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Clinical Waste Management: A Review on Important Factors in Clinical Waste Generation Rate

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ABSTRACT

As in many developing countries the generation of clinical waste has increased significantly over the last few decades, management of this kind of waste continues to be a major challenge. Developing appropriate model for accurate prediction of waste generation rate can be useful in the storage, transportation, treatment and disposal of clinical waste. Selecting appropriate features is the primary requirement for offering a model. This research is an overview on the existing researches in the area of clinical waste management to investigate different findings regarding associated factors on quantity of waste generation. The aim is to find, integrate and enhance accessibility to hospital key factors in waste generation forecasting. It is revealed that the number of patients, number of beds, bed occupancy rate and type of hospitals were as the most important factors in waste generation.

Keywords: healthcare facility, clinical waste, management, waste generation, associated factors.

1. INTRODUCTION

Over the years, the world has witnessed the rapid population growth in different patterns and extraordinary waste generation. In many developed and developing countries, collection, transportation, treatment and disposal of waste are the major challenges for government, organizations and other institutions. Different types of solid wastes depending on the generation resource can be classified into household waste or municipal waste, industrial waste as hazardous waste and biomedical waste.

Biomedical waste or clinical waste is classified as one of the most dangerous wastes in the world. Clinical waste refers to any waste that is generated during medical activities such as diagnosis, monitoring, and immunisation or treatment of human beings or animals (Rutala and Mayhall, 1992). It includes viruses and bacteria that potentially cause diseases which are produced by hospitals, clinics, doctor's offices and other types of healthcare institutions.

In recent years, concern over clinical waste has increased throughout the world. Improper management of clinical waste poses a public health risk. Therefore, appropriate Clinical Waste Management (CWM) is a crucial issue for maintaining human and public health (Nema et al., 2011). The CWM practices cover all processes from the point of identification the wastes, to the place it is disposed in an incinerator. Initial handling, collecting, transporting, disposing and monitoring of waste materials are collectively called waste management. The primary objectives of waste management are reducing the amount and hazards of waste. Reusing the waste through the provision of secondary raw materials and use of the waste as energy resource are other objectives of waste management (Mochungong, 2011).

The complexity and importance of waste management issue can be changed in developed and developing nations. Although there are many legal rules and national health policies concerning the CWM in many countries but improper handling and disposal of clinical waste represents lack of sufficient attention to management of clinical waste in some developing countries (Abor and Bouwer, 2008).
Obviously, rate of clinical waste generation differs in different hospitals and in different times. Recently, assessment of waste generation rate receives increasing attention in literature. Many researchers applied statistical methods and developed equations to estimate medical waste generation rates at hospital. The present study provides a review of articles comparing effective factors in quantities of waste generation in hospitals and other healthcare centres. The main objective of this study is identification and extraction of key factors in waste production to predict clinical waste generation in different healthcare establishments. The next section summarized relevant articles and gathered their key points regarding to waste generation rate in the table. On the other hand, the results of key hospital parameters in clinical waste generation have been shown in a table in next sections in order to enhance readability and provide a quick comparison of the reviewed papers in this study.

2. A REVIEW OF LITERATURE

A survey by Suwannee (2002) was carried out to review medical waste management in Phitsanulok province, Thailand in order to improve waste management. The objective of study was to classify the characteristics of waste and create the implementation structures at hospital. The research was conducted to find the average daily waste generated from hospital and clinics. Numerous factors such as type of hospital, specialization, proportion of reusable items, and waste

management plan were investigated in waste generation assessment.

Askarian et al. (2004) conducted a survey on management and disposal of clinical waste in private hospitals in Fars province, Iran. In this study, the amount of different kinds of waste produced at hospitals was determined and a relationship between the weight of the waste generated and several factors such as number of bed, economic, social and cultural status of the patients and the general condition of the area where the hospital was situated was found. But the results did not confirm a statistically significant correlation between types of health services provided.

