QUANTITATIVE ASSESSMENT OF MEDICAL WASTE GENERATION IN THE CAPITAL CITY OF BANGLADESH

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Abstract

There is a concern that mismanagement of medical waste in developing countries may be a significant risk factor for disease transmission. Quantitative estimation of medical waste generation is needed to estimate the potential risk and as a basis for any waste management plan. Dhaka city, the capital of Bangladesh, is an example of a major city in a developing country where there has been no rigorous estimation of medical waste generation based upon a thorough scientific study. These estimates were obtained by stringent weighing of waste in a carefully chosen, representative, sample of HCEs, including non-residential diagnostic centres. The present study used a statistically designed sampling of waste generation in a broad range of Health Care Establishments (HCE) to indicate that the amount of waste produced in Dhaka can be estimated to be 37 ± 5 tonnes per day. The proportion of this waste that would be classified as hazardous waste by World Health Organisation (WHO) guidelines was found to be approximately 21%. The amount of waste, and the proportion of hazardous waste, was found to vary significantly with the size and type of HCE.

Key words: medical waste, healthcare establishments, hospital, clinic, hazardous waste, Dhaka.

Introduction

Medical waste may contain highly toxic chemicals (Muhlich *et al.*, 2003) and can present a mechanism for transmission of diseases (Chintis *et al*., 2004; Silva *et. al*. 2005; Sabour *et.al.* 2007; Birpinar *et. al*., 2008). The growth of the medical sector around the world over the last decade (WHO, 2002; Karamouz *et.al.,* 2007) combined with an increase in the use of disposable medical products has contributed to the large amount of medical waste being generated (Silva *et. al*., 2005).

Bangladesh is a developing country with a rapidly growing urban population, extensive health problems, low educational status and environmental pollution (Kabir *et. al.,* 2003; Rahman *et. al.,* 2007). The selected study area is the Dhaka City Corporation (DCC) area. This is located in the middle part of Dhaka District, the capital of Bangladesh, divided into ninety nine administrative zones known as 'wards' and with a population of 11.9 million (BBS, 2007).

Rapid population growth has resulted in a demand led growth in hospitals, clinics, private individual practitioners, diagnostic centres and pathology services (Rahman *et.al.,* 2007). There has been concern that the facilities for waste disposal from healthcare establishments cannot cope with these growing demands (PRISM, 2004; Hassan *et. al.*, 2008). Any waste management plan should be based upon a reliable estimate of the amount of waste generated (Karamouz *et.al.,* 2007) and the objective of this study was to use a rigorous sampling method to gain a reliable estimate of the hazardous and non-hazardous waste generated by HCEs in Dhaka city. Reports dealing with the total waste generated in Dhaka and Bangladesh (Table 1) give estimates of total waste generation in the city ranging from 7.2 tones per day to 400 tones per day. Some of the estimates, including those from the best resourced studies, are associated with projects not primarily intended to obtain a reliable estimate of total waste generation, while others use extrapolation from studies undertaken in other countries, and still others do not provide details of the basis of their estimates.

Methodology

The quantity of waste generated was estimated by collecting and weighing waste from a representative sample of HCEs over a period of 5 months in 2006.

The population of HCEs in Dhaka was defined by a list supplied by the Directorate General of Health (DG Health report, 2005). These were sampled according to a desired 90% confidence level using a Population Proportionate to Size (PPS) stratified plan (Barnett, 2002; Islam 2005) considering three types of HCEs: (1) hospital services (in-patient and out-patient) including pathological and diagnostic laboratories, teaching and research facilities (2) Clinics and (3) Diagnostic Centres. This suggested a

