Sustainable Bio Medical Waste Management—Case Study in India

Vandana, V. Venkateswara Rao and Sadhan Kumar Ghosh

Abstract The Biomedical waste (BMW) is an area of concern which has a direct impact on the health and human safety. Management of BMW may be an ethical, social and obligation of all supporting and funding health-care activities. The scavengers sort out open, unprotected health-care wastes for recycling, and reuse of syringe, bottles and other medical aides compounded for BMW problems without using personal protective equipment (PPE)s, namely, gloves, masks, shoes etc. It's been ascertained that 10–25% of BMW is dangerous, whereas remaining 75–95% is non-hazardous. The dangerous part of the waste involves the physical, chemical, and/or microbiological risk to the health-care staff that is associated in handling, treatment, and disposal of waste. BWM rules in India were introduced first in the year 1998 and with the recent revision on the Bio Medical Waste management rules 2016 there after the 2018 amendments to boost the segregation, transportation, and disposal strategies, to decrease environmental impact therefore on amendment the dynamic of BMW disposal and treatment in India. The objectives of this article are, (a) assessing the present status of handling and treatment system of hospital biomedical solid wastes, (b) analysing the requirements in BMW Management Rules 2016, (c) identifying issue and challenges in the practical problems for its effective implementation, the major drawback of conventional technological interventions, the latest technologies for BMW disposal, and potential solutions, (d) comparing the SWM system in India with a few developed countries like USA, UK, Japan and S. Korea and (e) to present a case study on the BMW treatment facility at Mangalgiri, AP BMWM facility. This paper will be helpful for making strategies in different states in India and other developing countries for the management of biomedical wastes.

Keywords Biomedical waste · Treatment · Autoclave · Incineration · Business model

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1 Introduction

The Health care institution or hospitals which are responsible for generation of BMW are emitting 517 tonnes/day (Central Pollution Control Board 2018) from wards, operation theatre and outpatient areas. Management of hospital waste is crucial to take care of hygiene, aesthetics, cleanliness and management of environmental pollution. Communicable diseases which are caused through water, sweat, blood, body fluids and contaminated organs are vital and need to be prevented. Hospitals generate 10–15% Hazardous waste (which is infectious, injurious, Cytotoxic and Chemical) and 75–85% Non-Hazardous Waste (General Municipal Waste) (Fig. 1). Nonhazardous waste while mixed with hazardous waste entirely becomes hazardous. Biomedical waste *means "any waste, which is generated during the diagnosis, treatment or immunisation of human beings or animals or research activities pertaining thereto or in the production or testing of biological or in health camps.*"

Data from Government of India site (CPCB-as on 13.06.2018) BMW generated in the country in 2016 is 517 TPD (tonnes per day) from 1,87,160 HCFs, when compared to 501 tonnes/day from 1,88,098 HCFs in 2015 (Table 1). Unfortunately, only 501 TPD is treated and 16 TPD is left untreated in 199 CBMWTF and 23 under construction. The number of HCFs using CBMWTFs are 91,061, and approximately 15,281 HCFs have their own treatment facilities on-site. India will generate nearly 775.5 tons of medical waste/day by 2022 growing at a compound annual growth rate (CAGR) of about 7% (ASSOCHAM 2018). Figure 1 shows composition of Bio Medical Waste. The comparison between the Annual Report Information for the year 2015 and 2016 (Table 1) reveals the following:

- 938 (0.49%) numbers of Healthcare Facilities (HCFs) are inoperative in the year 2016 as compared to the numbers of HCFs reported for the year 2015.
- No. of HCFs/CBWTFs violating the provisions of BMW Rules in 2016 has increased to 12,034 in the year 2016 from 6074 in the year 2015.

