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Biomedical waste generation and its management in hospitals of NCR-Delhi, India

Abstract

The quantity of waste generation and its quality along with treatment mechanisms has become a matter of concern. Bio-medical waste management is an integral part of future sustainability. The paper is aimed at evaluating the solid bio-medical waste generation pattern according to the bed strength of hospitals and to analyse the water consumption and effluent generation pattern in hospitals of Delhi. The questionnaire survey was done in seventy five hospitals and thirty six hospitals were visited to achieve the objectives of the study. In Delhi, the waste generation on a per bed per day basis range from only 110 grams to 2783 grams. The yearly solid biomedical waste generation in Delhi is approximated to 9200 tonnes. The average water consumption per bed per day in a hospital of Delhi ranges between 500-600 LPD. The annual water consumption in hospitals of Delhi is approximated to 9125 million litres. The impact of improper biomedical waste and hospital effluent on aquatic environment and society has also been discussed in the paper. Further, this paper has highlighted the certain grey areas in the implementation of new Bio-medical waste management rules, 2016 by the hospitals. The deficiencies in the existing bio-medical waste management system and compliance of BMW Rules, 2016 has also been assessed. It is observed that the latest technologies like pulpmatic macerators, sharp blasters and dry heat sterilization and the best waste management practices can be adopted to control the menace caused due to improper bio-medical waste management.

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Keywords

Biomedical waste, hospital effluent, management, generation pattern, hospitals

Introduction

Although, the Bio-medical waste management rules are in existence since, 1998 but effluent generated from hospitals has remained in the grey area. There are no specific discharge standards for the probable contaminants emerging from the health care facilities like drug residues, formaldehyde, gluteraldehyde, adsorbable organic halogens, hypochlorites etc. However, now the new Bio-medical waste management rules, 2016 has laid attention on the pre-treatment of the liquid chemical waste generated in the hospitals (Manasi *et al.* 2014). But still, there are challenges in the implementation of BMW Rules, 2016 which have been discussed in this paper. Further, the compliance of BMW Rules, 2016 has also been assessed. In view of the current situation, there is a need to develop a scientific scheme for the processing, treatment and disposal of the solid bio-medical waste. Simultaneously an emphasis should be given for the treatment of wastewater and its reuse. Basic philosophy towards sustainable approach for Biomedical Waste (BMW) Management is governed by assessing the quantum and pattern of generation of bio-medical waste, its segregation, categorization and treatment of respective category waste. Present scenario of effluent treatment and waste management demands triangulation methods viz waste reduction, prevention of hazardous impact and economically viable pollution control technologies (Kishore *et al.,* 2014). The best management practices and appropriate technologies is an important tool for proper Bio-medical waste management. The composition, generation pattern and quantity of the medical waste is important to further decide on the apt treatment of the health care waste (Acharya *et al.*, 2014; Verma *et al.*, 2008).

The objective of the study is to assess the management of the Biomedical waste and hospital effluent considering their composition, generation pattern and impacts on society and environment. The best waste management practices and technologies have also been discussed.

Composition of solid bio-medical waste: Most of the waste from medical activities resembles the waste generated by other businesses and residences. Between 75-90% of the medical waste consists of the non-regulated solid waste, 10-25% of the medical waste, however, requires special precautions because of the associated risk of transmitting disease or of hazards from exposure to chemicals or radioactivity. The latter includes infectious and pathological waste and sharps such as used needles or scalpel blades. It may also include small quantities of hazardous material such as discarded pharmaceuticals, cleaning products and chemical

solvents. In addition, nuclear medicine departments may generate small amounts of low-level radioactive wastes from diagnostic procedures (Col *et al.*, 2003).

Composition of hospital effluent: The hospital effluent is loaded with numerous chemicals, drug residues, hormones, personal care products, disinfectants, microbes, infectious fluids, pathogens, radioactives, nuclear medicine residues etc which adversely impacts the environment. There is an ample literature support regarding occurrence of drug residues including that of antibiotics, antidepressants and even cytotoxics, chemicals, disinfectants, hormones affecting the reproductive behaviour of fishes (Mesdaghinia *et al.*, 2015). The detrimental effects of the emerging contaminants present in untreated hospital effluent on aquatic environment are known through literature.

Considering the composition of medical waste, the medical facilities can adopt various approaches to treat and manage the medical waste. The appropriateness and effectiveness of these approaches will, however, depend upon the local regulations and priorities. Another key issue is the ability and willingness of the responsible parties and adopt prevention of waste generation as a priority. It is possible for creative and flexible administrators including organizations to implement innovative waste prevention and management techniques in fulfilment of rules even without abundant financing.

Status of bio-medical waste generation: The per capita bio-medical waste generation varies from country to country on the basis of facilities available in the hospital, number of beds, average occupancy and footfall, number of employees etc. The per capita bio-medical waste generation is higher in developed countries.

International scenario of BMW generation: Hospital waste generated in developing countries (per patient) is much less as compared to the volume generated in the developed countries. Volume of waste generated from a medical facility in developing countries ranges from 1-3 kg/day/bed as compared to 3-8kg/day/bed in developed countries. The quantum of infectious waste accounts to 250-750 g/day/bed. For instance, the solid bio-medical waste generation in USA is as high as 4.5 kg, in Spain 3kg Bio-medical waste is generated per bed. The UK and France also generates high quantum of waste *i.e.* 2.5 kg/bed. In western Europe 3-6 kg BMW is generated per bed per day. In Asia, the high income countries generate more waste (2.5-4 Kg) in comparison to low income countries that generate 1.8-2.2 kg/bed/day (Babu *et al.*, 2009). The reason of such huge amount of waste generated in the developed countries is that they follow "dispose after use" for every durable item used in the hospitals. The single use of certain consumables is a must for infection control but not for every item (Deblonde *et al.*, 2015).