sample size of 67 HCEs, made up of 2 hospitals, 21 clinics and 44 diagnostic/pathology centres. As the sample size for the hospital group is small, a further 2 units were added to provide better representation of this group, giving a total sample size for this study of 69, which is 8.21% of the total population (Table 2). Each HCE was assigned a unique number, and a table of random numbers (Daniel, 2006) was used for selection of the sample. Where substitutions were required, the nearest unsampled HCE in the same category was chosen. Seven substitutions were required due to inaccurate addresses. As such published lists often tend to be out of date, this was not considered to have introduced a significant bias. Six substitutions were required for HCEs that were unwilling to take part in the survey. In these cases the substitutions may have introduced some bias to the sample although the observable characteristics of the HCEs, which refused to take part (apparent number of beds, locations, type) were not otherwise out of line with the sampled population. A similar problem was encountered by Hassan *et al.* (2008) who suggested that some institutions were reluctant to be interviewed as they were aware that they were not following proper rules and regulations relating to waste management.

The fieldwork was carried out by a main researcher and a team of 10 locally recruited field investigators. Waste generation data were recorded over three shifts (4 am - 12 noon, 12 noon - 8 pm and 8pm - 4 am) on each of three days in a week (two weekdays and one weekend) in each HCE. The field investigators placed a designated bin-bag in each ward or department at the start of a shift and collected the bag at the end of the shift, replacing it with a new one to continue the survey program. The bin-bags were individually weighed using a hand held scale. Then the waste was manually segregated (following appropriate safety precautions) into two categories (hazardous or non-hazardous) as designated in WHO guidelines (Pruess *et al.,* 1999) and weighed again. Each investigator received training on how to measure the waste quantity, on safe operation during segregation of hazardous and non-hazardous waste, on replacing bin-bags and on data recording procedures. This method was applied to all departments of each HCE, including both of the official mortuary departments in the study area.

Data analysis

The quantities of waste generated by the sampled facilities was generalised to estimate medical waste production for the entire study area using this formula.

$$\hat{Y} = \left(T_{hb}\hat{W}_{hb}\right) + \left(T_{cb}\hat{W}_{cb}\right) + \left(T_{dt}\hat{W}_{dt}\right)$$

Where $\hat{Y}$ = total waste generated per day

T_{hb} = total number of hospital beds in Dhaka

$\hat{W}_{\text{hb}}$ = average waste per hospital bed per day in sampled hospitals

T_{cb} = total number of clinic beds in Dhaka

$\hat{W}_{cb}$ = average waste per clinic bed per day in sampled clinics

T_{dt} = total number of diagnostic centre tests per day in Dhaka

$\hat{W}_{dt}$ = average waste per diagnostic test in sampled diagnostic centres

Errors in the estimates:

The data was recorded in MINITAB (version 15) and analysed by descriptive statistical methods. The data used to calculate $\hat{W}_{hb}$, $\hat{W}_{cb}$ and $\hat{W}_{dt}$ were found to be normally distributed and average values are given ± 95% confidence intervals. Other estimates of error are explained where they are given.

T_{hb} This was estimated from official records (BBS, 2007). In each case, the number of beds in the sampled hospitals was checked during data collection, and was in line with the official values.

T_{cb} The total number of beds in clinics (6136) was based on the estimate previously reported in "The Study on the Solid Waste Management in Dhaka City" (JICA, 2005) and derived from government records (BBS, 2007). There is no indication of the error in this estimate but it is likely that it may be a slight underestimate.

T_{dt} This was estimated by assuming that the 44 sampled diagnostic centres were representative of the population of 551 centres in terms of the number of tests per centre, allowing T_{dt} to be calculated as 14000±1100. This approach is considered reasonable, as the 44 sampled centres were found to be quite homogeneous in terms of the number of tests per centre per day (25±2). However, it is likely that 551 is a slight underestimate of the number of centres.

Results and Discussion

Source, composition and generation of waste in the surveyed HCEs

The composition of medical waste depends upon different parameters, such as the size of the HCE, type of patient care provided and the waste segregation system (Tudor, 2005). In the present study, an average 21% of waste generated by HCEs was classified as hazardous (Table 5). This is generally in line with the range found in a WHO (2001) study on the composition of medical waste, where 10 – 25% of waste from HCEs was found to be hazardous (Pruess *et.al*, 1999). The overall rate of hazardous waste per bed in Dhaka (0.28 kg bed^{-1} day^{-1}, estimated by dividing the total amount of hazardous medical waste generated by hospitals and clinics by the total number of beds) was found to be lower than that reported by Silva *et al*. (2005) in Brazil (0.57 kg bed^{-1} day^{-1}). The differences are probably due to socio-economic and cultural conditions, living standard of the patients, and availability of temporary storage facilities and ways of waste categorising and segregation system.

