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Review of Literature
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The importance of disposal of solid waste generated by the population has been recognized even by the early civilizations. The Dravidians in 5000 BC incorporated safe and effective disposal methods for solid and liquid waste. This emphasizes the saying “cleanliness is next to godliness” which is to remain healthy and free from diseases.

Health is man’s greatest possession and a real source of happiness. The present health care system in India was initiated by Sir Joseph Bhore, Chairman of Health Survey and Development Committee in 1943. The primary health care centre was launched by the community development programme in 1952 for the development of rural areas. An important milestone in India’s health services was reached in 1978 when recommendation was “Health for all by 2000 AD”.

Madhu Kumar and Ramesh (2012) reported that 9.9% of biomedical waste management is unnecessary extra burden on healthcare staff. 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 for 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.
Kagonji and Manyele (2011) used statistical methods to measure and analyze clinical waste generation rate at Amana hospital and Ligula hospital in Tanzania. 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 that daily medical waste generation rates were not consistent at the two studied hospitals. The high fluctuation in pathological waste can be related to a large number and type of surgical procedures conducted on specific day and the fluctuations in infectious waste could be related to the large number of in-patient admissions. Comparison of the range of medical waste generation 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.

A study 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, the number of tests performed daily and the hazardous medical waste generation rates at the General Hospital of Ikaria. The result based on statistical correlation showed that the selected hospital parameters were statistically significant predictor of medical waste generation rate. Eker and Bilgili (2011) determined the waste 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, 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 was 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 service categories. Manoj Bansal et al., (2011) assessed the awareness and existing practices regarding biomedical waste management in urban and rural health facilities of Gwalior district from January to June 2008 and found the practices to be grossly inadequate, particularly in rural areas.

Adegbita et al., (2010), Coker et al., (2009), PATH (2009), Oke (2008) and WHO (2002, 1999) reported that each year there are about 8 to 16 million new cases of Hepatitis B virus (HBV), 2.3 to 4.7 million cases of Hepatitis C virus (HCV) and 80,000 to 160,000 cases of human immune deficiency virus (HIV) due to unsafe injections and mostly due to very poor waste management systems.

Manyele et al., (2010) stated that during incineration, if no proper filtering of flue gases is done, air can be polluted causing illnesses to the nearby population. Usmani et al., (2010) stated that about 52% of the doctors had received needle prick injuries more than once in their lives. 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. The 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 the characteristics of waste generation. It was 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 amount of infectious medical waste generated daily and average generation indices were determined in relation to several parameters at a public hospital in Central Macedonia, Greece. The 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 tests performed. A research was conducted in Malaysia to evaluate the management of clinical waste and its obstacles in Selangor hospital by Razali and Ishak (2010). From the results, it was conducted that the quantity of clinical waste depends upon the hospital size, the segregation program and the medical activities.


Chandira Boss et al., (2009) studied the character and quantity of BMW generation in Government General Hospital (GH), Puducherry. Unhygienic disposal of non-segregated BMW in Puducherry poses a serious health hazard to the population and to scavengers. They opined that the current practices of handling, transportation, storage, and disposal of BMW generated at GH need to be strict. Of late, more and more patients from abroad are opting to undergo advanced medical treatment in India, because they can
be carried out at a fraction of the cost in India. With this "medical tourism" expanding (Connell, 2006 and Lee, 2007).

Cheng et al., (2009), investigated the quantity of generated medical waste and the factors associated with the generation rate in Taiwan. The research examined the medical waste generation rate with the potential associated factors such as the type of hospital, number of beds, bed occupancy, reimbursement payment and out patients per day. Multiple variable regression analysis was applied to predict the factors associated with waste generation. The results demonstrated that 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 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 is attributed to a large number of patients as it was situated in the capital of Libya.

