A review of Medical waste, its Environmental consequences and Management Strategies: a Burning issue of the present day Society

Abstract

Medical waste has enormous consequences for human health and the environment. It has the potential to cause severe disease, if not death. If drugs end up near wildlife refuges like parks, lakes, and other natural environments, whole populations of species might be wiped off therefore its management is vital due to the potential for environmental and public health hazards, especially in countries which are in the process of development. It is crucial to collect data and examples from a developed nation or a nation with an efficient medical waste management system. Cities are expected to accommodate 65 percent of the globe's population by 2030. The amount of residential waste produced in Mumbai on a regular basis is approximated to be the equal of an eight-story building complex. The atmosphere in cities is so bad that an estimated two million kids under the age of five die from respiratory problems each year. Hospitals, retail stores selling vegetables, seafood, and other items, as well as bus stops, train stations, and amusement parks, are all filthy and serve as breeding grounds for dangerous diseases. In developing nations like India, the amount of trash generated by hospitals is significantly rising, hence monitoring is important. The growing interest for public health excellence and pollution management, necessities that the large quantity of hazardous waste be rendered as innocuous very quickly, prior to its disposal. The main aim of this paper is to highlight the issues surrounding medical waste, its environmental repercussions, and the management procedure.

Keywords: Healthcare waste, Illness, Infectious waste, Management

A. Introduction

Waste generated at health protection centers such as hospitals, dispensaries, medical practitioner centers, dental operations, blood donor centers, veterinarian clinics and medical laboratories etc. is termed as medical waste (WHO, 2015). A rising amount of waste is produced by hospitals and other healthcare facilities, 15% of which may be infectious, poisonous, or radioactive (Borowy, 2020). For our survival, health, and general well-being, hospital services are essential. On the other hand, because of the high risk of disease transmission, the waste produced by hospitals can be exceedingly poisonous, harmful, and even fatal and have detrimental consequences on the environment, including wildlife, water quality, and the significant risk of disease transmission (Chisholm *et al.*, 2021). If not handled properly or mixed with other municipal waste, the poisonous and hazardous components of waste from public healthcare institutions, such as toxic, and radioactive material, in addition to other materials (blades, scalpels, and so forth), constitute a serious concern (Brindha and Kanchan, 2013).It puts the entire effort to manage municipal waste at risk because of its propensity to encourage the spread of many diseases and their vectors, as well as because of its propensity to infect non-hazardous, non-toxic municipal waste. Garbage collectors and trash workers suffer the most damage because they unintentionally or intentionally sift through a variety of hazardous materials in their quest to recover items that they may resell or reuse. The aforementioned practice of unauthorized as well as irresponsible utilization can also be exceptionally harmful and fatal. Serious public health hazards include diarrhoea, , TB, tetanus hepatitis, human immunodeficiency viruses, whooping cough and other illnesses and can turn into an epidemic or endemic (Alam *et al.,* 2019).

The hazard, however, can be considerably reduced with good planning and control. According to research, roughly 1/3rd of total waste produced healthcare institutions, is non-dangerous and non-poisonous (Pasupathi *et al.,* 2011).Some estimates say that infectious waste accounts for 15% of total waste, with other hazardous waste accounting for 5%. Therefore, the problem can be mitigated by implementing stringent segregation rules at the source. Similarly, with better management and planning, garbage generation can be reduced, as well as capital incurred on management of waste be minimised. Institutional buildings and other things are given a lot of importance these days. Perfect education and coaching of personnel during all stages accompanying with current inspiration and stimulation can result in tremendous change. Medical waste requires special treatment given its impact on the environment and on humanity (Bucataru *et al.,* 2021). However, the amount and improper management of medical waste could increases a result of several societal, economic, and technical forces and constraints. These problems might have detrimental effects on the natural environment, human well-being and economy (Al-Omran, *et al.,* 2023). Jangre, *et al.,* (2023) stressed on prioritization of factors and selection of best business practice from bio-medical waste generated using best–worst method. The Management and Handling Rules, 1998 for waste, formulated by Government of India, put in place compatible guidelines and codes of practice for entire Nation. The 'occupier' of organisation that generates clinical waste, or bio-hazardous medical waste is plainly explained in this rule to be accountable for initiating appropriate actions to guarantee that refuse is managed properly and is not causing any harm to any persons wellness or its habitat (Tippat *et al.,*2015). India's

Biomedical Waste Management and Handling Rules, 1998 defines medical waste as waste produced in the course of recognition, surgery, or vaccination of humans and other organisms, or during related experimentation processes, or even in creation or examining of living products in health camps (Mandal and Dutta, 2009).

B) Sources of medical waste: Sutrisno *et al.,* (2020) reported that sources of medical waste generation are health care activities in various health care intuitions. As per WHO (2014), there are two types waste generation sources:

a) Major sources

i Govt. and private hospitals

ii Animal and human research Labourites.

iii Colleges imparting medical education including Veterinary colleges etc.

iv Blood donating centres, Biotechnology units, Production units etc.

b) Minor sources

i Medical practitioner centres.

ii Animal shelters.

iii Blood donation camps.

iv Immunization centers.

v Homeopathic canters

vi Psychiatry centres

vii Burial practices.

viii Rehabilitation canters etc.