It was found that the proportion of waste classified as hazardous varied significantly between different types of HCE ($p < 0.001$). The highest values (48.4 ± 1.4 %) were found at diagnostic centres, while the proportions of hazardous waste recorded at clinics and hospitals were much lower at 22.5 ± 1.1 % and 16.8 ± 1.6 % respectively. While hospitals with large number of patients generate large volumes of total solid waste (Table 4), the amount of waste per bed is lower than that found in clinics ($p < 0.05$, Table 3). The two government hospitals included in the survey generated more waste than the two private hospitals (due to higher patient numbers), but both total waste and hazardous waste generated per bed is similar in private and public hospitals. Figures 1 and 2 suggest that the most useful distinction may be between small clinics (≤14 beds) and large clinics (>15 beds), rather than between clinics and hospitals. The values recorded at hospitals (both private and public) and large clinics seem comparable, but small clinics seem to generate larger amounts of waste (including hazardous waste) per bed. The sample of private clinics included some very small clinics, accommodating less than ten patients and employing specialists at a favourable patient: specialist ratio. These may have a greater proportion of non-residential clients and may attract more affluent patients with an expectation of better treatment and modern facilities (Rahman *et. al.,* 2007) and this may be associated with more comfortable residential care and an increased number of tests per patient, generating amounts of waste comparable to those found in European studies. Bdour *et.al.,* (2007) have reported the average waste generation in European HCEs to be 3.9 kg bed^{-1} day^{-1} (Norway), 4.4 kg bed^{-1} day^{-1} (Spain) and 3.3 kg bed^{-1} day^{-1} (UK and France).

Table 4 indicates the highest percentage of waste generation (by weight) in facilities providing residential or food services for patients is from kitchens (hospitals, 50.46% and clinics 45.42%) Unless it becomes mixed with hazardous waste, this waste is mostly non-hazardous. The proportion of waste from kitchens is higher than previously observed (28%) in the HCEs in the northern part of Jordan (Bdour *et. al.,* 2007). As the third category of HCE surveyed, pathology/diagnostic centres, treat patients on a day-care, those included in the survey produced less waste per bed, but a higher proportion of hazardous waste. Kitchens made only a very low contribution to total waste and these non-residential facilities produced less non-hazardous waste arising from non-medical patient care. The average waste generation rate was 0.58 ± 0.09 kg $test^{-1}$ day^{-1} in the surveyed pathology/diagnostic centres. This is higher than Jordan, where the rate of generation was 0.034-0.102 kg $test^{-1}$ day^{-1} (Bdour, 2007) but lower than Brazil, where it was found to be 1.28 kg day^{-1} (Silva *et al.* 2005).

Although bins were placed conveniently, so that workers would use them without disruption to their normal routine, there may be systematic error in the measurement of waste relating to the size of the HCE. In larger establishments, there is an increased possibility that some waste may leave a department without being weighed, while in smaller establishments there may be some transfer of waste between departments before being weighed. It is not considered likely that either of these effects could have contributed significantly to the large differences in the amount of waste produced per bed. Similar findings have been reported in Delhi (Verma *et. al*., 2008) and Ulaanbaatar (Shinee *et. al.,* 2008).