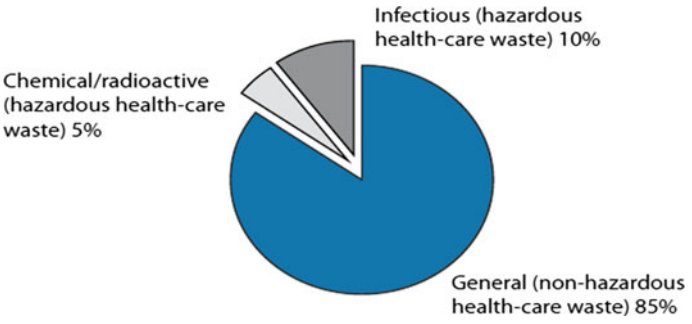


Fig. 1 Composition of bio medical waste

Table 1 Comparison between the annual report for the year 2015 and 2016

Particulars	As per annual report information for the year 2015	As per annual report information for the year 2016
No. of healthcare facilities	1,88,098	1,87,160
No. of beds	17,61,316	18,99,269
No. of common bio-medical Waste treatment facilities (CBWTFs)	203 + 32	199 + 23
No. of healthcare facilities applied for authorization	46,697	95,723
No. of healthcare facilities granted authorization	99,945	91,061
Quantity of bio-medical waste generated in Tonnes/day	501	517
Quantity of bio-medical waste treated in Tonnes/day	486	501
No. of HCFs/CBWTFs violated BMW rules	6074	12,034
No. of show-cause notices/directions issued to defaulter HCFs/CBWTFs	5103	11,272

2 Literature Review

In the twenty first century with accrued use of disposable material and therefore the presence of infectious disease like Hep-B and AIDS, it's utmost vital to require care for infected and dangerous waste to save lots of the group from disaster. Rag pickers within the hospital, looking for the garbage are at a risk of obtaining tetanus and HIV infections. The scattered Bio Medical Waste in and around the hospitals invites infectious and dangerous flies, insects, rodents, cats and dogs that are responsible for the spread of different disease like plague and rabies. The recycling of disposable syringes, needles, IV sets and alternative article like glass bottles without proper sterilization are liable for infectious disease, and alternative diseases. It becomes primary responsibility of Health directors to manage hospital waste in most safe and eco-friendly manner (Sengodan 2014, Mishra et al. 2016).

A study shows that 16 billion injections are administered every year. The indiscipline, unsafe and indiscriminate ways of disposal of needles and syringes within the bio medical wastes creates the opportunity for reuse, possible risk of injury and infection. The efforts have been made to reduce the possibilities of injection with contaminated needles and syringes in developing countries that have reduced infections. Due to use of contaminated syringe, in 2010, 33,800 new HIV infections, 1.7 million hepatitis B infections and 315,000 hepatitis C infections were reported

(WHO 2014). Risk of a person being infected with HBV, HCV and HIV due to use of an infected needle stick is 30, 1.8, and 0.3% respectively.

Segregation is the key for proper biomedical waste management at the source, namely, all the inpatient and out Patient Department (IPD and OPD) in different care activity areas, operation theatres, labour rooms, diagnostic services areas, treatment rooms etc. The biomedical waste generators, e.g., doctors, nurses, technicians and the patient (medical and paramedical personnel) are responsible for the segregation. Biomedical waste is segregated and collected by the cleaning personnel/ayahs in color coded, labelled bags. These bags are filled 3/4th and tied at the top, to prevent accidental spillage. Covered containers/trolleys with wheels are labeled and used to transport the waste to common collection point. Waste is stored in a separately at room temperature. Waste is collected within 48 h from the generation site and transported thru designated vehicles to the final treatment facility.

The impact of mismanaging the bio medical waste enormously affect the environment and human health. Followings are some of the potential hazards out of the mismanaged bio medical waste. Injuries inflicted by Sharps may cause danger to the human and animal health. Exposure to toxic substances, e.g., mercury, dioxins, pharmaceutical products, antibiotics and cytotoxic drugs released into the surrounding environment may cause damage to the health of the bio medical waste handlers for storing, transportation, incineration etc. without PPEs. Health hazards may occur from emission during bio medical waste incineration, chemical burns from disinfection, sterilization and other waste treatment activities, thermal injuries with open burning and radiation burns etc.

