predetermined routes and elevators for waste transportation [7]. Furthermore, waste collectors are always wearing their protective clothing to minimize contact with the BMW and the waste is collected twice daily to prevent waste accumulation and spillages. These are not standardized BMW collection times across India as 4 collection times have been reported in some hospitals [34]. BMW collection times are mostly based on the waste generation rate within the different medical facilities of the hospital and the chosen time slots are such that the waste bags are not too full during collection [32, 35]. The collected waste is transported to a BMW management site within the hospital or a temporary waste storage facility prior treatment or disposal.

The secondary separation of different types of BMW occurs in the BMW management site in the hospital. In this site, the different waste streams are disinfected, shredded, incinerated or further transported for disposal in a landfill. The disinfection process involves the use of sodium hypochlorite however use of other chemical reagents with the similar effect are used in other hospitals. Shredding is done to prevent unauthorized use of waste types such as needles, however, plastic wastes in the hospital is shredded after disinfection and sold to plastic recycling companies to generate revenue for the hospital. The hospital uses an incinerator for waste sharps such as needles, syringes, scalpels *et cetera* and infectious waste. After incineration, the waste sharps are then buried in a ditch to prevent any unauthorized use whereas the ash from the infectious waste is transported to the landfill site for disposal.

Generally an incinerator emits pollutants such as furans, dioxins, carbon monoxide, nitrogen oxide which pose environmental and health concerns [36]. However, the design of the incinerator in hospital allows the scrubbing of these toxins through the use of caustic soda prior discharge into the atmosphere such that very minute concentrations are released. There are other types of thermal treatments which could be considered and these include non-burn technologies such as an autoclave, hydroclave, microwave, plasma pyrolysis and electro-thermal deactivation. These technologies are as effective as an incinerator, however, the type of the BMW generated or that requires treatment often determines the preferred technology including maintenance, operation and the availability of the financial resources [37- 38]. The ash from the incinerator is transported by the CCB trucks to a landfill site for disposal. Although the costs of the BMW transportation services to the hospital is unknown, the estimate's based on fuel consumption suggest that the service might be expensive. A study that was conducted by Rao and colleagues noted that managing of the BMW takes a significant portion of the hospital budget and that on top of the construction, operation and management of the BMW management systems, internal and external costs are accrued [39]. Furthermore, the authors also noted that the hospitals that adhere to the recommended BMW handling rules of 1998 usually have high capital costs. If the hospital could open its own landfill site on its premises, the external costs which refer to the costs associated with transporting the waste to the municipal landfill could be eliminated and the financial resources would be redirected to areas of need such as training and updating the skills of the BMW handlers.

To conclude, the study identified public and environmental health as the major factors that facilitate BMW management in the hospital including the country's regulations regarding how such waste should be managed. The BMW management system that was implemented in the hospital is in line with the national regulation of BMW (management and handling) Rules of India. However, the lack of the assessment and monitoring of the training programme for BMW handlers in the hospital including equipping the staff with the latest knowledge, skills and techniques of BMW management is a problem. Environmental health awareness campaigns should be conducted frequently and the senior hospital management should be involved so as to ensure that training of waste handlers is prioritized to prevent unnecessary environmental and health risks. This would be in line with the recommendations made by the WHO regarding how trainings should be conducted and monitored. With the training in place, a strict monitoring programme for compliance with the waste handling rules could be introduced to avoid cases of waste mixing which could lead to the transmission of infectious agents thereby exposing unsuspecting individuals to preventable risks. If financial constraints are the reason due to a strict budget, perhaps abandoning the services of the CCB by constructing an on-site landfill site and redirecting the financial resources to the training of BMW staff could solve the problem. Proper training of the BMW handlers and generators is imperative for the in ensuring that the BMW management system is sustainable and fully functional as shown by Kumar and colleagues [40].

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