Estimation of total medical waste produced in Dhaka

A representative sampling plan was adopted for the current study, with the intention of extrapolating the results to provide a reliable estimate of the total rate of medical waste production in Dhaka City. Based on the data presented here, it can be estimated that the total rate is 37±5 tonnes per day. This is higher than the estimate of 13.6 tonnes per day given in a JICA report (JICA, 2004) but much less than the estimates of 255 tonnes per day given by Visvananthan (2006), 200 tonnes per day reported by Lawson (2003) and 400 tonnes per day reported by Haque (2000). The estimated rate is similar to that of 37.6 tonnes per day given in the World Bank Report, (World Bank, 2003). It is also slightly lower than the DCC estimate of 50 tonnes per day, reported in a daily newspaper (DCC, 2003). The reason for the wide variation is undoubtedly due to differences in methodology. Although it is also possible that the quantity of waste being produced has changed over the years, there is no obvious relationship between the date and the size of the estimates.

Most of the reports listed in Table 1 used convenience and purposive sampling (PRISM, 2004; Hassan *et.al.,* 2008) or secondary data (JICA, 2005; Visvanathan, 2006). The PRISM study (2004) used purposive sampling based on constricted project objectives, and so is not free from bias (Islam, 2005). Many of the reported estimates are found in news reports, where the primary source or sampling system was not given (DCC, 2003; Lawson, 2003).

Hassan *et.al*., (2008) suggested that, because of difficulties in gaining access to a representative sample of HCEs, no statistically rigorous sampling plan was possible. This means that the study effectively applied a form of convenience sampling, where samples are chosen based on criteria such as accessibility. This is likely to introduce a significant bias (Daniel, 2006). In the present study, relatively few HCEs refused to take part. On first contact, many HCEs were reluctant, however all but six were persuaded to take part following a second visit, and following reassurance that the study was not part of a government initiative.

The six HCEs which refused to take part were each replaced in the study by their nearest neighbour. Although these replacements did not significantly alter the number of beds or tests included in the study, it is possible that the quantity of waste produced per bed or per test will be different in non-participating establishments. It is considered unlikely that the impact of this is significant as they represent less than 10% of the intended sample, and because they were not among the larger establishments. Of the HCEs which refused to take part, none was a hospital. Two were clinics, but these were both quite small (7 and 12 beds compared with an average in the sample population of 40 beds). Four of the non-responding HCEs were diagnostic centres, the largest of which was estimated to undertake 15 tests per day, compared with an average in the sample population of 25 tests per day.

The estimate given in the current study is based upon a measurement of waste generation per bed in a representative sample of hospitals and clinics, and a similar measurement of waste per test in a sample of diagnostic centres. These values were then multiplied by an estimate of the total number of beds or tests to get an overall estimate. There is a problem with this approach; the estimate of the number of beds or tests may be unreliable because the list kept by 'DG Health' may not be accurate. There is a tendency to underestimate the number of occupied beds, partly because institutions pay tax according to the recorded number of beds (BBS, 2006). In addition, any published list must be, to some extent, out of date and in an expanding sector this will always make it an underestimate of the true current condition. Furthermore, as there was no official estimate of the number of tests made in diagnostic centres, it was necessary to extrapolate from the sampled centres, thus assuming that they were representative in terms of number of tests as well as the quantity of waste produced per test. The chosen sampling plan was designed to achieve this, and so is considered to give the best possible estimate, given the resources available.

Conclusion

This study is the first to apply a thorough, rational, and representative sampling plan to the estimation of medical waste generation in Dhaka. It is also the first to fully consider the contribution of non-residential diagnostic centres, which were found to contribute a substantial proportion of waste. It is hoped that this estimate will be sufficiently reliable to allow sound planning. A review of the literature suggests that the remarkable relationships between the size of residential HCE and both the amount of hazardous waste per bed, and the proportion of hazardous waste produced, has not previously been observed. It, too, may have significance in planning.

Detailed analysis of the make-up and sources of waste from HCEs has shown that a major proportion is not initially hazardous, and only becomes hazardous due to mixing with clinical waste. Thus, although

almost all of the waste produced by HCEs was considered hazardous, it is likely that better segregation of waste would have a quick and dramatic impact on lowering the total hazardous waste. In particular, there would be a huge benefit arising from better procedures for dealing with kitchen waste, and for keeping it separate from clinical waste.