3 Rules in India

BMW is a real problem for the community and environment. Management of BMW came into limelight only after 1990s. Some landmark decisions have been made to streamline hospital waste management in the recent past (Sutha Irin 2018, Datta et al. 2018, Shreedevi 2019). These are:

1. Supreme Court judgment for safe disposal of hospital waste: Ordered dated 01.03.1996—all hospitals with 50 beds and above have to install either their own incinerator or an equally effective alternative method before 30.11.1996.
2. The then Ministry of Environment and Forest, Govt. of India: Issued notification for Biomedical Waste (Management and Handling) Rules 1998.

The BMW Rules 1998 (Fig. 2) were modified in the years 2000, 2003, 2011, 2016 and 2018. The draft of BMW rules 2011 remained as draft and did not get notified. Ministry of Environment, Forest and Climate change (MoEF and CC) in March 2016 and subsequently in 2018 has amended the BMWM rules. These rules have simplified the categories (Tables 2, 3 and 4) and defined the roles of the operators of Common Bio Medical waste treatment Facility (CBMWTF) and the occupiers

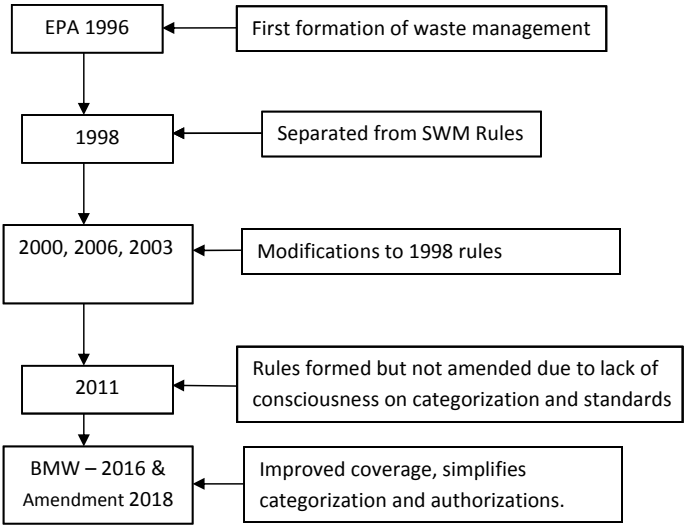


Fig. 2 Chronology of bio-medical waste management rules in India

Table 2 Forms with Biomedical Waste Management 2016

Forms	Use of the form
F1	Accident reporting
F2	Application for authorization or renewal of authorization (submitted by occupier of HCWs of CBMWTFs)
F3	Authorization (for operating, facility) for generation, collection, reception, treatment, storage, transport, disposal
F4	Annual report
F5	Application for filling "appeal" against order pass by the prescribed authority

HCWs healthcare workers, *CBMWTFs* common bio-medical waste treatment and disposal facilities

(Hospitals/Generators) at large. These new rules have improved the segregation, transportation and disposal methods.

These rules have been modified to include bring more clarity in the application and also included the word handling. In addition to improvement in categories, schedules have been reduced and forms for annual report, accident report with biomedical waste have also been changed (Table 2). Usage of non-chlorinated plastic bags and the thickness of the bag (50 μm) have been made mandatory. Efforts have been made for improving the effectiveness of collection, segregation, transport, and disposal of waste. Role of incinerator in increasing environmental air pollution has been controlled and checked by introducing stringent parameters with online monitoring systems. The new monitoring condition increases the retention time in secondary chamber. Figure 2 shows the evolution of BMW Management Rules in India.

Table 3 Categories as per Biomedical Waste Management Rules—1998

Option	Waste category	Treatments disposal
Category No. 1	Human anatomical waste	Incineration/deep burial
Category No. 2	Animal waste	Incineration/deep burial
Category No. 3	Microbiology and biotechnology waste	Local autoclaving/microwaving/incineration
Category No. 4	Waste sharps	Disinfection by chemical treatment/autoclaving/microwaving and mutilation/shredding
Category No. 5	Discarded medicines and cytoxic drugs	Incineration/destruction and drugs disposal in secured landfills
Category No. 6	Solid waste	Incineration/autoclaving/microwaving
Category No. 7	Solid waste	Disinfection by chemical treatment/autoclaving/microwaving and mutilation/shredding
Category No. 8	Liquid waste	Disinfection by chemical treatment and discharge into drains
Category No. 9	Incineration ash	Disposal in municipal landfill
Category No. 10	Chemical waste	Chemical treatment and discharge into drains for liquids and secured land for solids