Indian scenario of BMW generation: The total bio-medical waste generation in India is 484 TPD. However, the Biomedical waste treated per day in India is 447 TPD. This waste is generated by around 1,68,869 HCFs in India. The number of operators or common bio-medical treatment facilities in India are 198. The upcoming CBWTFs in India are 32. In India the quantity of bio-medical waste generated in the hospitals has been estimated to be 1.5 kg/ bed/day (Pollution and Board 2015).

Impact of improper hospital waste management: Only 10-15% of the total medical waste is hazardous but it has the potential to convert even the non-hazardous waste into hazardous. Thus, the quantity of hazardous waste increases manifold because of improper segregation. There are certain risks associated with mis-handling of waste from hospitals (Acharya *et al.*, 2014; Verma *et al.*, 2008; Gupta *et al.,* 2009; Manasi *et al.*, 2014; Zhou *et al.*, 2009; Verlicchi *et al.*, 2010; Deblonde *et al.*, 2015; Fent *et al.*, 2006; Emmanuel *et al.,* 2002; Pinto and Garcy, 2014)

Materials and Methods

The twenty five hospitals were selected from each category of hospitals having bed strengths 10-49, 50-99 and more than 100. In total, the questionnaire survey was done in 75 hospitals. The questionnaire asked about the water consumption in various water utility heads in the hospitals to assess the water consumption pattern. The data on wastewater generation and its utility has also been gathered. The questionnaire also emphasized on the areas of reutilization of wastewater, the capacity and treatment technology of the sewage treatment plant. The data on category wise solid bio-medical waste generation was procured from the operators of the common bio-medical waste treatment facility namely SMS Water Grace pvt ltd. Howsoever, 36 hospitals were visited including 12 hospitals from each category of bed strength to understand the existing bio-medical waste management and to assess the deficiencies in the existing system. The various stakeholders have been interviewed including operators, doctors, nurses, waste handlers. The meetings were also conducted with representatives of companies providing the waste management tools and academicians to come up with the best waste management practices and technologies available in the market. The important mechanism for existing system has also been discussed.

Result and Discussion

Solid bio-medical waste management: Delhi, the capital city of India is a major hub of health care facilities. In India seventy five percent of the health facilities and hospitals are located in urban areas where only twenty seven percent of the total population lives. There are around 48,000 beds in health care facilities of Delhi. The average number of beds per 1000 inhabitants in Delhi is 2.58. The hospital beds are increasing in Delhi day by day due to rapid development in the health care facilities which has put Delhi among top cities with advanced medical facilities in the country. The medical facilities are negligible in rural areas where more than 70% of our population lives. The same is represented in fig. 1. The average water consumption per bed per day is 560 LPD. Since, Delhi provides better health care facilities, patients from all over India comes here for treatment. The average occupancy of hospitals is around 75% -80% throughout the year. The BMW generation also has an increasing trend with respect to population of Delhi. The BMW per bed per day has increased from 306 grams in 2001to 432 grams in 2011 and 520 grams in 2017.

Analysis of bio-medical waste in Delhi -

Generation Pattern: The Bio-medical waste management rules, 2016 has demarcated the waste into four categories namely yellow

Table-1: Impact of improper bio-medical waste management

Solid waste	Liquid waste
Waste related diseases like gastro enteric troubles, respiratory and skin diseases.	Degrades water quality by altering pH, BOD, DO, COD etc.
Anatomical waste can effect waste handlers through direct contact of vectors.	Deteriorates natural environment and cause imbalance
Microbial cultures from labs leads to health disorders like headache, cough, eyeburn and skin burn.	DNA Damage and genotoxicity
Needles, scalpels and syringes (sharp injuries) leads to spreading of tetanus, hepatitis, AIIDS and septicemia.	Ecotoxicity/ Toxicity
IV fluid and blood bags, urobags releases dioxin, furan, SPM, gases like SO_x, NO_x etc	Microbial Resistance
Catheters, PVC gloves, tubes etc leads to formation of carcinogens and may disturb function of hormones.	Disease outbreaks like diarrhoeal diseases, gastroenteric disorders.
Cytotoxic chemical waste causes cytotoxicity, malignancy, ulcers, anemia, teratogenecity, skin ailments etc.	Bioaccumulation/ Biomagnification / Persistence of the emerging contaminants present in the effluent.
Radiation burns	Cytotoxic contaminants in the effluent leads injury to the cells, malignancy etc.
Poisoning and pollution by cytotoxic and genotoxic substances.	Human blood and body fluids leads to diseases like typhoid, tuberculosis, hepatits etc.
Pollution by toxic elements or compounds such as mercury or dioxins that are released during incineration.	Radioactive substances in the effluent can come from body organ imaging, radioimmunoassay, patients urine etc.

waste which includes anatomical, microbiological waste etc; blue waste including sharps; white waste includes sharps with metals and red waste includes infected waste (Bio-Medical Waste Management Rules, 2016) (Katoch and Kumar 2015).