Awad et al. (2004) used mathematical-statistical models to predict quantity of waste generated at hospitals in Irbid, Jordan. The generation rates were evaluated on the basis of kilogram per patient/per day and kilogram per bed/per day. In their model, they observed that the significant factors including the number of patients, number of beds and type of hospital affect on weight of generated waste. They showed that there is a linear relationship between the waste quantities and number of beds occupied.

Hamoda et al. (2005) determined hazardous and nonhazardous waste generation rates at two public hospitals in Kuwait. Some important factors such as the number of patients, number of beds and the type of activity were identified in relation to the generation rates. The results indicated that the calculation of generation rates based on number of patients was more applicable than the number of beds.

Da Silva et al. (2005) evaluated CWM practices in the south of Brazil and reported the amount of medical waste depend upon several factor such as the type of healthcare facility, status, capacity, level of instrumentation, and location of the facility.

A study was conducted by Alhumoud and Alhumoud, (2007) to determine the amount of different kinds of solid wastes and assess the obstacles in the existing hospital's solid waste management system in government hospitals of Kuwait. The waste generation rates depend on several factors such as established waste management methods, type of health-care establishment, hospital specializations, proportion of reusable items employed in health care and proportion of patients treated on a day-care basis.

Bdour et al. (2007) conducted a survey on all existing methods for handling and management of medical waste disposal. In the study, statistical methods were used to develop mathematical models for prediction of hospital waste quantities. Moreover, important factors including the number of patients, number of beds, and hospital type which are effective in waste management were investigated. Their study provided tools for better medical waste management.

Marinkovic et al. (2008) provided a review of management of hazardous waste production in Croatia. They mentioned that the quantity of clinical waste generation depends on the size and the type of healthcare institution, but also based on national income and level of development, it differs from country to country.

Katoch and Kumar (2008) presented a technique to develop mathematical model in biomedical waste generation in three major hospitals in Shimla town, India. Their proposed model correlated the waste generation rate as function of bed occupancy and type of ailment in terms of seasonal changes. They stated that biomedical waste quantities depend upon the number of patients and the nature of illnesses of patients in different seasons. Different trends in waste generation rate and bed occupancy were observed during the research period. In addition, due to the similar seasonal illnesses pattern and social factors, a fixed seasonal variation was observed in biomedical waste generation rate.

Taghipour and Mosaferi (2009) argued that the availability of sufficient information about the amount and composition of the waste generated are fundamental prerequisites for the implementation of CWM. Study determined the characteristics of medical waste such as quantity, quality, composition and medical waste generation rate at different hospitals. The results showed the effect of many factors such as medical waste management methods, type of hospital (i.e., governmental, educational, university, private, NGO and military), type of specializations, ratio of reusable items, the general condition of the place where the hospital is located, number of patents per day and their economic, social and cultural conditions in generation rate among hospitals.

In the study of Yong et al. (2009), medical waste management status was analyzed in Nanjing, China. A survey was conducted to evaluate medical waste management aspects in selected hospitals. Moreover, the medical waste generation rate was calculated in order to improve waste management practices. Several factors such as hospital size, hospital location, beds occupancy percentage, medical waste segregation program, type of hospital and type of services were investigated in order to calculate medical waste generation rate.

In a research by Cheng et al. (2009), the quantities of generated medical waste and the factors associated with the generation rate in Taiwan were evaluated. Research examined the medical waste generation rate with the potential associated factors such as the types of hospital, number of beds, bed occupancy, reimbursement payment, number of infectious disease beds and outpatients per day. Multiple variable regression analysis was applied to predict the factors associated with waste generation. The results demonstrated that two insurance reimbursement and number of beds were the significant medical waste prediction factors in medical establishments with the multivariate regression model. It is suggested that large hospitals are the major source of medical waste in Taiwan.

A case study was conducted by Sawalem et al. (2009) to evaluate hospital waste management in Libya. The study found that several factors such as the type of healthcare establishment, level of instrumentation and location affect waste generation rates. The result showed that the highest generation rates at Tripoli Medical Centre are attributed to larger number of patients due to being in the capital of Libya.