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Table 1 Average medical waste generation rate in Dhaka City, as reported in different studies

Study	Date	Sampling	Waste Generation Estimate	
			Per day (tonne)	Per bed per day (kg)
Hassan et.al.	2008	Convenience sampling of HCEs willing to take part in the study. No indication is given of the number that did not agree.	--	1.9
Visvanathan	2006	Not given. Apparently secondary data, mostly from other reports included in this table.	255	0.8 – 1.67
JICA	2005	Secondary data taken from DG Health Directory	7.2 – 23	1.2
PRISM	2004	Purposive sampling of two (from a total of 99) DCC administrative wards involved in the particular project being studied.	--	2.63
JICA	2004	Secondary data taken from DG Health Directory	13.6	1.2
DCC	2003	DCC Personal interview with 'The Bangladesh Observer', Daily Newspaper, but source not given.	50	--
World Bank	2003	Extrapolated from studies done in other countries	37.6	--
Lawson	2003	Secondary data, but source not given.	200	--
Akter and Trankler	2003	Representative sampling system. The sample included four large public hospitals and one private hospital, but only two clinics and two diagnostic centres.	--	0.55 – 1.10
Nessa et.al.	2001	Secondary data, but source not given.	200	--
Haque	2000	Secondary data received through survey, but sampling system was not given.	400	--
Rahman and Ali	2000	A combination of secondary data and extrapolation from studies done in other countries	255	1.17
Rahman et.al.	1999	Apparently convenience sampling of selected HCEs (8 hospitals and clinics but no consideration of diagnostic/pathology centres).	--	0.8 – 1.67
Asaduzzaman and Hye	1997	Not given	199.5	--

Table 2 Selected HCEs in Dhaka City Corporation

Strata	Total HCE	Allocation of the sample on PPS basis
Hospitals	29	4
Clinics	260	21
Diagnostic/pathology	551	44
Total	**840**	**69**

Table 3 Waste generation rate in surveyed HCEs

HCEs	Size of HCE		Waste generation rate		
	Beds	Test day^{-1}	kg day^{-1} (%)	Average	
				kg bed^{-1} day^{-1}	kg $test^{-1}$ day^{-1}
Public hospital	2425		3600 (52)	1.50 ± 0.06	
Private hospital	800		1200 (17)	1.53 ± 0.18	
Clinic	846		1450 (21)	1.71 ± 0.75	
Pathology/ diagnostic	0	1098	640 (9)		0.58 ± 0.09

Data were collected in three different days (2 weekdays and one weekend).
Total waste generation for each type of HCE is shown in kg day^{-1}, with percentages of the overall total (6890 kg day^{-1}) in brackets.
Averages per bed or per test are shown ± 95% confidence interval.

Table 4 Amount of waste generated by different departments in surveyed HCEs

Source of waste	Average waste generated at source kg day^{-1}			Total
	Hospital	Clinic	Pathology /diagnostic	
Administration/ support service	425 ±5(8.84)	119 ±2 (8.23)	72±2 (11.20)	617(8.94)
Patient service/ward	870±7(18.11)	240 ±2(16.51)	0.00	1110 (16.09)
Laboratories/research	85±4 (1.78)	39 ± 3 (2.6)	285 ± 46(44.45)	409 (5.93)
Operating theatre	225±4(4.69)	61 ±5 (4.21)	0.00	286 (4.15)
House keeping	60 ±3(1.24)	31 ± 3(2.13)	62±3(9.60)	153 (2.21)
Disinfecting activities	255 ±5(5.31)	67 ±5 (4.59)	52 ±4(8.05)	373 (5.41)
Emergency	70 ±4(1.46)	42 ±2 (2.89)	0.00	112(1.62)
Blood bank	40 ±5 (0.83)	30 ±1 (2.00)	0.00	69 (1.00)
Pharmacy	90 ±4 (1.87)	71 ±4(4.85)	66±5(10.32)	227(3.29)
Laundry	40 ±4(0.83)	36 ±3 (2.47)	0.00	76(1.10)
Kitchen	2425±13 (50.46)	660 ±7 (45.42)	105 ±4(16.37)	3190 (46.24)
Engineering	70 ±3(1.46)	26 ± 2 (1.79)	0.00	96 (1.39)
Public areas	150 ±6 (3.12)	32 ±1 (2.20)	0.00	182(2.64)
Total	4805 ±21(100)	1454 ±12 (100)	642± 9 (100)	6900 (100)
Data were collected in three different days (2 weekdays and one weekend) Averages are shown ± 95% confidence interval and with percentages of the total shown in brackets.				