The Bio-medical waste from hospitals of Delhi is treated by two common bio-medical waste treatment facilities namely SMS Water Grace BMW Pvt. Ltd. that caters to West, South west, Central, East, Shahdara and North East parts of Delhi and Biotic Waste Solutions Pvt. Ltd. which caters to North, North west, New Delhi, South and South East areas of Delhi. Available stats reveal that around 25 metric tons of Bio-Medical Waste is being processed by two Bio-Medical waste Facilities each day. On analysis of total quantum of bio-medical waste treated by both the operators of CBWTFs in Delhi, it was found that on an average, 59% component of total BMW is incinerable, 8.0% is glass, 30% is autoclavable, and 3% are sharps. The percentage wise bio-medical waste generation is presented in fig. 2.

On the basis of the data collected through questionnaire survey it was found that the waste generation on a per bed per day basis ranges from 110 to 2783 grams per bed per day. The variation in range is attributable to factors like, type of HCF, occupancy, number of beds, category of hospitals like government or private and effectiveness of segregation. The analysis of data also reveals the following:

- The bio-medical waste generation in hospitals having bed strength 50-99 is 5.3 TPD.
- The bio-medical waste generation in hospitals having bed strength 100 and above is 18 TPD.
- Study reveals that the waste generation in 100 bed and above in capital is ranging from 0.028 to 1.669 kg/bed/day with an average of 0.486 kg/bed/day.

Hospital effluent management: The hospital effluent is the wastewater being generated in the premises of health care facilities from all the activities including medical and non-medical activities. The effluent is generated in the hospitals from wards, operation theatres, laboratories, dialysis units, emergency and first aid, wards, radiology and kitchen and laundry activities. The effluent generated from hospitals constitutes domestic wastewater as well as infectious and hazardous wastewater since it contains pathogenic microbes, drug residues, chemicals, biological tissues, cultures, chemical toxins etc (Mesdaghinia *et al.,* 2015; Sciences *et al.,* 2015; Tsai *et al*., 2015). The composition of hospital effluent is presented in fig 3.

The health care is one of the major water consuming sectors. The water consumption in a hospital varies from 400-1200 litres/ bed/day (Sule *et al*., 2010). In America, the amount of hospital effluent generated is approximately 1000 l/person/day. Through a questionnaire survey conducted in 75 hospitals of Delhi, it is found that the water consumption in hospitals of Delhi varies from 450-980 Litres/bed/day(Singh *et al*., 2013).On the basis of data collected, the water consumption and wastewater generation has been evaluated.The quantum of wastewater generated from hospitals is huge and poses a great threat to environment and thus human health.

The major water consuming units in a hospital are wards, kitchen, laundry, laboratories, operation theatres, haemodialysis units etc (Singh *et al*., 2013).The maximum water is consumed in wards followed by toilets, laboratories and floor washing. The water consumption pattern in the hospitals is shown in fig. 4.The wastewater discharged from laboratories, wards, operation theatres and trolley washing areas may have emerging contaminants in their discharge. According to the questionnaire survey, it is found that 56% of the total effluent is expected to have emerging contaminants. The effluent generation pattern is presented in the fig. 5.Thus, it is very important to impart adequate treatment to hospital wastewater before discharging into drain.

As per the data collected from hospitals of Delhi, it is found that the quantum of water consumption and wastewater generation increases with the increase in bed strength. The same is represented in the Fig. 6. The total water consumption by hospitals having bed strength above 50 is 31.09 MLD and in turn the wastewater generated is 24.79 MLD. However, the treated water has to be characterized with respect to various chemicals and other priority contaminants that could be probably present in the effluent to explore its reuse