Azage and Kumie (2010) evaluated waste management system and assessed the rate of waste generation at ten public health centres in West Gojjam Zone, Amhara Region, Ethiopia. A cross-sectional survey was conducted to estimate waste generation rate. Study reported that numerous factors such as established methods of waste management, type of healthcare establishment, degree of healthcare facility specializations, reusable items employed in health care, seasonal variation and patient work load affect on characteristics of waste generation. It is concluded that the unit generation rate was relatively lower than similar health facilities in developing countries.

In the study by Sanida et al. (2010), the amounts of infectious medical waste generated daily and average generation indexes were determined in relation to several parameters factors at public hospital in Central Macedonia, Greece. Various parameters were number of beds, type of hospital, bed coverage and the difference in hospital divisions and wards and the number of operations and laboratory test performed. The provided tools for estimating waste quantities are useful for medical waste management.

A research was conducted in Malaysia to evaluate the management of clinical waste and its obstacles in Selangor 'hospital by Razali and Ishak (2010). In the results, it was mentioned that the quantity of clinical waste depends upon the hospital size, the segregation program and the medical activities.

Kagonji and Manyele (2011) carried out statistical methods to measure and analyze clinical waste generation rate at Amana hospital and Ligula hospital in Tanzanian. They have described that the generation rates depend on number of factors such as the number of patients, number of beds and the type of activity in different sections. The study indicated the daily medical waste generation rates were not consistent at the two studied hospitals. The high fluctuation in pathological waste can be related to large number and type of surgical procedures conducted on specific day and the fluctuations in infectious waste could be related to large number of in-patients admissions. Comparison of the range of medical waste generations over a period of time between these two hospitals revealed that Amana hospital had higher range compared to Ligula hospital. The high range in Amana can be attributed to its nature of location in the big city. Therefore, the location of a hospital can be another factor in waste generation rate. This study also measured the amount of waste based on generation rate per bed. Two hospitals had fewer beds and this caused high waste generation rate per bed/day. Therefore, waste generation rate based on number of patient is more applicable than the number of beds.

A research was carried out by Komilis and Katsafaros (2011) to investigate the potential correlation between the various hospital parameters such as the number of examinees, the number of patients that occupied beds and the number of tests performed daily and the hazardous medical waste generation rates at the General Hospital of Ikaria. The result based on statistical correlations showed that the selected hospital parameters were statistically significant predictor of medical waste generation rate.

Eker and Bilgili (2011) determined waste was generated from healthcare services (e.g. private hospitals, state hospitals, university hospitals and etc.) in Istanbul, Turkey. Statistical analysis was performed to evaluate the relationship between the amount of waste (e.g. medical waste materials, sharps, liquid waste, recyclables and etc.) and the bed capacities, inpatient and outpatient numbers. It was concluded that except for recyclable and hazardous waste, evaluation of waste generation in accordance with the bed capacity is reasonable. The results indicated that only the amount of sharps and medical waste can be evaluated using number of inpatients. Moreover, the evaluation of waste stream on the basis of number of outpatients was more applicable than other evaluation method because it did not show any reasonable change according to services categories.

The hazardous medical waste unit generation rate was calculated by Komilis et al. (2012) in different categories of health-care facilities including public and private and seven sub-categories in Greece based on the quantities of the wastes that were regularly transferred to the specific incinerator. Results revealed that there is variance in the weights of medical waste even among hospitals of the same categories. The reason of this variance may be attributed to other parameters in medical waste generation. For example, in the public hospitals, medical waste generation rate is correlated positively with number of beds. Therefore, the number of beds is the prediction factor in medical waste generation rate.

Articles reviewed have examined CWM and applied treatment and disposal methods of clinical waste and have determined amount of waste, generation rate, quality and composition of clinical waste in different healthcare centres. Waste generation rate in each research paper is given in Table 1. The table consists of six columns and each row pertains to a paper reviewed in this study as mentioned in Column 1. Column 2, 3, 4 and 5 give information of region, generation period, number of samples and waste generation rate respectively and the percentage of clinical waste is given in the last column of table.