These rules described the duties of the Occupier or Operator of a Common BMW Treatment Facility as well as the identified authorities. Every occupier or operator handling BMW, irrespective of the quantity, must obtain authorisation from the prescribed authority, i.e. State Pollution Control Board and Pollution Control Committee, as the case may be. These rules consist of four schedules and five forms.

4 Waste Handling and Treatment Systems

The objective of biomedical waste management is to reduce generation of waste. A secure and reliable technique for handling of BMW is crucial to save lots of human beings from the “adverse effects of health care waste”. Effective management of BMW is not legal necessity however additionally a “social responsibility”. Segregation is the key to proper management of biomedical waste. To achieve an effective Bio-medical waste management four steps are to be followed accurately and routinely. The steps are as follows. Trollies and vehicle used for outside transport are designed to facilitate minimum damage to structural integrity of waste. Waste should be transported only through the pre-designated route. The waste handlers should use personnel protection Equipment. Proper documentation of the type and quantity of waste being transported should be logged as per the prescribed format. To avoid illegal reuse of needles and other kind of waste barcoding systems have been introduced for waste collection.

Table 4 Categories as per Biomedical Waste Management Rules—2016

Colour code	Category	Treatment
Yellow	Anatomical waste, Animal waste, Soiled waste, Solid waste, Discarded linen, expired and discarded medicine, chemical waste	Incineration, plasma pyrolysis or deep burial
	Microbiology, biotechnology and other clinical waste	Pre-treat to sterilize with non-chlorinated chemicals on-site thereafter for Incineration
	Chemical liquid waste	Separate collection system should lead to effluent treatment system. On completion of the resource recovery, the chemical liquid waste shall be pre-treated before mixing with other wastewater
Red	Contaminated waste recyclables	Autoclaving or micro-waving/hydroclaving followed by shredding or mutilation or combination of sterilization and shredding. Treated waste has to be sent to registered or authorized recyclers
White	Waste sharps including metals	Autoclaving or micro-waving/hydroclaving followed by shredding or mutilation or combination of sterilization and shredding. Treated waste has to be sent to registered or authorized recyclers
Blue	Glassware	Disinfection (by soaking the washed glass waste after cleaning with detergent and Sodium Hypochlorite treatment) or through autoclaving or microwaving or hydroclaving and then sent for recycling

5 Issues and Challenges

Improper segregation—Even after a long time of implementation of these rules there are still some hospitals and some healthcare institutions which do not segregate the waste in desired standards of segregation. This may be due to insufficient funds, confusion due to large number of categories and lack of awareness in healthcare facilities. Improper segregation of BMW causes Corrosion and also accidents while incinerating.

Usage of Chlorinated Plastic Bags—Due to low cost of chlorinated bags, hospitals are still using them. Which increase the particulate matter and the flu gases while incineration. These bags are also not labelled as per the Schedule-IV.

Storage and Packing—The hospital waste, namely, body parts, organs, tissues, blood and body fluids along with soiled linen, bandage, cotton, plaster casts from

infected and contaminated areas must be properly collected, segregated, stored, transported, treated and disposed of in safe manner to prevent nosocomial or hospital acquired infection. No proper designated storage is provided at the hospitals. Bags are not being tied at the top, which will attract flies and rodents.

Internet connection—As per the new rules, Air pollution Equipments are to be connected to the CPCB/SPCB websites. This is major problem, since most of the providers do not provide wired connection to remote areas. As per the new BMW rules, a CBMWTF is to be located 2 km away from habitation. Since there is no wired connection, a dongle has to be used. Dongle being a wireless connection and the location of CBMWTF, network is on-off most of the times. Also, every state has its own rules. Now in AP, CBMWTF are to connect webcams and GPS Tracking systems of Vehicles also to SPCB site.