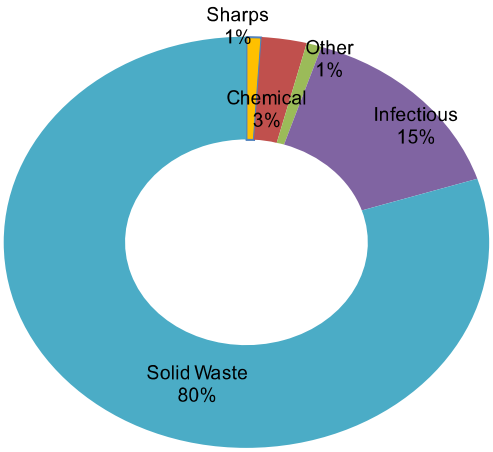


Fig. 1a: Composition of solid bio-medical waste

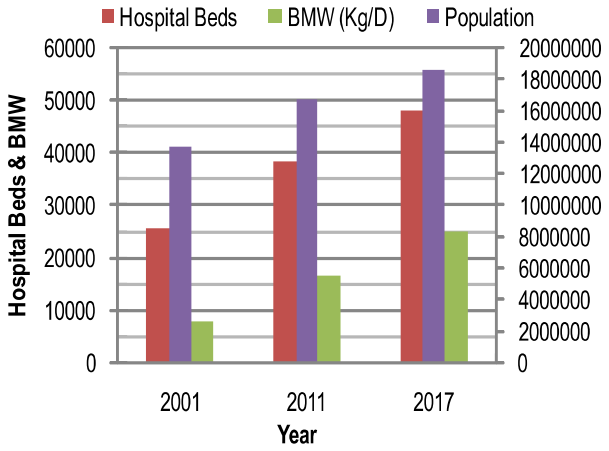


Fig.1b: Trend of Bio-medical waste generation, population and hospital beds

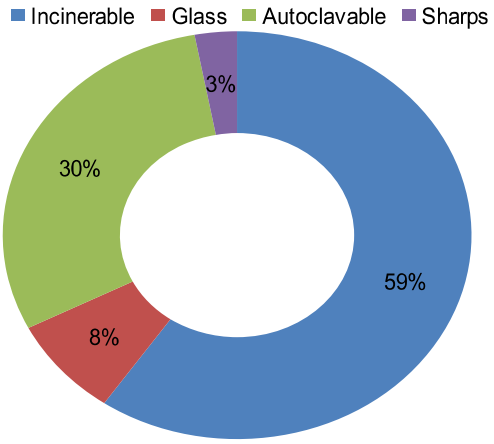


Fig. 2: Category wise Bio-medical waste generation

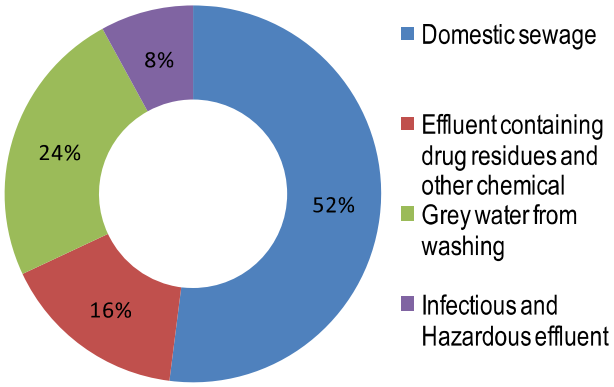


Fig. 3: Composition of hospital effluent

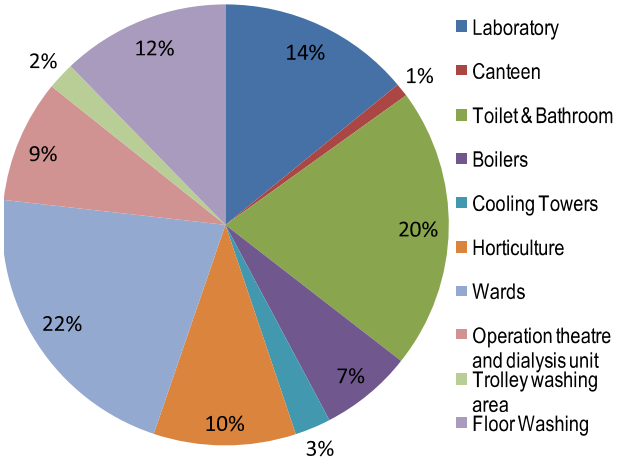


Fig. 4: Water consumption pattern

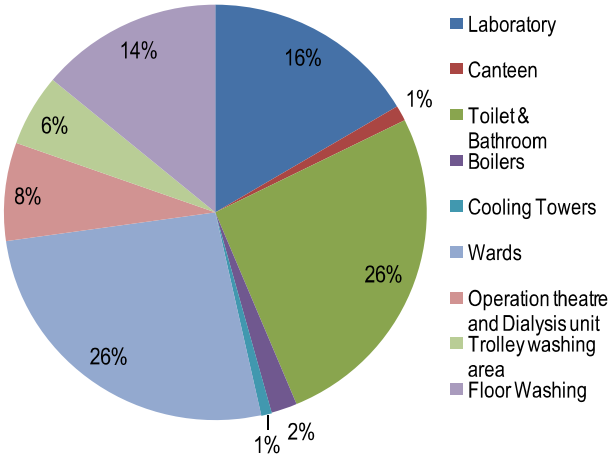


Fig. 5: Effluent generation pattern

potential. However, before this certain contaminants have to be identified which must be analyzed in the effluent discharged from the hospitals. Though, it is recommended to use this treated water for non-consumptive purposes like washing pavements, flushing etc.

Current bio-medical waste management practices:

The bio-medical waste management has become a daunting reality for the healthcare administrators specially in large hospitals. The issue needs in depth knowledge for executing a plan to implement the provisions of the rules (Katoch and Kumar 2015). There are three dimensions of the Bio Medical Waste Management, Rules 2016. First, to prevent harm to the environment, to the community, and public health. Secondly, to protect health and safety of the healthcare workers (handlers) and lastly, to prevent incidents and injuries which sometimes can become like minor emergency (Kumari *et al*., 2012).

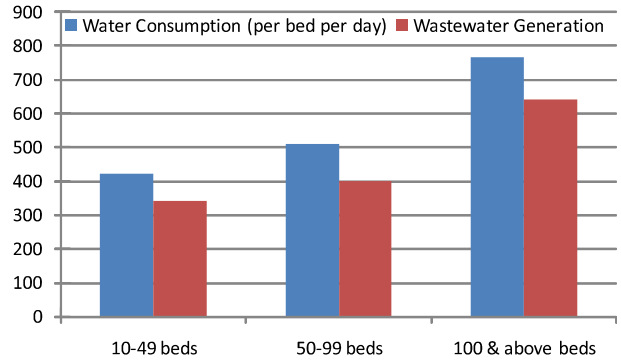
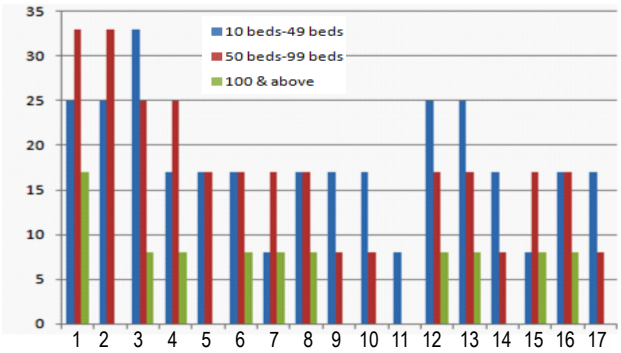