Table 1: Average Healthcare Waste Generation Rate in Different Articles

References	Region	Generation period	Number of sample	Waste generation rate	Clinical Waste%
Suwannee (2002)	Thailand	7 days	12 Government and private hospitals 184 clinics	government: private:(kg/bed) general: 1.751 0.323 medical: 0.284 0.041 hazardous: 0.013 0.002	10.6
Askarian et al. (2004)	Iran	4 months Mar- Jun 2002	15 private hospitals	4.45 kg/bed/day domestic:1,830 kg infectious: 712 Kg sharps: 19.6 Kg	infectious 27.8 sharps 0.76
Da Silva et al. (2005)	Brazil	7 month s Sep 2001-Mar 2002	21 hospitals, 48 health centers, 22 clinical laboratories	total: 3.245 infectious/ biological: 0.570 (kg/bed-day)	15-20
Hamoda et al. (2005)	Kuwait	2 weeks spring 2 weeks summer	2 public hospitals	hazardous, non- hazardous and kitchen: 4.89 - 5.4 kg/patient/day	24.3- 28.6
Bdour et al. (2007)	Jordan	Mar- Sep 2004	4 hospitals 10 clinical laboratories	hospitals: 15.74 kg/patient/day clinical laboratories (kg/test-day): governmental: 0.053–0.065 private: 0.034–0.102	26
Alhumoud and Alhumoud (2007)	Kuwait	6 months 2005-2006	16 government hospitals	3.87 - 7.44 kg/bed/day domestic: 10,534 Kg hazardous/infectious: 4,099 Kg sharps: 112.1 Kg	infectious 27.8 sharps 0.76
Marinkovic et al. (2008)	Croatia	N/A	75 state-owned health care centers, 76 private practices	non- medical and medical: 10,064 tons per year	14
Taghipour and Mosaferi (2009)	Iran	7 days	10 hospitals	medical: 3.48 general: 2.439 hazardous/infectious: 1.039 (kg/bed-day)	29.89
Yong et al. (2009)	China	Jul- Aug 2007	15 hospitals	clinical waste: 0.5- 0.8 kg/bed day	N/A
Cheng et al. (2009)	Taiwan	N/A	150 health care establishments	general and infectious: 0.19- 0.88 kg/bed/day	6.6- 17.2
Sawalem et al. (2009)	Libya	N/A	14 hospitals	1.3 kg/patient/day general (72%) and hazardous (28%)	26 % of hazardous
Azage and Kumie (2010)	Ethiopia	Mar -Apr 2007	10 health centers	general and hazardous (pharmaceutical, infectious and sharps): 1.79 ± 0.54 kg/day	48
Sanida et al. (2010)	Greece	7 days	12 public hospitals	clinical waste: 0.26 to 0.89 kg/bed/day 0.51 to 1.22 kg/patient/day	N/A
Razali and Ishak (2010)	Malaysia	Jan -Dec 2009	10 government hospitals	clinical waste: 1.355 kg/bed/day	N/A
Kagonji and Manyele (2011)	Tanzania	91 days	2 district hospitals	clinical and non- clinical (kg/day): Amana hospital: 2,250 Ligula hospital: 2,500	67
Eker and Bilgili (2011)	Turkey	N/A	375 healthcare services	2.11-3. 83 kg/bed/day 1.45- 9.84 kg/outpatient/day	28.8
Komilis et al. (2012)	Greece	22 months 2009 -2010	132 health-care facilities	clinical waste (kg/bed/day): public psychiatric hospitals: 0.012 public university hospitals: 0.72 private psychiatric clinics: 0.0012 private birth clinics: 0.49	N/A

N/A: Data Is Not Available.

3. SUMMARY AND FINDINGS

This paper presents a review of studies in CWM areas focusing on the identification and extraction of significant factors on quantity of clinical waste generated in healthcare centres. 20 papers reviewed are those report the effective factors in clinical waste generation. Some factors such as type of hospital, hospital size, kind and number of department, number of beds, percentage of bed occupancy, type of specialization, ratio of disposable items and number of outpatients are described as functions of key hospital parameters in medical waste generation rate. Table 2 shows the distribution of extracted features in articles reviewed. The first and last column show the name of features and the total number of researches in order and other columns show the presence or absence of each feature in the research.