C) Classification of medical waste: Medical waste can be classified into following groups (WHO, 2014):

1. **Infectious waste:** Anything that is contagious or transmissible in nature. It includes tissues of animals as well as human beings, blood stained bandages, used surgical gloves, diseased waste, etc.
2. **Hazardous waste:** The waste that has the capacity to cause diseases in human beings in non-infectious manner. Discarded medicine and other chemicals come under this category
3. **Sharps waste:** This includes those substances that penetrate the dermis layer of skin eg. glass pieces, syringes, scalpels, needles, etc.
4. **Pharmaceutical waste:** Unused and expired drugs or medicines, like creams, pills, and antibiotics.

5. **Mutagenic waste**: Toxic drugs and other dangerous wastes, having clastogenic, mutagenic, properties
6. **Radioactive waste:** Waste that emits harmful radiations mostly produced from cancer treatment therapies, nuclear medicine treatments, and apparatus that make use of radioactive isotopes
7. **Chemical waste:** It is potentially in the form of fluid, mostly from appliances, antibacterial, antifungal agents etc.
8. **Other unwanted wastes**: These are called general wastes and include garbage, market waste, kitchen waste, packing waste, excreta of all animals, torn clothes, carcases of different animals, cans, plant waste etc.

D) Classification of elements in medical waste as per WHO

As per the report of WHO (2014), different elements in medical waste are classified on the basis of weight as shown in fig 1. Medical waste includes almost eighty percent of noninfectious waste, fifteen percent of infectious, three percent chemical and medicinal waste, one percent each of chemical and radiation emitting waste, cytotoxin, and weighty minerals (Mastorakis *et al.*,2010). The hazardous component of waste is the physical, synthetic or bacterial and fungal threat to medical management personnel involved with waste processing, treatment, and disposal (Rao and Ghosh, 2020).

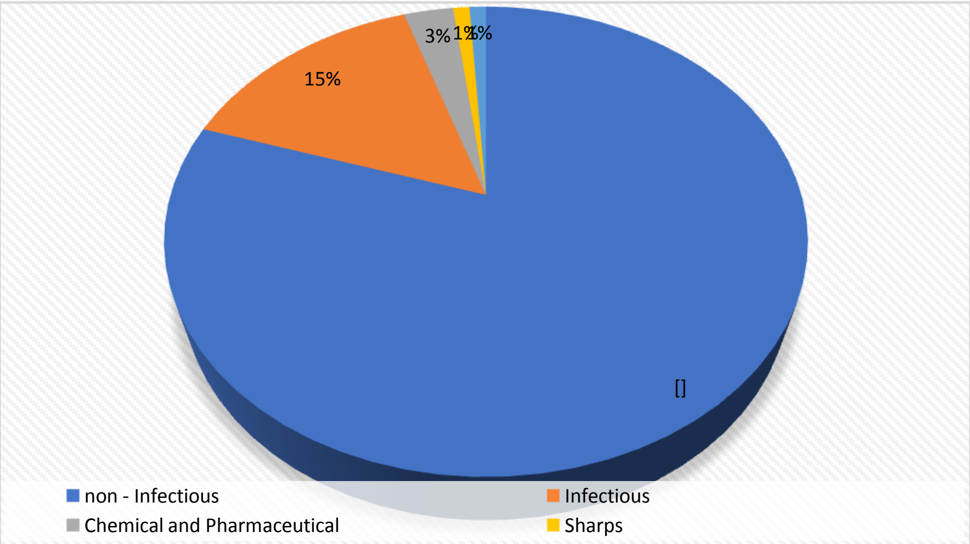


Figure 1:- Classification of elements in medical waste

E) Assessing safety practices and healthcare for healthcare personnel: For collecting and disposing BMW workers need:

- ✓ Personal clothing: workers collecting wastes lacked proper protection and were seen wearing simple latex gloves and masks.
- ✓ Personnel used hand wash for washing hands.
- ✓ They are not immunized against hepatitis B and tetanus.

F) Cytotoxicity

- ✓ No safety procedures are written for handling and processing cytotoxic drugs.
- ✓ Procedures for emergency spills have not been mentioned.
- ✓ **Recommendation for managing BMW colour coding of bio-medical wastes**

G) Impact of medical waste on various components of the environment

a. Human health: According to the WHO (2014), communicable diseases are cause of death, of approximately fifty thousand people in the world. The infection causing wastes, if not handled rightly, results in occurrence of certain diseases like cancers, impotence, reproductive organ malformations, mutations, skin and chest diseases, and mental distortion in people of different age groups. It may also cause acquired immunity deficiency syndrome, cholera cirrhosis, and other dread full infections from the fine pointed objects soiled with blood (Adedigba *et al.*, 2010). Injuries may not appear immediately but may accumulate or stay latent for many years in the different organs of the body, like hepatitis in liver and malignancies etc. As a result, all questionable and unknown chemicals should be regarded as harmful. (Mandal and Dutta, 2009). As per year 2000 report of WHO, the illegitimate handling of hospital waste had resulted in prevalence of certain specific diseases throughout world like hepatitis B,C and HIV(Pittet *et al.*, 2006)

b. Water: Various contaminants may percolate into groundwater into fresh water bodies from the waste dumping sites. Burning of medical waste comprises a significant amount of polycyclic aromatic hydrocarbons (Heera and Rajor, 2014). It also contains heavy minerals like calcium, Iron etc. (Bano *et al.*, 2022a, 2021). All these things ultimately results in formation of unwarranted levels of harmful substances which result in contamination of soil and groundwater (Heera and Rajor, 2014).Wastewaters from healthcare facilities is another factor that degrade the quality of water.