Fig. 6: Water consumption and wastewater generation in hospitals of Delhi



1- Segregation; 2- Bins; 3-Package material; 4-Schedule IV label; 5-Bin Trolleys; 6-barcoding; 7-Internal treatment record; 8-Training record; 9-Waste generation record; 10-Immunisation record; 11-Segregation labels; 12-Isolated storage sites; 13-Trolly washing area; 14-Pretreatment of solid waste; 15-Preatement of liquid waste; 16-STP/ETP; 17-PPEs

Fig. 8: Partial Compliance of parameters in hospitals of Delhi

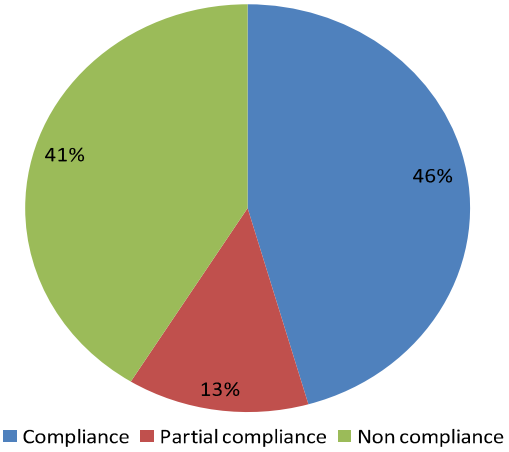


Fig. 10: Percentage of compliance of parameters

The deficiencies in the 36 hospitals with respect to seventeen parameters for compliance of Bio-medical Waste Management Rules, 2016 have been rated. One point was given for compliance and zero for partial or non-compliance. The total compliance in each category was calculated and is represented in the graph. The seventeen parameters for compliance are presented in table 2.

The shortcomings in the bio-medical waste and effluent management in the hospitals has been studied by visiting 36 hospitals including 12 hospitals of each category having bed strength of 10-49; 50-99 and 100 &above. A checklist was made for recording the compliance and deficiencies in the existing system. The checklist focussed on details of general infrastructure and compliance of Bio-medical waste management rules with respect to these 17 parameters. The visits to the hospitals and meetings with the stake holders including officials of Delhi Pollution Control Committee and nodal officers of bio-medical waste management made us clear

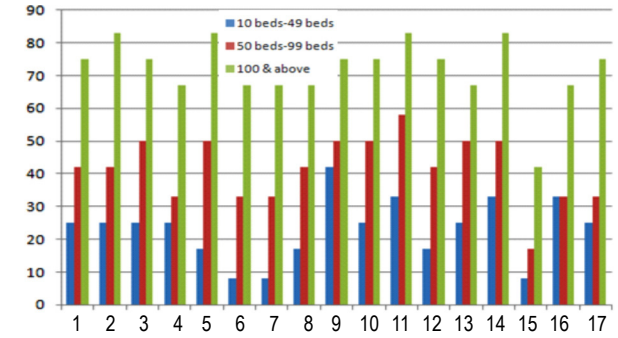


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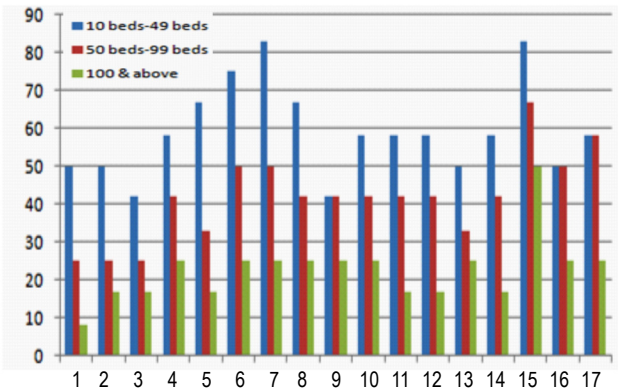
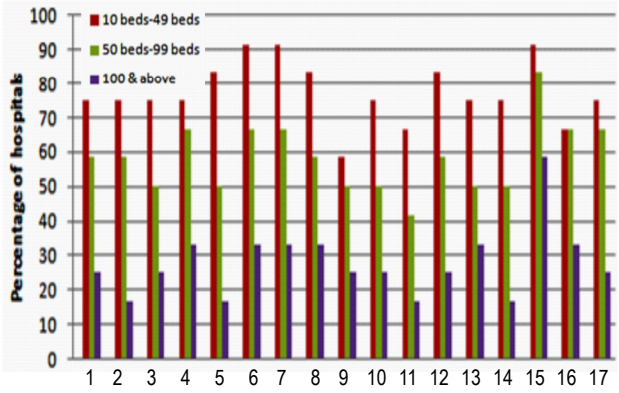
Fig. 7: Compliance of parameters in hospitals



1- Segregation; 2- Bins; 3-Package material; 4-Schedule IV label; 5-Bin Trolleys; 6-barcoding; 7-Internal treatment record; 8-Training record; 9-Waste generation record; 10-Immunisation record; 11-Segregation labels; 12-Isolated storage sites; 13-Trolly washing area; 14-Pretreatment of solid waste; 15-Preatement of liquid waste; 16-STP/ETP; 17-PPEs

Fig. 9: Non- compliance of parameters in hospitals of Delhi



1- Segregation; 2- Bins; 3-Package material; 4-Schedule IV label; 5-Bin Trolleys; 6-barcoding; 7-Internal treatment record; 8-Training record; 9-Waste generation record; 10-Immunisation record; 11-Segregation labels; 12-Isolated storage sites; 13-Trolly washing area; 14-Pretreatment of solid waste; 15-Preatement of liquid waste; 16-STP/ETP; 17-PPEs

Fig. 11: Deficiencies in the existing BMWM

about the following deficiencies in the compliance of Bio-medical waste management rules, 2016.