As reported by Olubukola (2009) there may not be much of a difference in the way and manner the wastes are generated in various health care institutions that are managed in Nigeria. A good example is given by the findings of the study in Lagos which reported the similarity in waste data and HCW management practices in two general hospitals, characterized by lack of waste minimization or waste reduction strategies, poor waste segregation practices, lack of instructive posters on waste segregation and disposal of HCW with general waste.
Taghipour and Mosaferi (2009) argued that the availability of sufficient information on the amount and composition of the waste generated are the fundamental prerequisites for the implementation of Clinical Waste Management. The 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 specialization, ratio of reusable items, the general condition of the place where the hospital is located, number of patients per day and the economic, social and cultural conditions among hospitals. Yong et al., (2009) conducted a study on medical waste management status in Nanjing, China. 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.

Katoch and Kumar (2008) presented a technique to develop mathematical model in biomedical waste generation in three major hospitals in Shimla, India. They 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 illness 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 illness pattern and social factors, a fixed seasonal variation was observed in biomedical waste generation rate.
Marincovic et al., (2008a) reported that the medical waste generation rate depends on the size and the type of the medical institution, but also that it differs from country to country based on the level of economic development. Furthermore, the use of disposable instruments and packaging materials rather than the use of reusable items in the healthcare centers in developed countries has increased the amount of waste generation. Marinkovic et al., (2008) reviewed the 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 and also based on national income and level of development.

Shalini Sharma and Chauhan (2008) in their study on assessment of biomedical waste management in 3 apex government hospitals of Agra, collected data with the help of personal observations and questionnaires. Martin Pavlas and Michal Tous (2008) studied the problem of efficient energy utilization in the field of thermal processing of waste (waste-to-energy). The waste combustion (incineration) processes are accompanied by release of large amount of energy, which shall be effectively utilized. The most serious problem of effectively running incineration plants consists in economical utilization of energy produced.

A study was conducted by Alhumoud and Alhumoud (2007) to determine the kind of solid wastes and to 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 healthcare 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. 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. Tsakona et al., (2007) examined the existing hospital waste strategy in Greece with a bed capacity of 400-600. Infectious waste production was estimated by weighing the incinerated waste as 880 Kg/day. It was concluded that inappropriate segregation practices was the dominant problem, which led to increased quantity of generated infectious waste and hence higher costs for their disposal.

Blenkharn (2007) reveals that, efficient supply chain management may offer an effective response to demands for the improved segregation of wastes, reducing costs without compromise of safety and supporting effective risk reduction. Vijaya Kumar Goddu et al., (2007) have opined that between 75% and 90% of the waste produced by health care providers is non-risk and the remaining 10-25% of health care waste is regarded as hazardous and may create a variety of health risks. Sabour, Mohamedifard and Kamalan (2007) have stated that by managing BMW properly, risks can be minimized. All health care institutions should ensure the safety of the workers. They should provide secure methods of BMW collection and transportation and the necessary facilities for safe treatment and disposal. In less developed and transitional countries, waste disposal options are limited and small scale incinerators have been used as an interim solution. Incinerators emit a variety of harmful pollutants, including particulate matter, mercury, dioxin and furans that pollute the environment.
Mohammad Karamouz et al., (2007) stated that disposal of about 1750 tons of solid waste per day is the result of a rapid population growth in the province of Khuzestan in the south west of Iran. The framework of a master plan for managing hospital solid wastes in the province of Khuzestan, Iran was proposed considering different criteria for evaluating the pollution of hospital solid waste loads. The effectiveness of the management schemes was also evaluated. In order to rank the hospitals and determine the share of each hospital in the total hospital solid waste pollution load, a multiple criteria decision making technique, namely analytical hierarchy process (AHP), was used. The results have shown that the hospitals located near the capital city of the province, Ahvaz, produce more than 43% of the total hospital solid waste pollution load of the province. The results have also shown the importance of improving management techniques rather than building new facilities. The proposed methodology is used to formulate a master plan for hospital solid waste management.