c. Soil: The existence of significant amounts of heavy minerals in hospital waste like Zinc etc. may eventually enter into the soil/sediment (Bano *et al.*, 2022b). These heavy minerals leach along different soil horizons and may cause serious harm (Huiying and Huaqing 2002). Non-biodegradable property of heavy metals is a basic trouble because these reside in different environments for longer periods of time. Further disposal of biomedical waste degrades soil quality and reduces vegetation abundance as well (Manzoor and Sharma, 2019).

d. Air: Healthcare waste combustion contaminates the environment with pulverised fuel ash and harmful minerals in the burnt ash, acid gases, nitrogen oxides, Sulphur oxides, and xenobiotic compounds etc. (Javied *et al.,* 2008). Other hazards caused by the burning of hospital wastes include acidification, climate change, formation of ozone and smog through photochemical reaction. The Healthcare of the U.S constitutes approximately eight percent of the Countries greenhouse gas discharge (Chung and Meltzer, 2009). As per Manzoor and Sharma, 2019 medical waste has a negative impact on air quality; various effects on air quality include acid rain formation (twelve percent), greenhouse gas emission (ten percent), smog formation (ten percent), air pollutants (nine percent), stratospheric ozone depletion (one percent), and carcinogenic and non-carcinogenic air toxics (one percent).

H) Medical waste production in India and some of the leading hospitals of Union territory of Jammu and Kashmir

As per Bakiu.*et al.,* (2018) mean waste quantity produced in aggregate in hospitals in nine countries across the world is mentioned in Table 1, with maximum medical waste generated by the United States that is 10.7 kg/bed/day and minimum by Tanzania that is 0.14 kg/bed/day.

Table 1: Medical Waste Production in the World

Country	Quantity (kg/bed/day)
UK	3.3
US	10.7
France	3.3
Spain	4.4
India	0.5-1.5
Saudi Arabia	0.2-1
Jordan	6.1
Pakistan	2.07
Tanzania	0.14

I) Medical waste production in India

The quantity of waste produced by healthcare institutions in the country is approximated to be between 0.5 and 2.0 kilograms per bed per day. (Mandal and Dutta, 2009).

According to the CPCB research, the whole quantity of medical waste produced in India in 2016 was roughly 517 tonnes per day, which is presumed to increase to 775.5tones per day by the year 2022 (Yadav *et al.,* 2020). Every day, hospitals in major cities generate more than 30 tons of biomedical waste. (Manzoor and Sharma, 2019). As per annual report of CPCB on

Biomedical Waste Management total medical waste produced during the year, 2014 was 420 tons/day and it increased to 774 tons/ day in the year 2020 as shown in table 2.

Table 2: Medical waste produced in India (CPCB, 2020)

Year	Tons/day
2014	420
2016	510
2018	608
2020	774

J) Hospital waste production and handling in few prominent hospitals of Union territory of Jammu and Kashmir

i) S.M.H.S. (Shree Maharaja Hari Singh) Hospital Srinagar:

It is a 750 bed affiliated hospital of the Government Medical College in Srinagar, with roughly 4,200 inpatient admissions each year and a yearly outpatient department inflow of about twelve lakh cases. It is the largest alternative hospital in the Kashmir valley. According to J&K State Pollution Control Board, S.M.H.S hospital generates 2Kg waste/ bed/ day. S.M.H.S hospital having 120% bed occupancy produces 1800 Kgs/day that is 650 tonnes per year. Waste generated is collected by 3-4 sweepers in each ward. No proper protective clothing is used while collection. BMW is collected by sweepers with hands and temporarily stored in plastic buckets. No segregation or colour coding of wastes is followed. BMW generated is dragged out by sanitation staff from wards out from the hospital to dumping site near incinerator. The activity is carried on during regular basis. It is stored at a dumping site near incinerator and rest kept in dumper of SMC (http://brighterkashmir.com/bio-medical-waste-generated-from-premier-jk-hospitals-treated-unscientifically). BMW is not subjected to any treatment except sprinkling of lime over it. It is stored at dumping site is un-segregated. Some segregation is done but no proper scientific techniques are adopted. Major portion is fed to incinerator that is run irregularly. It also pollutes the atmosphere.

ii) Sheri Kashmir Institute of Medical Sciences (SKIMS)-Soura: It is located in Soura, Srinagar, is a multispecialty hospital with a capacity of 600 beds that serves the average socioeconomic class of the population. Waste generated per day per bed in SKIMS-Soura is given in Fig.2 (Pandit et al., 2007). The collection and transportation activities to final disposal in the Institute are practiced properly, however, the waste management processes are not followed in a proper way in the Institute (Pandit et al., 2007). All kinds of waste generated by the people are dumped in the Wetlands (Bano *et al.*, 2018). Similarly the waste generated in SKIMS-Soura is directly thrown into Anchar Lake (Gulzar and Abubakr, 2019).