Out of 20 studies, 13 studies (65%) reported that the type of healthcare establishment has significant effect on waste generation rate followed by the number of patients, number of beds and the percentage of bed occupancy with 50%, 40% and 35% respectively. Different articles categorized healthcare facilitates into different types such as government, private, public, teaching, military, specialist, hospitals, medical centres and clinical laboratories. In addition, 30% of papers have argued that amount of clinical waste production depends on healthcare facility location, established waste management methods and type of activity in different sections. Although, other waste generation factors have been reported only in 20% of these papers of or less but, it is demonstrated that have significant role in waste generation.

Table 2: Distribution Associated Factors in Clinical Waste Generation in Investigated Studies

Extracted features	Resources																					
	Suwannee (2002)	Askarian et al. (2004)	Awad et al. (2004)	Hamoda et al. (2005)	Da Silva et al. (2005)	Alhumoud and Alhumoud (2007)	Bdour et al. (2007)	Marinkovic et al. (2008)	Katoch and Kumar (2008)	Taghipour and Mosaferi (2009)	Yong et al. (2009)	Cheng et al. (2009)	Sawalem et al. (2009)	Azage and Kumie (2010)	Sanida et al. (2010)	Razali and Ishak (2010)	Kagonii and Manvele (2011)	Komilis and Katsafaros (2011)	Eker and Bilgili (2011)	Komilis et al. (2012)	**Total**
Type of Healthcare facility	X		X		X	X	X	X		X	X	X	X	X	X					X	13
Healthcare Facility Size					X					X	X					X					4
Specialization	X					X								X							3
Type of Activities				X							X				X	X	X	X			6
Healthcare Facility Location		X			X					X	X		X				X				6
Number of Beds		X	X	X			X					X			X		X			X	8
Bed Occupancy			X						X		X	X			X			X	X		7
Number of Patients			X	X		X	X		X	X		X					X	X	X		10
Reusable Items	X					X				X				X							4
Waste Management Plan	X					X				X	X			X		X					6
Economic Status of Patients		X						X		X											3
Reimbursement Payment												X									1
Level of instrumentation					X								X								2
Type of ailment									X												1

Number of infectious disease bed	X	1

X: Mark for Presenting the Related Parameters in Each Reference.

Some of these researches have evaluated some parameters as prediction factors in clinical waste generation and have used the statistical methods to consider the linear relationship between these parameters as independent variables and generation rate (dependent variable). These researches developed a mathematical model to correlate the clinical waste generation as a function of independent variables and applied statistical analysis like multivariate regression analysis to show that some variables were the most significant factors affecting the generation rate. It was observed a linear relation between the amount of waste generated from hospitals and the number of patients, number of beds, bed occupancy rate and type of hospitals (Awad et al., 2004; Hamoda et al., 2005; Katoch and Kumar, 2008; Cheng et al., 2009; Komilis and Katsafaros, 2011; Eker and Bilgili, 2011).

4. CONCLUSIONS

Accurate estimation of clinical waste management rate plays an important role in successful implementation of CWM practices. The present study is conducted to find key hospital parameters in waste generation to estimate amount of clinical waste generation in different healthcare facilities. This research carried out a literature review in study of waste management and waste generation at hospitals and selected 20 research papers that reported or investigated relevant associated factors in clinical waste production. It is found that several factors such as type and size of healthcare facility, specialization, type of activities, healthcare facility location, number of beds, bed occupancy rate, number of patients, reusable items, waste management plan, economic, social and cultural status of the patients and etc. affect on quantity of waste generation. It is concluded that some of these extracted features such as number of patients, number of beds, bed occupancy rate and type of hospitals were the most significant prediction factors in clinical waste generation. These factors have been applied to estimate amount of waste generation by using traditional statistical methods at hospital. These conventional models have obtained acceptable prediction performance measure values but if the relationship between variables is unknown or complex, it is difficult to apply statistical techniques.

In conclusion, obtained results are useful for healthcare facility and CWM service providers and also for researchers to develop and offer suitable models for predicting clinical waste generation rate using the factors associated with the generation rate.

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