Mohammad Reza Sabour et al., (2007) developed a mathematical model to calculate the generation of (infectious) hospital wastes for any desired year. Utilizing the model, generated infectious hospital waste was estimated as 698,937 tonnes for 2008 (short-term) and 3,494,387 tonnes for 2028 (long-term period). If the real infectious wastes are collected separately, then the generated infectious wastes will be reduced by 15.1% of the above-mentioned amount (139,787 tonnes for 2008, and 698,877 tonnes for 2028). Results of physical analysis show the components of the hospital waste as 67.3% infectious, 8.8% medical, 1.8% biological and 22.1% common municipal wastes.

Sahar Mohamed Soliman et al., (2007) stated that 60% of surgical, medical and laboratory departments store biomedical waste inside utility rooms, followed by 40% of
intensive care units. Labour, operating rooms and dialysis units do not store biomedical waste in the department, but the waste is immediately transported to the general storage area of the hospital. The mean period of storage for biomedical wastes in the storage areas of the healthcare setting was $4.6 \pm 8.1$ days while the study was conducted in five hospitals and ten primary healthcare settings of Egypt. It was concluded that inadequate and inefficient segregation, collection and transportation of biomedical waste contributes to increased risk of exposure of staff, patients and the community to biomedical hazards.

Satnam Singh and Vinit Prakash (2007) reviewed toxic releases from medical waste incineration comprising organic emissions such as polychlorinated dibenzo-dioxin/furan (PCDD/Fs) and polycyclic aromatic hydrocarbons (PAHs), inorganic emissions and ashes containing toxic metals. Hosny and El-Zarka (2007) conducted a survey for medical waste disposal in order to examine the current status of medical waste disposal in some hospitals in Alexandria and to properly assess management of hazardous waste. As Alexandria has about 3911 health care facilities providing medical services for people, huge amount of medical waste is generated daily with about 208 tons generated per month. The results revealed that the most common problems associated with healthcare wastes are the absence of waste management, lack of awareness about their health hazards, insufficient financial and human resources for proper management and poor control of waste disposal. The current situation of medical waste disposal in Alexandria is depending on incinerators. Some of these incinerators are not working anymore. Incineration as a system is not accepted in most developed countries due to the risks associated with it and suitable substitution management system for medical waste disposal is now taking its place.
Blenkharn (2006) observed the arrangements for bulk clinical waste handling in 26 UK hospitals. Storage of waste carts in areas freely accessible to the public and failure to lock individual carts was common. Many clinical waste carts and areas dedicated to their storage were in a poor state of repair. Substantial improvement was required in the management of clinical waste in hospitals in order (1) to eliminate the possibility of acquired infection through unauthorized, inappropriate access to clinical waste and to minimize adverse effects resulting from contact with waste pharmaceuticals; (2) to comply with the Duty of Care imposed by UK Health and Safety legislation; and (3) to satisfy concerns regarding the general standard of hospital hygiene.

David Rogers and Alan Brent (2006) established a protocol for the first quantitative and qualitative evaluation of relatively low cost small-scale incinerators for use at rural primary healthcare clinics. The incinerators must be used within a safe waste management programme that provides the necessary resources in the form of collection containers, maintenance support, acceptable energy sources and understandable operational instructions for the incinerators, whilst minimizing the exposure risks to emissions through the correct placement of the units in relation to the clinic and the surrounding communities.

Dwivedi et al., (2006) reported that the minimization and effective management of biomedical waste is through identification and segregation of the hazardous waste. To tackle the problem of identification of biomedical waste, different types of colour code plastic bags or containers are used which is the most appropriate way. Nemathaga et al., (2008) reveals that healthcare is one of the fastest growing sectors in India. The healthcare facilities are a basic requirement of human kind but these are also sources of
life threatening wastes and toxins. Rao (2008) reported that the hazards of BMW can range from gastroenteritis, respiratory tuberculosis, septicemia, tetanus and skin infections to more deadly diseases such as HIV/AIDS and Hepatitis.