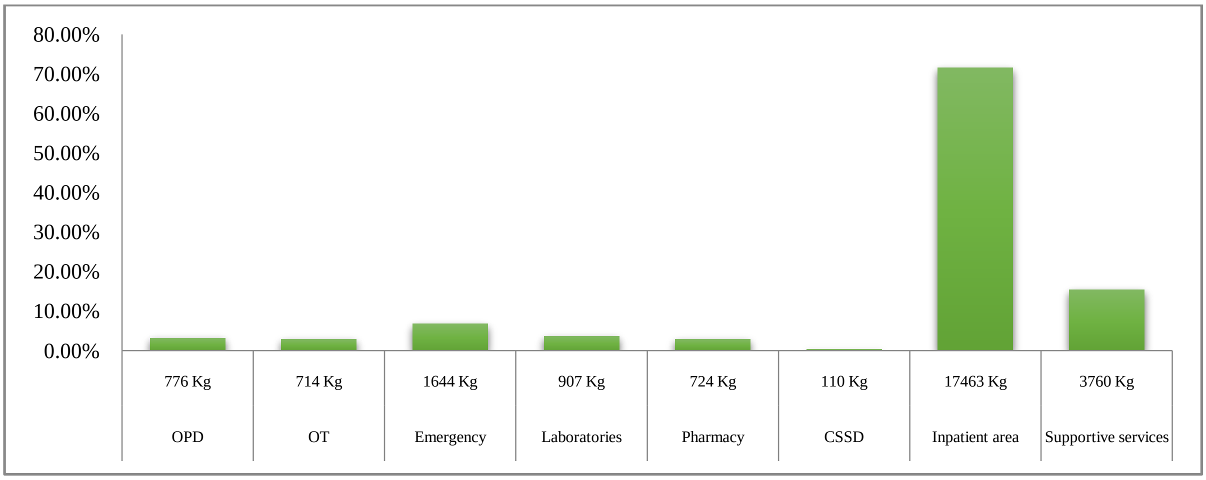


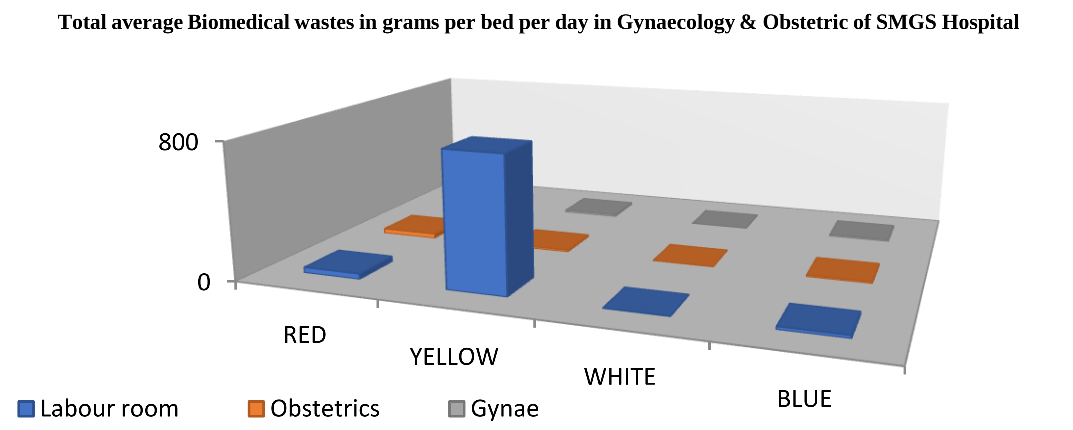
Fig.2 : Biomedical wastes generated at SKIMS, Srinagar

iii) Lal-Ded Hospital Srinagar:

It is a 700 bedded hospital and is the lone maternity hospital of Kashmir Valley with bed occupancy rate of above 200% in labour room and recovery wards. No information is available with the authorities on the production and quantity of biomedical waste produced in the hospital. Wastes are not segregated properly, although the coloured bins are there throughout in the hospital, but mixing of waste occurs in labour room and wards. Furthermore, there are no safe tools accessible for processing biomedical waste in hospitals (Haq *et al.*, 2019).