6 Comparing the SWM System in India with a Few Developed Countries like USA, UK, Japan and S. Korea

In 2012, WHO conducted a survey on the BMWM status of twenty four West Pacific countries on five main areas, namely, management, training, policy and regulatory framework, technologies implemented, and financial resources. In the field of management, training, and policies regarding BMWM, except Micronesia, Nauru, and Kiribati all other West Pacific countries were satisfactory. It has been observed that the best available technologies for BMW logistics and treatment were used only in Japan and Republic of Korea, which were well maintained and regularly tested. Most of the countries had very less financial resources for BMWM. In 2015, a joint WHO/UNICEF assessment just over half (58%) of sampled facilities from those 24 countries of west pacific area. It was found that adequate systems have been followed for the safe disposal of health care waste.

The pharmaceutical and healthcare companies are major medical waste generators. When it comes to the handling of medical waste, European and American regulatory bodies are stringent. By 2018, the Medical Waste Management market is anticipated to reach a value of $10.3 billion, at a CAGR of 4.9%. Pharmaceutical waste management with an expected market size of $5.8 billion by 2018 will lead waste management (Reddiar Janagi et al. 2015). As seen from the Table 5, the

Table 5 Waste generated in different countries as per 2015

Country	Quantity (kg/bed/day)
UK	2.5
USA	4.5
France	2.5
Spain	3.0
India	1.5

Medical Waste Management market is highest for US which are the followed by Europe.

With the growing awareness in health care waste management, there has been an gradual increase in the no of CBMWTFs setup till 2014. But in 2015, authorizations have been issued to all/most of the applicants without proper evaluation of need, because of which there has been a steep growth in no of CBMWTFs setup. When there is a competition, the quality of the service drops. Which led to closure of facilities since they couldn't with stand the competition and the daily needs. The last century Andhra Pradesh (AP) witnessed the rapid mushrooming of hospital in the public and private sector for serving the growing demands of expanding population. The advent and acceptance of "disposable" has made the generation of hospital waste a significant factor in current scenario. Figure 3 and Tables 6 and 7 demonstrate the growth and status of BWM systems in the ate of AP, India.

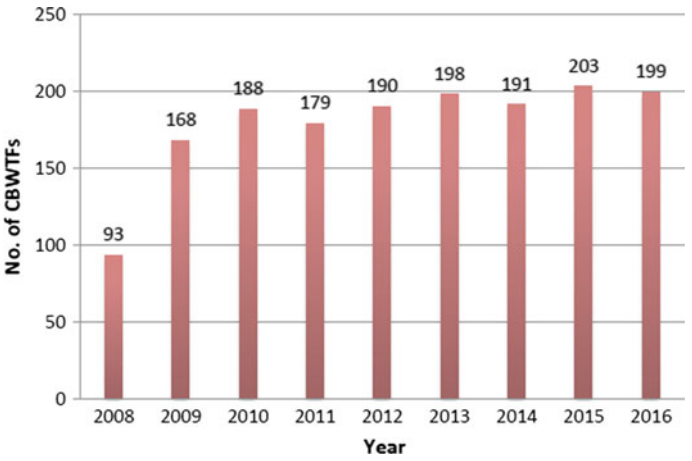


Fig. 3 No. of CBWTFs in Andhra Pradesh from FY 2008 to 2016

Table 6 Growth in no. of hospitals in Andhra Pradesh

S. no	Year	No. of HCE's	NO. OF BEDS	QTY waste kg/day
1	2013	2861	61,266	5491
2	2014	3096	67,484	6494
3	2015	5016	96,300	8360
4	2016	5721	102,464	9841.7

Table 7 Common bio-medical waste treatment and disposal facilities in AP (for the year 2016)