Gupta et al., (2006) have reported that, there is a lack of segregation practice and mixing of hospital wastes with general waste which makes whole waste stream hazardous. They also states that biomedical waste management practices of Balrampur hospital in Lucknow, was severely lacking in action to dispose off its waste and uphold its statutory responsibilities. This was due to lack of education, awareness and trained personnel to manage the waste in the hospital. The study concluded that healthcare waste management should go beyond data compilation, enforcement of regulations and acquisition of better equipment. It should be supported through appropriate education, training and the commitment of the healthcare staff, management and healthcare managers within an effective policy and legislative framework.

Another study by Gupta et al., (2006a) at Vivekananda Polyclinic in Lucknow, revealed that there is a need to improve the capability of the staff in terms of providing facilities and on-job training in order to develop a model of BMWM system. They observed that the personnel working under the occupier were trained to take adequate precautionary measures in handling these bio hazardous waste materials. The process of segregation, collection, transport, storage and final disposal of infectious waste was done in compliance with the standard procedures. They also stated that in developed countries, legislation and good guidelines state the various ways for the collection, transport, storage and disposal of biomedical waste.
Mosse and Savchin (2006) analyzed the composition and the degree of toxicity of medico-biological wastes with the use of the results of investigations made in different countries. It has been shown that such wastes are highly hazardous to ecology and a universal technology of their management is needed. They developed and tested a plasma chamber incinerator for plasmo-thermal treatment of medico-biological waste. To optimize the operating conditions of the facility and prevent chemical and thermal pollution of the environment, they constructed a model of thermal calculation of the plasma chamber incinerator.

Chitnis et al., (2005) reported that pathology, microbiology, blood bank and other diagnostic laboratories generate sizable amount of biomedical waste. The audit of the BMW is required for planning proper strategies. The audit in laboratory revealed 8 Kg anatomical waste, 600 Kg microbiology waste, 220 Kg waste sharps, 15 Kg soiled waste, 111 Kg solid waste, 480 litres liquid waste along with 33,000 litres per month liquid waste generated from labware washing and laboratory cleaning and 162 litres of chemical waste per month. Needle sharps are collected in puncture proof containers and the needles autoclaved before sending to needle pit. The formalin containing tissues cannot be sent for incineration for the fear of toxic gas release and the guidelines by the biomedical waste rule makers need to be amended for the issue. The segregation of waste at source is the key step and reduction, reuse and recycling should be considered in proper perspectives. Mohee, (2005) examined characteristics of solid and liquid wastes generated in healthcare institutions and to provide a framework for the safe management of these wastes. The project was carried at three major medical institutions, namely, the Jeetoo Hospital, SSRN Hospital and the Clinic Mauricienne at Mauritius. A waste audit
carried out at these sites revealed that approximately 10% of solid wastes were hazardous in nature, consisting mainly of infectious, pathological and chemical wastes. The average amount of hazardous wastes per patient per day was found to be 0.072 Kg at Jeetoo hospital, 0.091 Kg at SSRN hospital and 0.179 Kg at the clinic. Further analysis revealed that the wastewater was polluting with COD, BOD, total suspended solids (TSS) and coliform content well above permissible limits. Kanemitsu et al., (2005) performed basic experiments to confirm that Bacillus spores are killed by incineration in a muffle furnace. Biological samples containing 106 spores of *Bacillus stearothermophilus* were placed in stainless steel petridishes and then into hot furnaces. The furnace temperature and duration of incineration was 300°C for 15 min, 300°C for 30 min, 500°C for 15 min, 500 °C for 30 min and 1100°C for 3 min. They reported that all spores of *Bacillus stearothermophilus* were killed at each of these settings. The effect of incineration seems to be equivalent to that of sterilization, based on the satisfactory sterilization assurance level of 10⁻⁶. Amouroux et al., (2005) reported that the European Union is creating strict standards for air and water pollution and waste treatment and implementing aggressive regulations. Compliance with these regulations is impossible without the development of new depollution processes involving plasma or laser technology.