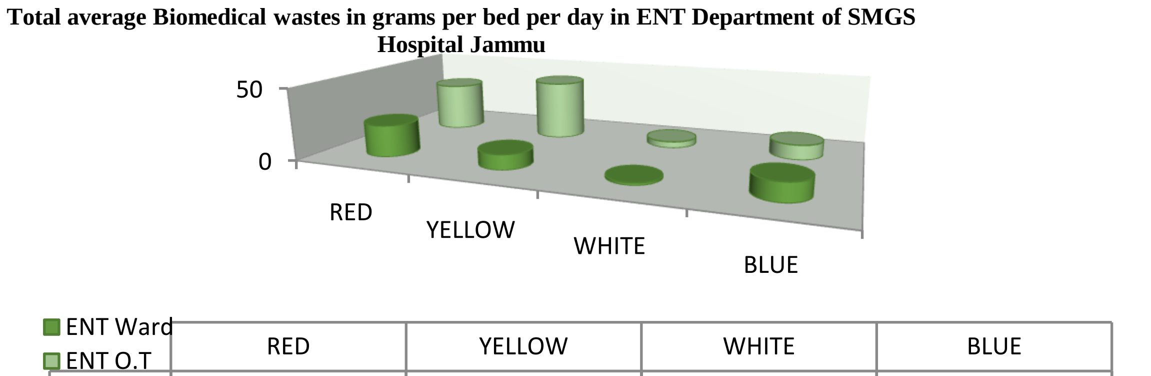
iv) Shree Maharaja Gulab Singh (SMGS) Hospital, Shalimar, Jammu:

The 750 bed SMGS hospital is located in Jammu. In their study of the biological waste disposal at the SMGS Hospital in Jammu, Rani and Rampal (2019) found that each bed produces a mean of 116.37g of garbage per day. Nonetheless, the maximum average biomedical waste generated in Gynaecology and Obstetrics on per bed per day bases was 315.61g, in ENT wards it was 68.34g, in Paediatric wards its amount was 37.28g and in Dermatology wards it was 44.27g on per bed per day bases respectively. The average red, yellow, white and blue biomedical waste (Per bed per day) produced in different departments of Hospital is presented in Fig. 3, 4, and 5 respectively.



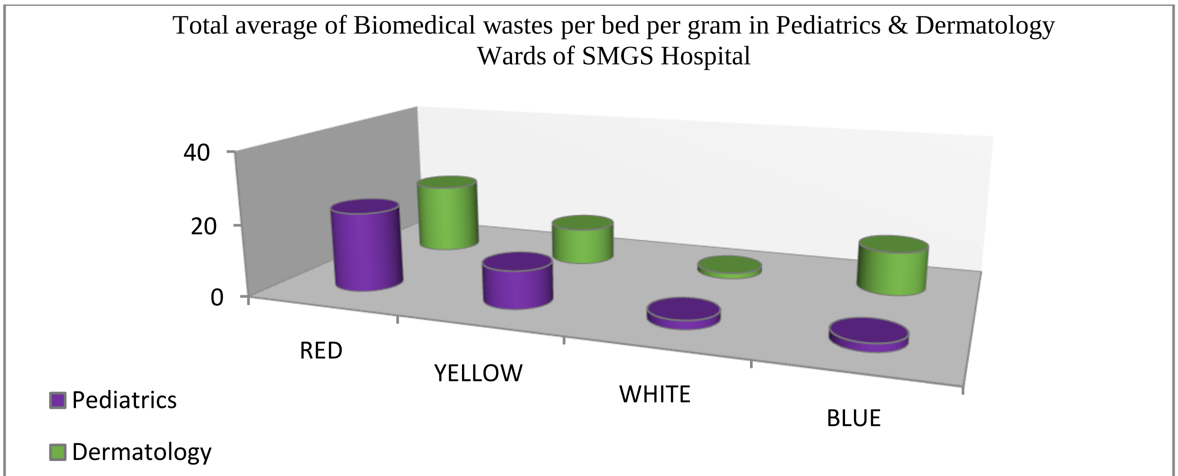
	RED	YELLOW	WHITE	BLUE
Labour room	32.5	787.3	3.58	17.2

Fig 3: Average Biomedical waste (Per bed per day) in Gynecology and Obstetrics Dept. of Shree Maharaja Gulab Singh Hospital (SMGS), Jammu



	RED	YELLOW	WHITE	BLUE
ENT Ward	22	10.5	1.72	12.6
ENT O.T	33.8	41.25	4.48	10.35

Fig 4: Average Biomedical waste (Per bed per day) in ENT Dept. of SMGS Hospital Jammu



	RED	YELLOW	WHITE	BLUE
Pediatrics	22	10.5	2.48	2.3
Dermatology	19.9	10.5	1.72	12.15

Fig 5: Average Biomedical waste (Per bed per day) in Pediatrics& Dermatology Dept. of SMGS Hospital Jammu

K) The problem of medical waste in India

a) As per the WHO report, 2017:72 percent of India's hospitals do not segregate their waste (Sebastian and Louis., 2021)

b) Only half of the approved Common Bio-medical trash treatment and management facility ensures daily waste collection (CBWTF).

c) In India, 70% of the medical waste produced is processed in incinerators, while 30% is either unlawfully discarded or seen as regular rubbish on the highways. (Pattnaik and Reddy, 2010)

d) According to the CPCB, out of 2.7 lakhmedical centers, only 1.1 lakh had complied with the 2016 BMWM and Solid Waste rules.

e) Lack of funding is one of the most significant issues that governmental hospitals and small medical centers encounter.