Sl. no	Name of CBMWTF at health care facilities (HCFs)	District	Total no of HCFs covered	Total no of beds covered	Quantity of BMW collected (kg/day)
1	Rainbow Industries	Srikakulam and Vizianagaram	370	6732	438.2
2.	Maridi Eco Industries Pvt.	Visakhapatnam	704	13,917	2000
3.	EVB Technologies Pvt Ltd.	East Godavari	525	11,589	679.5
4.	Safenviron and Associates	West Godavari	524	6068	510
5.	Safenviron Unit II	Krishna	752	12,848	1468
6.	Safenviron	Guntur	700	13,683	896
7.	S S Bio Care	Nellore	601	7921	1011
8.	Ongole Medical Waste Treatment Facility	Prakasam	357	4638	462
9.	Sriven Environ Technologies	Ananthapur	354	9593	712
10.	AWM Consulting Ltd	Chittoor	449	9552	975
11.	Medical Waste Solutions	Kurnool	385	5923	690

7 Case Study on the BMW Treatment Facility at Mangalgiri, AP

M/s Safenviron, a full-fledged Bio Medical Waste (BMW) Treatment facility was established in the year 2001 at Chinakakani Village in Guntur District, about 15 km away from Vijayawada, M/s Safenviron has been functioning fully complying with the norms of A.P. Pollution Control Board from time to time. M/s Safenviron is an operator dealing with collection, transportation and disposal of BMW with trained manpower, fleet of vehicles and well established plants, for more than 1399 Health Care establishments in Krishna and Guntur Districts. With a fleet of 15 vehicles registered with the concerned SPCB/PCC BMW is collected from enrolled members within 48 h of generation. Since 2014, with its sister concern M/s Safe Medi Aids, bags and bins used for BMW disposal are supplied to the enrolled hospitals.

Fig. 4 The 8th IconSWM delegates from India, Nepal, Kenya, Sri Lanka, Japan and members of ISWMAW and APPCB visited the facility on Nov 27, 2018

BMW collection bags at the M/s Safenviron are labelled and manufactured as per Schedule-III and IV of the Bio-medical waste (Management and Handling) Rules 2016. Vehicles are labelled with the bio-medical waste and cytotoxic symbols (as per the Schedule-III of the Rules) and the name, address and telephone number of the CBWTF (Fig. 4).

Coloured bags handed over by the healthcare units are collected in similar coloured containers with proper cover. Waste storage cabins in the vehicles have provisions for the sufficient openings in the rear and/or sides for easy loading and unloading. Vehicles used for collection are partitioned according to norms with FRP coating, to withstand any possible damage that may occur during loading, transportation or unloading. The base of the waste cabin is made leak proof to avoid pilferage of liquid during transportation. A manifest is issued to the HCE during collection; manifest contains details like name of the HCF, date, no of bags and Weight disposed. All vehicles are having GPS tracking systems. Vehicles used for collection of BMW are cleaned using jet pumps and disinfected daily. Waste water generated from vehicle wash and during the treatment process is cleaned in ETP.

Treatment and disposal of segregated BMW is done in conformity with A.P. Pollution Control Board norms/rules and regulations with quality and commitment. All the vehicles unload the waste collected from the HCE's in their respective storage areas at the treatment facility. In and Out timing and the total weight unloaded at the facility are recorded. Yellow bags from the storage room are incinerated immediately. Incineration, a high temperature thermal process, employs combustion of the waste under controlled condition for converting them into inert material and gases. Incinerators have primary and secondary combustion chambers with refractory lining to ensure optimal combustion. The primary chamber has pyrolytic conditions with a temperature of 800 °C. The secondary chamber operates under excess air conditions at about 1050 (±)50 °C. Flue gasses from incinerator are passed via Air Pollution

Control Equipment for removal of particulate matter. Quality of incineration is determined by Online monitoring systems attached to Air Pollution Control Equipment. The chimney is 30 m above ground level.

Red, White and Blue waste from the storage room is treated in an autoclave. Autoclaving is a sterilization method using high-pressure steam. The working principles of autoclaving based on the concept of boiling point of water (or steam) increases under higher pressure. It is a thermal process where steam comes in direct contact with waste in a controlled environment for significant time duration to disinfect the wastes as stipulated under the Bio-medical Waste Management Rules. For ease and safety in operation, a horizontal type autoclave is used. Pre-vacuum based system is gives optimum results than the gravity type system. A PLC is attached to the autoclave and incinerator separately with efficient display and recording devices for recording critical parameters such as time, temperature, pressure, date and batch number etc. as required under the BMWM Rules. Figure 5 shows the visitors in the facilities from different countries.