Evaluation of compliance of BMW Rules, 2016: Although in most of the countries, the medical waste is not being given a special attention and it is not regulated under strict laws and rules. . In European countries like Spain, the biomedical waste is being regulated in various laws for example Law 10/98 on waste, Decree 2263/1974, Royal Decree 1349/2003 for radioactive waste Ministerial Orders of 13 July 1998 and 21 July 2001 and Royal Decree 833/1988 for hazardous waste have been implemented. (Insa et al., 2010) . In India the biomedical waste has to be managed as per Bio-medical waste management rules, 2016. (Kishore et al., 2014)

On the basis of visits made to 36 hospitals of Delhi, the grading in terms of compliance (C), partial compliance (PC) and non-compliance (NC) has been done for 17 parameters which are represented in the Table 3. The percentage of parameters complied, partially complied and non-complied with Bio-medical waste management rules, 2016 is represented in fig 10. It is found that only 46% of the parameters are complied by the 36 hospitals. The compliance, partial compliance and non-compliance of the parameters in 3 categories of hospitals is presented in fig 7,8&9 respectively. Not even 50% hospitals having the bed strength of 10-49 & 50-99 are complying with these parameters in accordance to the rules as shown in fig. 7. There is a maximum partial compliance in middle strength hospitals as depicted in fig. 8. In hospitals having more than 100 beds the compliance of maximum parameters is more than 70%, however, maximum hospitals are still not pre-treating the liquid waste discharged by them as shown in fig. 9.

All people handling Bio-medical waste need to strictly follow the colour coding segregation rules. Improper segregation of waste may increase the chance for infection and cross contamination. The Occupier has the responsibility to train, guide and help the health care facility and workers to achieve 100% segregation of waste. The deficiencies in the existing Bio-medical waste management system are presented in the fig 11. It is found that the nursing homes/ hospitals having low bed strength ranging from 10-49 beds are poor in compliance of the rules. More than 70% are deficient in all the parameters. Only 40% hospitals in these categories are maintaining the waste generation records. In the second category of hospitals having 50-99 beds, it is found that 50% of the hospitals are not able to efficiently comply with the norms prescribed in the bio-medical rules. In hospitals having more than 100 beds, the compliance is still better. The compliance with respect to most of the parameters is more than 70%, however it is still lacking in terms of maintenance of ETP/STP, record keeping and displaying of BMW segregation labels. Thus, it can be concluded that the rate of compliance improves with the increase in size and bed strength of the hospitals.

Implementation challenges in the Bio-medical waste management rules, 2016: The new Bio-medical waste management rules were notified on 28th march, 2016. Since, then health care facilities are in process of implementing these rules. These rules have made the key stakeholders to be responsible for pretreatment of waste in addition to segregation but there are certain challenges faced by them due to certain grey areas in the new rules (Capoor MR 2018; Kishore *et al.*, 2014) have been highlighted below:

- The new rules have made it mandatory to pretreat the effluent probably containing chemicals, drug residues, disinfectants, hazardous contaminants, microbial residues etc. Howsoever, our country has very few photocatalysis units which ensure 100% removal of microbes and decontamination of drugs specially antimicrobials.
- The antibiotics and certain hazardous chemicals are capable to pass through the existing treatment technologies like ozonation, reverse osmosis, membrane filtration, biological treatment, ultraviolet radiation etc.
- The rules have mandated the use of non chlorinated blood bags, howsoever; they have a disadvantage of decreasing the shelf life of blood corpuscles.
- The pre-treatment of chemical liquid waste includes urine of the patients, body fluids etc. Collecting them separately and then treating them before discharging into sewage treatment plant is a challenge.
- The use of sodium hypochlorite at such high concentration is costly as well as hazardous.
- Segregation as per color coding raises questions regarding many consumables of all the waste categories: In yellow category, the caps, gowns, mask, shoe covers, blotting paper, paraffin blocks, swabs, indicator tapes, drugs dispensed in dextrose/ saline bottles are still the grey areas. If the non-infective waste is sent for incineration it just adds to the concentration of dioxins and furans in the air. The disposal of vacutainers, eppendorf tubes, PVC gloves is still confusing in red category. In the white category, the mutilation of all sharps is not possible for example: laryngoscope blade, all wires, metal insulin needle, eye needle, stab knife.
  In the blue category, the grey areas include glass slides coverslip, glass chambers, sternal wire, orthopaedic splint etc.