L) Need for Medical waste disposal

a) To reduce the possibility of injury to medical professionals, the public, and the ecosystem.

b) To decrease the production of garbage.

c) To guarantee waste segregation.

d) Establishing appropriate garbage collection stations in medical specialties and healthcare units.

e) Establishing an appropriate internal control transportation route

f) Attempting to recover as much waste as feasible

g) To collect the waste in an environmentally and health-conscious manner.

M) The Biomedical Waste Management and Handling Rules, 1998 of India outline a number of measures that go into managing medical waste, including:

1. Survey of Medical Waste

a) Differentiate the waste categories.

b) Quantity of the waste generated

c) Determine the point of generation

d) Determine the level of generation

2. Segregation, Collection, Storage & Transportation of Medical Waste

a) Segregation means the basic isolation of several waste types generated at the source.

b) Appropriate bio-medical waste management can be achieved alone through effective segregation.

c) The BMW needs to be separated in line with requirements outlined in Schedule 1 of the Medical Waste Rules of 1998.

d) Waste storage refers to garbage storage within wards or waste-collecting stations within divisions.

e) No unprocessed hospital waste should be kept for over a period of 48 hours.

f) For transportation of BMW, there should be a separate hallway and elevator to move waste in a hospital.

g) Regular trash is dumped at municipal landfills.

h) Carriage needs to be done in a leak-proof container, and a sanitary inspector needs to watch out for that.

N) Categorization of waste

According to India's 1998, Biomedical Waste Management and Handling Rules, Schedule I, Rule 5 there are 10 types of medical waste for which there are different removal and treatment plans as per WHO (2014) (table3).

Table 3: Bio medical waste categorization

Option	Waste type	Treatment and management
Category- 1	Human Anatomical Waste	Burning/underground burying
Category- 2	Animal Waste	Burning/underground burying
Category -3	Microbiology and Biotechnology	Municipal sterilizing, microwaving, and burning
Category -4	Waste Sharps	Purification, chemical treatment, thermal treatment, microwaving, and dismembering

Category -5	Discarded Medicines and Cytotoxic agents	Burning / destroying and drugs dumping in secured landfills
Category -6	Garbage, sewage etc.	Burning, autoclaving/ microwaving
Category -7	Garbage, sewage etc.	Disinfections chemical and thermal treatment, sterilizing, and destruction.
Category -8	Liquid Waste	Disinfection by chemical treatment and disposal into drainage
Category -9	Ash produced by burning	Local Landfill disposal
Category -10	Chemical Waste	Chemical treatment and discharges into the drainage

1. Techniques for disposal and treatment

a) Incineration

The WHO report from 2015 claims that this heat flux technique involves controlled burning of waste to convert it into gases and inert substances. Petroleum, electric, or hybrid incinerators are all possible. Three types of incinerators are utilised for medical waste: multi furnace, rotary kiln, and regulated air. These kinds can have both primary and secondary combustors to provide efficient burning. A multiple-hearth furnace uses its primary compartment for solid-phase burning and its secondary compartment for gas-phase burning. These are referred to as "excess air incinerators" since additional air is generated in both compartments. The rotational kiln is a cylindrical container with refractor liner that is gently sloped to facilitate mingling and circulation of the waste. It is equipped with a ventilation system. The primary solid-phase compartment is the kiln, and the secondary gaseous combustion chamber comes next. In the third type, the first chamber operates at low air levels, followed by a chamber that operates at high air levels. Particle matter in the flue gas is better controlled as a result of the primary chamber's lower oxygen levels. The first chamber releases the volatiles, while the second eliminates them. Examples include the Educator technique, which maintains negative pressure in the system and makes it easier to manage flue gases. At least 30 metres should separate the chimney from the ground. High population areas shouldn't have incinerators erected. The Bio-Medical Waste (Management and Handling) Rules recommend incinerating human anatomical waste, animal garbage, cytotoxic drugs, unused medications, and unclean waste.

b) Chemical Disinfecting

Chemical trash, solid and liquid waste, and sharps waste are all recommended for this treatment. Chemical therapy involves employing 1% hypochlorite solution or an analogous chemical agent for 30 minutes, such as phenolics, iodine, hexachlorophene, iodine-alcohol, or a formaldehyde-alcohol mixture. To improve interaction with the waste, it should be preshredded. Chemical treatment facilities are reachable in mobile vans in the United States. Depending on the variation, the garbage may first be crushed before being subjected to a 10 percent hypochlorite solution, then further crushed and dried. The refined substance is thrown away.

c) Autoclave Treatment (wet thermal treating)