Gita Ramaswamy (2005) opines that in some hospitals there is no proper training of the employees in hazardous material management and waste minimization aspects. This indicates the lack of even basic awareness among hospital personnel regarding safe disposal of biomedical waste. Saini et al., (2005) concluded that most of the surveys regarding Health Care Waste Management in South East Asian Countries have lack of training which is one of the main reason for poor management. WHO (2005) suggested
that good medical waste management in a hospital depends on a dedicated waste management team, good administration, careful planning, sound organization, adequate financing, and full participation by trained staff. In the study conducted in Sylhet city in Bangladesh, the average generation rate of medical wastes was about 0.934 Kg/bed-day. A study conducted by Abdulla et al., (2008) indicated that the average generation rate was 0.83 Kg/bed-day in northern Jordan. Abd El-Salam (2010) reported an average generation in El-Be- Heira Governorate, Egypt, of about 2.07 Kg/bed-day. Birpinar et al., (2009) investigated 192 hospitals in Istanbul, Turkey, and reported an average generation rate of 0.63 Kg/bed-day. Silva et al., (2005) have indicated that with apparently no administrative machinery for ensuring safe disposal of BMWs generated in India, the problem of safe disposal of these dangerous wastes is only expected to increase.

Hamoda et al., (2005) determined hazardous and non-hazardous 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 the practices of medical wastes in the south of Brazil and reported that the amount of medical waste depends upon several factors such as the type of healthcare facility, status, capacity, level of instrumentation and location of the facility. Diaz et al., (2005) identified some of the more common treatment and disposal methods utilized in the management of infectious medical wastes in developing countries. The main treatment method used in the final disposal of infectious waste is incineration. Miyazaki and Une, (2005) carried out a study on the waste management practice in Japan. The first
rule of infectious waste management was regulated in 1992 and revised criteria for infectious waste management were promulgated by the Ministry of Environment in 2004. Gayathri Patil et al., (2005) assessed the waste handling and treatment system of hospital biomedical solid waste at KLE Society's J.N. Hospital and Medical Research Center, Belgaum, India to estimate the amount of non-infectious and infectious waste generated in different wards/sections and reported that an average of about 520 Kg of noninfectious and 101 Kg of infectious waste was generated per day (about 2.31 Kg per day per bed, gross weight comprising both infectious and noninfectious waste).

Townend and Cheeseman (2005) have indicated that the inappropriate handling and disposal of healthcare waste poses health risks to health workers who may be directly exposed and to people near health facilities, particularly children and scavengers who may become exposed to infectious wastes and a higher risk of diseases like hepatitis and HIV/AIDS. After the BMW guidelines were explained, observations indicate that proper management of BMW has improved and that the segregation of BMW is much better than before. Farzadika et al., (2009) have detailed the nature and quantity of healthcare waste generated as well as institutional practices with regards to sustainable methods of healthcare waste management, including waste segregation and waste recycling which was often poorly examined and documented in several countries of the world despite the health risks posed by the improper handling of Health Care Waste.

Bdour (2004) and Tudor et al., (2005) reported that the best available technologies are used for developing alternatives for proper disposal of biomedical waste. Hoppe et al., (2005) stated that in countries such as India, BMW has not received sufficient attention. In India, the Biomedical Waste (Management and Handling) Rules
1998 (The Gazette of India, 1998), make it mandatory for hospitals, clinics, and other medical and veterinary institutes to dispose of BMW strictly according to the rules. Many Indian newspapers and magazines have reported that re-use of disposable syringes, needles, catheters, bags, drug vials, bottles and intravenous drip sets are picked up by rag pickers and purchased by duplicators, recycled and replaced without proper treatment.