Suitable management practices and treatment technologies: The spirit of the law demands three things, firstly all infected waste has to be disinfected. Secondly all items that can be reused, have to be disfigured /mutilated /destroyed and lastly and most important is prevention and control of harmful impacts on environment. For achieving these, it is essential to adopt the most suitable waste management practices and technologies (Kumari *et al*., 2012; Gautam *et al*., 2010). For solid bio-medical waste treatment and management, the following treatment technologies should be used:

Autoclave is the wet steam sterilization process in which waste is subjected to temperatures around 160°C and pressure upto 6 bars for 45 minutes. The autoclave process gives a very high pathogen and virus kill rate, although the fibrous products which come from the process are susceptible to bacteria and fungus as they are high in starch, cellulose and amino acids.

Dry Heat Sterilization (killing or removal of all microorganisms, including bacterial spores) technique requires longer exposure time of 1.5 to 3 hours and higher temperatures than wet heat sterilization. Dry heat does most of the damage by oxidizing molecules. The essential cell constituents are destroyed and the organism dies. The temperature is maintained for almost an hour to kill the most difficult of the resistant spores.

Table-2: Deficiencies in the existing Bio-medical waste management in hospitals of Delhi

Parameters	Compliance as per BMW Rules, 2016	Deficiencies in the existing system (Partial/ Non- Compliance)
Segregation	As per the color coding prescribed in the rules.	Segregation is not in accordance with color coding mentioned in the Rules, 2016.Beddings and linen contaminated by blood and other infected fluid not discarded as per the norms. Voluminous materials need to be cut to the size of the yellow colored waste bag.Bags, boxes and sharp containers carrying waste have not been found sealed in few hospitals.
Bins	Should be color coded, pedal operated and of appropriate volume.	Pedal operated bins are still not used in all the hospitals.
Package Material	Needs to be of certain specific size, grade, design, symbols, markings and should comply with Bio-medical waste management Rules, 2016.	Color coded storage material (bags) not provided in all hospitals.
Schedule IV Label	For tracking the point of generation of waste. Should be there on each bag carrying waste.	The stickers on the BMW bags are not in accordance with Schedule IV.
Bin Trolleys	Should be proper according to the bin volume.	In few places, the bins have been found dirty as in they were not being regularly washed with detergent and hypochlorite solution.
Barcoding	To ensure there is no pilferage of waste from point of generation to final disposal, it is important to implement barcoding of each bag. Has to be done in each HCF.	Barcoding is yet to be implemented to track the waste from the source of generation to final disposal. Installation of a Barcode tracking system has been mandated to ensure no pilferage of waste happens from the point of generation upto final disposal.
Internal treatment record	Regarding operation of all treatment equipment including microwave, autoclave, STP, ETP etc.	Poor record maintenance.
Training records	To ensure effective management.	Gap among various stakeholders including policy makers, academicians, hospital representatives.Lack of training among the staff handling bio-medical waste.There is no clarification regarding provisions of the
Waste generation record at ward level and end point level	To track the waste generation and its quantum	Poor record maintenance.
Immunisation of handlers record	To be provided as per their work profile. The records have to be maintained for 5 years	Poor record maintenance.
BMW Segregation labels	Should be present at each point of waste generation	Labels are not adequately provided at each segregation point.
Isolated storage site	It should be in an isolated space, well partitioned and of appropriate volume	Isolated storage sites are not proper in terms of partitioning and in some hospitals, they are located in open access areas.
Trolley washing area	Should be separately allocated and connected to STP	Trolley washing areas are not separately allocated and not maintained.Trolley washing area is not connected with STP/ ETP in some cases.
Pre-treatment of solid waste	To be done by autoclaving, microwave, sharp blaster, dry heat sterilization etc	Sharp blasters and dry heat sterilization is not adopted in many hospitals. The spore tests in many hospitals are found to be positive.
Pre-treatment of liquid waste	The liquid waste probably contains emerging contaminants. It should be treated before discharging into STP	The liquid waste from laundry and laboratories is being sent to Sewage treatment plant without imparting chemical treatment.The laundry facility is lacking in terms of compliance.Untreated wastewater generated from laboratories/tissue cultures containing chemicals may hamper the biological treatment being imparted.
STP/ ETP	Should be adequate and operational	None of the visited hospitals ever got the characterisation of the hospital effluent done with respect to the probable emerging contaminants present.
Personal protective equipments	The PPEs should be made available to waste handlers.	The waste handling staff at storage site are not equipped with personal protection equipments like masks, gumboots etc.

Sources: Gupta et al., 2009; Anon 2015

Microwave technology of clinical waste in the healthcare waste sector is considered an alternative technology of the incinerator and is a steam-based process, and electromagnetic waves with frequencies between radio and infrared waves that use wet inside the wastes or by additional steam to sterilize wastes and destroy infectious agents and pathogenic organisms in the waste.

Incineration is a waste treatment process that involves the combustion of organic substances contained in waste materials. Incineration and other high-temperature waste treatment systems are described as "thermal treatment". Incineration of waste materials converts the waste into ash, flue gas and heat.

Macerators of single use pulp items greatly reduce the risk of

cross contamination. This modern, hygienic and environmentally friendly method of disposal has become the standard and best practice in hospitals and increasingly around the world. Pulpmatic range of machines offer a complete macerator system for the disposal of medical pulp and human waste providing a hygienic, safe disposal system.

Sharp Blasters The unit processes the sharps in a metal container for up to two and a half hours at temperature reaching 185°C, sterilizing, mutilating the infectious wastes and encapsulating the same into a sealed container for safe disposal. Computerized system ensures maintenance of critical operational parameters not requiring any manual handling (Kumari *et al*., 2012; Gautam *et al.,* 2010). Dry heat sterilization, macerator and sharp blasters are newer technologies having less adverse impacts on environment. These are more efficient in infection control and reducing sharp injuries. Till date they have been adopted only in few hospitals of Delhi.