Red bags after autoclave are shredded and then sold to authorized recyclers. Waste are de-shaped or cut into smaller pieces by shredding which make the wastes unrecognizable. It helps in prevention of reuse of bio-medical waste and also acts as identifier that the wastes have been disinfected and are safe to dispose. M/s Safenviron has established waste treatment facility with essential machinery and trained manpower to endure day-to-day operation of collection, transportation and disposal of BMW in accordance with A.P. Pollution Control Board norms/rules and regulations. The

Fig. 5 Prof. Sadhan K Ghosh, Mentor of M/s Safenviron and the Chairman, IconSWM (4th from right), Mr. Venkateswara Rao, Owner of the plant, (5th from right) and other personnel in the plant

Fig. 6 Blooming flowers in the tank using treated water from ETP in M/s Safenviron

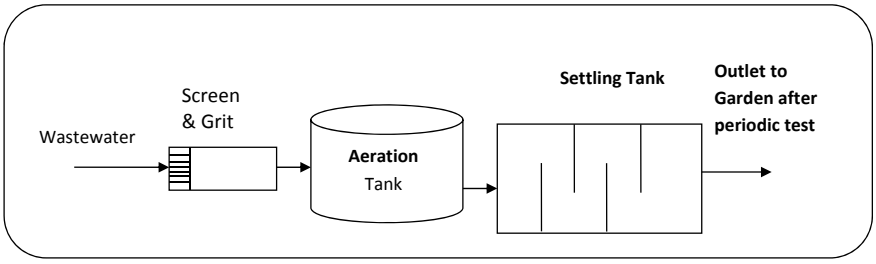
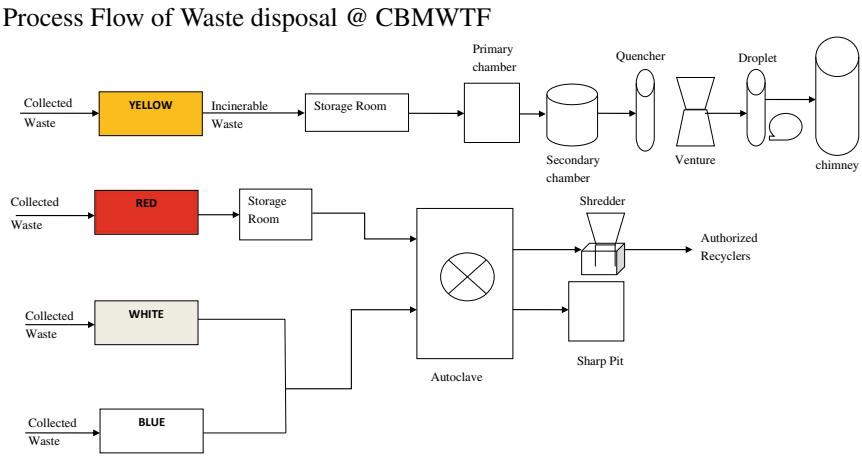


Fig. 7 Schematic diagram of Effluent treatment plant at M/s Safenviron

operation is being continued for more than 14 years which has modernized the facility recently for better quality service to meet ever-increasing loads. After incineration, ash generated is stored in secure landfill on the premises. Secured landfill is a concrete construction lined with HDPE sheets to prevent perforation of leachate into the ground water. But as per the new BMW rules, 2016, Incineration ash is to be disposed of at TSDF. Figure 6 shows the effluent Treatment Plant (Fig. 7).



8 Conclusions

Medical Waste handling is a hazardous waste management process which requires a high standard of preparation. Biomedical waste management is the need of the hour, scientific and cost effective methods have to be developed. The waste should be segregated at the source rather than end of pipe approach. Specific training should be given depending on the nature of the work, responsibilities in the hospital and worker experience of individual workers. Training for health-care staff is essential in the efforts to minimize the transmission of secondary infections. Staff training helps to achieve higher standards of infection control measures.

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