Table 5 Composition of waste generated in surveyed HCEs

Types of waste		Average type of waste generates kg day^{-1}			Total
		Hospital	Clinic	Pathology /diagnostic	
Non-Hazardous	General	3960 ±10 (82.42)	1135±5(78.24)	331±4 (51.77)	5426 (78.70)
Hazardous	Pathological	230 ±5 (4.78)	90 ±2 (6.20)	79±2 (12.41)	399(5.79)
	Infectious	120 ±2(2.49)	71±2(4.88)	70 ±2 (10.93)	261(3.78)
	Pharmaceuticals	95±3(1.97)	61 ±2(4.17)	54±2(8.48)	210(3.04)
	Chemical	121±4(2.51)	40±2(2.74)	31 ±2(4.77)	191(2.77)
	Sharps	139±3(2.90)	30±1 (2.04)	25±1 (3.94)	194(2.82)
	Toxic	115±2 (2.39)	15±1(1.05)	29±2 (4.54)	159(2.31)
	Radioactive	25 ±1 (0.51)	10 ±1(0.65)	20 ±2(3.13)	54(0.79)
Total		4805±13(100)	1452±6 (100)	639 ±7 (100)	6894(100)

Waste from HCEs was classified as non-hazardous or hazardous. Data were collected in three different days (2 weekdays and one weekend).
Averages are shown ± 95% confidence interval and with percentages of the total shown in brackets.

Figure 1

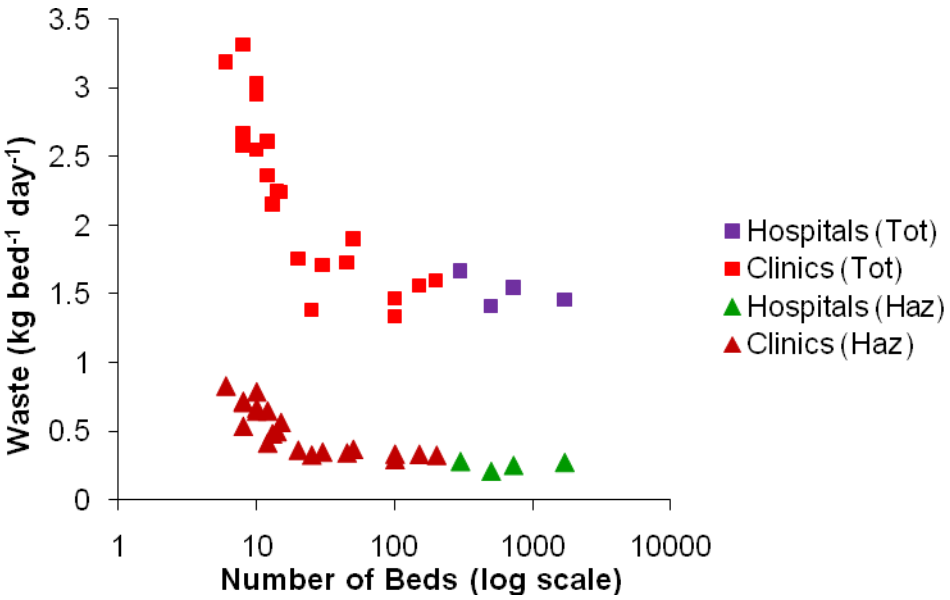

Figure 2