The wastewater should be imparted tertiary level treatment for its reuse of water for cleaning, flush washing purposes to save money as well as water. The organic municipal solid waste should be composted through organic waste converter and reused as manure. A buffer zone should be created in the form of green belt. The gas based boiler should be preferred over oil fired/coal fired boiler. The refillable pump spray bottles should be used rather than single-use aerosol cans. The rain water harvesting system should be installed on roof top. The gas based hot water generator and boiler should be used where possible. Hybrid type hot water generator by using solar water heater should be encouraged. The conventional water heating systems must be replaced in a phase manner and solar water heating system should be installed. The integrated HVAC system should be planned for all the heating, ventilation and air conditioning requirements. The retrofit fixtures should be installed in wards and public rest rooms. The low flow shower heads, bath and sink faucet aerators and low flow toilets should be used. Restrict lawn watering to evening hours to decrease evaporation and maximize effectiveness. The soaker hoses should be used instead of sprinklers in lawns to minimize evaporation. Water audit and energy audit must be conducted to save the water for future. The Occupier must conduct periodical checks to ensure that no municipal waste is being mixed with Bio-medical waste to keep service charges within the waste limit. Waste reduction can be optimized through a comprehensive program to oversee its environmentally sound segregation techniques such as source separation, storage, transportation, treatment and disposal(Rajkumar Joshi 2016). By providing training to the staff whose responsibilities include materials handling and waste management, health administrators can help reduce the impact of medical waste on humans and the environment (Anyinam 2010; Emmanuel *et al*., 2013).

It can be summarised that the BMW generation has an increasing trend with respect to population of Delhi. The BMW per bed per day has increased from 306 grams in 2001 to 432 grams in 2011 and 520 grams in 2017. On analysis of total quantum of bio-medical waste treated by both the operators of CBWTFs in Delhi, it was found that on an average, 59% component of total BMW is incinerable, 8.0% is glass, 30% is autoclavable, and 3% are sharps. Study reveals that the waste generation in 100 bed and above in capital is ranging from 0.028 to 1.669 kg/bed/day with an average of 0.486 kg/bed/day. The wastewater containing chemical residues, drugs and infectious substances constitutes 24% of the total effluent rest is domestic and grey effluent. As per the data collected from hospitals of Delhi, it is found that the quantum of water consumption and wastewater generation increases with the increase in bed strength. The total water consumption by hospitals having bed strength above 50 is 31.09 MLD and in turn the wastewater generated is 24.79 MLD. The compliance, partial compliance and non-compliance of the parameters as per the Biomedical waste management rules, 2016 in 3 categories of hospitals has been assessed and it is revealed that not even 50% hospitals having the bed strength of 10-49 & 50-99 are complying with the parameters in accordance to the rules. There is a maximum partial compliance in middle strength hospitals. In hospitals having more than 100 beds the compliance of maximum parameters is more than 70%, however, maximum hospitals are still not pre-treating the liquid waste discharged by them. Thus, it can be concluded that the rate of compliance improves with the increase in size and bed strength of the hospitals.

It is important that if the total quantum of waste calculated on a per bed per day basis is more than the benchmark of 250 grams/per bed/per day laid by Indian Medical Association, the total cost of treatment by the Operator should increase and eventually the hospital will have to pay more. This will encourage hospitals to focus on waste minimisation and effective segregation. The average bio-medical waste generation per bed per day in Delhi has been estimated to be 486 grams solid and 480 liters of wastewater per bed per day. It is therefore suggested that the HCF ensures proper segregation of waste as well as keep a track of the total BMW is generated as per Indian Medical Association standard. The successful implementation of a medical waste management rules requires significant cooperation among the concerned parties, and commitment in terms of time and resources management. The main problem relating to solid bio-medical waste management and disposal is the sharp injuries and spreading of infections which can be controlled by using modern technologies like dry heat sterilization, macerators and sharp blasters. To protect the aquatic environment, it is important to provide treatment to hospital effluent before it is discharged in the municipal sewage system. Sludge from effluent treatment plants installed in hospitals should be managed with more precautions as municipal waste sludge. There are still a lot of deficiencies in the implementation of new rules. Also, there are certain grey areas in the rules, 2016 that needs further clarification. In order to combat these issues it is important that a Policy Framework should be worked out. Then next step is to make a plan. This can only be done after a 'Situation analysis' has been conducted so that gaps have been identified. This would require preparing a map of all generation points, the work up of resources and materials required, appointing a technically qualified Nodal officer. A list of handlers should be prepared for Training, Occupational Health and Safety. The regular health check-ups should also be practiced

for handlers. Depending upon the number of handlers and the nature of their job, selection of Personal Protective Equipment (PPE) should be worked out. The immunization against tetanus and Hepatitis B must be offered within a fortnight to a worker joining duties. At least one person in every hospital must have a thorough knowledge of the subject. In the absence of such knowledge, unknowingly the hospitals are violating the Rules. The new rules should not be feared. Rather an attempt should be made to understand the duties and responsibilities. With almost all cities having Centralized facilities to treat waste with good quality incinerators and autoclaves, the burden on hospital administration has been considerably reduced. Thus hospitals can easily focus on segregation, maintenance of storage site and occupational safety.

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