This is a pressured steam sterilization method. A sufficient amount of time is spent bringing steam into direct contact with the waste in this low-heat procedure in order to disinfect it (Masorakis *et al.* 2011). These come in three different varieties as well: gravity type, pre-vacuum type, and retort type. The first type (gravity type) uses just gravity to expel air. The mechanism runs for 60 to 90 minutes at 121 degrees Celsius and 15 psi of steam pressure. The pre-vacuum autoclave system's air is removed using vacuum pumps, shortening the cycle time to 30 to 60 minutes. It operates at 132 degrees Celsius or such. Retort autoclaves are substantially more capable of handling larger volumes and operating at much greater steam pressures and temperatures. Pointed waste objects, microbiological and biotechnological waste, and filthy solid wastes should all be autoclave-treated (Mathur *et al.,* 2012). With the use of this technology, specific kinds of bio-medical waste become harmless and unrecognisable, enabling for the landfilling of the treated residue.

d) Microwave Treatment

Using a microwave instead of conventional thermal treatment systems, which heat the waste from the inside out, this method of wet thermal disinfection achieves a high level of sterility by heating the particular material from the inside out (Mastorakis *et al.,* 2011). A shredder is used to first shred the raw material. The material is then forced into a processed zone where hot steam is applied to it.

The material is then transported by a screw conveyor underneath a number of conventional microwave generators (typically 4-6), which raise the material's temperature to 95–100 degrees Celsius and uniformly disinfect it over the course of a minimum residence time of 30 minutes and a total cycle of 50 minutes. The debris is further reduced to unidentifiable pieces by a second shredder before being automatically discharged into a general/conventional garbage container (Jayasinghe and Hawboldt, 2012). As long as the microwave treatment was properly carried out, this treated garbage may be disposed of in landfills. In more recent iterations, the process control is computerised for smooth and effective control. There are several benefits to microwave technology, including the absence of hazardous air emissions, the lack of liquid discharges, the lack of chemicals, the reduction of trash volume due to shredding and moisture loss, and worker safety (due to automatic hoisting arrangement for the waste bins into the hopper so that human contact with the trash bags is not necessary). However, the current investment cost is high (Pasupathi *et al.,* 2011).Microwaves are grouped in four categories viz. Category- 3, 4, 6 and 7 (Table-3).

e) Controlled and hygienic landfilling

The following situations demand controlled and hygienic landfilling:

i Deeper disposal of human anatomic remains in accordance with Schedule I of the MoEF regulations (for rural areas and cities with fewer than five lakh inhabitants when proper burning is not possible) (Patil and Shakdar, 2001).

ii Animal faeces (under the same conditions as previously described) - Secured dump

iii Waste sterilized by autoclaving or reheated for disposal (unrecognizable) - Clean landfill

iv Hygienic dumping for incineration ash removal

v Bio-medical waste disposal in a secure landfill until suitable treatment and disposal facilities are available.

vi Sharps removal: Safe dumping. This is also possible inside hospitals, as stated below:

If a community does not have a system for disposing of sharp objects, a public healthcare facility, especially a hospital with more land, can construct a pit lined with concrete that is about 1 metres long, width, and depth and covering it with a thick slab of cement that has a steel pipe within that is 1 - 1.5 m tall and has a radius of about 25 mm. It is possible to introduce clean Sharps into this conduit. Cut the pipe when the pit is full, and then pour cement concrete into the hole. It should not be near a borehole or in a moist area.

f) Inertization:-Cement and other chemicals are added to rubbish as part of the inertiszation process before it is disposed of to lessen the likelihood that dangerous materials would leach into the groundwater or surface water (Sadia, 2020). 65 % medicinal residue, 15 % lime, 15 % cement, and 5 % water make up the average composition of the mixture. Before being moved to the proper storage place, a uniform mass is synthesised and formed into cubes or granules locally.

g) Recycling of waste: - Recycling waste is the process of using waste or by-products created for the same or other uses. Non-hazardous waste, which is primarily disposed of in landfills, makes up the majority of the waste generated by the medical industry. Recycling unwanted items like plastics, batteries, paper, glass, metals, and silver used in photography processing might help reduce the need for landfills and garbage dumps. Composting can be done with food scraps and organic waste. After treatment, fly ash from incineration can be utilised as building materials and in concrete mixtures. Water for a central heating system could be heated using the incineration's heat output (Ababneh *et al.*, 2020).

2. Advanced technologies for biomedical waste management

a. Improved autoclaves or improved steam sterilization: - Up to 90% of the volume can be lowered when steam therapy is combined with suction, inner blending or disintegration, inner tearing, drying, and compressing (Blenkharn, 2006).

b. Hydroclavetreatment: -A hydroclave is a state-of-the-art steam sterilisation device (like an autoclave). It is a double-walled tank in which the waste-filled inner chamber is heated by steam that is pumped into the outer jacket. The waste's water evaporating as steam creates the necessary steam pressure (35-36 psi). The trash is mixed and broken up inside the chamber by sturdy paddles that are steadily rotated by a powerful shaft. If there is insufficient moisture, additional steam is injected. At 132 degrees Celsius and 36 pounds per square inch of steam pressure, the appliance sterilises for 20 minutes. An entire cycle, including start-up, heat-up, sterilisation, venting and depressurization, and dehydration, takes around 50 minutes to complete. The treated material may be further shred before being disposed of. Savings of up to 85% and 70% in volume and weight are anticipated (Masorakis *et al.* 2010). Both the autoclave and the hydroclave can handle used sharp objects. Sharps are additionally divided. There are a number of benefits to this procedure, including the absence of hazardous air pollutants, the non-use of chemicals, the reduction of waste volume and weight, and others. The first hydroclave in India was built at the Tata Memorial Hospital in Mumbai in September 1999 (Pasupathi *et al.*2011).

c. Dry heat disinfection: - Itis the third method, and it involves heating without the use of steam or water. Alternatively, conduction, natural or forced convection, and/or thermal radiation are used to heat the waste (Makan and Fadili, 2021).

Dry heat sterilizing procedure: -A gate valve regulates the volume of waste introduced into the chamber following waste input, inner disintegration, and monitoring. After being dragged into the chamber, the shredded trash is exposed to hot air moving at a great velocity (at around 171°C), which is followed by unloading, consolidation, and discharge. Until being dumped in dumpsites, the dry, unidentifiable garbage is compressed and sealed.

d. Alkaline hydrolysis: is a distinct sort of synthetic method which utilizes hot salt solution to dissolve flesh, disease causing waste, cellular pieces, or animal corpses in extremely hot containers made of steel (Marimuthu *et al.*, 2021). This technology is used by the United States, and Australia (New South Wales).

e. Composting and vermicomposting: - These processes are used for decomposition of organic rich wastes, for example, carbon rich materials in hospital waste like kitchen waste and amnion (Yuvaraj *et al.*, 2021)

f. Plasma gasification: - It is a new technique for the continuous handling of hospital waste. Plasma gasifier works at exceedingly elevated temperatures without oxygen, causing degradation of wastes into H_2, CO, H_2O, and other compounds. The main product produced in plasma gasification is synthesis gas which may be changed into heat, electric current and even to liquid fuels. Metals and glass, which are inorganic components of medical waste, are transformed into a glassy aggregate. (Damodaranet al., 2010). This technology is best used by China (Wuhan).

O) Case studies

a) Syringe tide - The environmental disaster:-

Between 1987 and 1988, a large quantity of sharps/syringes together with other hospital waste, and crude rubbish degenerate on the shores of Long Island, New York City, and the Jersey Shore. The hospital waste and waste water overflow, dismissed huge numbers of annual guests, amounting the Jersey Shore alone a $1 billion loss of income in just one summer. The syringes put at risk/jeopardize organisms living in sea and constituted a great danger to human beings as well, HIV and hepatitis B were detected in the medical waste (Lum and Mitzner, 1987).

b) Biomedical waste management in hospitals in India:

In India, research was done in several medical management units. Statistical details were gathered from several hospital departments. The hospitals analysed were all considered as big hospitals, established on the aggregate of beds, with every one having additionally one hundred fifty beds. Discussions, interviews, and physical examinations were used to estimate the volumes of various waste categories. The amount of waste generated differs from one health care unit to another and were determined by the kind of healthcare service as well as the domestic commercial situations. The quantity of wastes were weighed in various health care units. Two forms of wastes are there in health care units i.e. Infectious and non-infectious wastes (Saini and Dadhwal, 1995). Table 4 shows the quantity of solid waste produced from different categories of healthcare units (Radha *et al.*, 2009).

Table 4: Quantity of waste generated by different units of hospital

Category of hospital unit	**Quantity(kg/bed/day)**
Pediatric Unit	0.56
Eye Unit	0.72
Orthopedic unit	2.12
Gynecology unit	1.56

Cardiology unit	0.73
Medicine unit	2.10
Surgery unit	1.52
OPD, burns, x-rays, canteens	2.63
General waste	1.83
Multi-specialty hospital	2.53

Hospital biological waste is thrown away with domestic solid trash. The hospitals' unprocessed wet waste is released into the drainage system. Garbage is typically gathered in open containers that have not been cleaned. Dressings, cotton, and other absorbent items are stored in plastic or other general bins. In America (USA), a few hospitals have designated their personal color-coding scheme. Pointed objects are disposed of without being disinfected or mangled, which may result in them being reutilized and thus escalating contamination. Workers in the garbage gathering and transit division of the health care unit sort reusable materials for selling. Similarly, garbage pickers separate all disposable plastic objects, which are then dumped with in health care unit premises or outward in the neighbourhood bins for onward transit and transfer with civic garbage. Later on the harmful hospital waste gets mixed with garbage, so, there great possibility that the entire quantity of waste become infectious under in unfavourable surrounding situations (Radhaet al., 2009)

c) Additional stress on hospital waste due to wide spread Corona virus disease/covid-19)

i Besides addition to hospitals, BMW has been generated from quarantined residences, isolation wards, cremation grounds, public areas, and testing/sampling labs throughout the present pandemic.

ii The amount of BMW ascribed to COVID was around 230 tonnes per day, on top of the 600 tonnes of non-COVID BMW generated each day. CPCB: 10 May 2021

iii Total garbage produced between June and December 2020: 28,747.91 tonnes and as per Sharma et al., (2020), medical waste produced per day in India between January to May in the year 2021 is shown in table 5

Table 5: Average monthly COVID-19 BMW in India in tones per day

Months of the year 2021	Bio medical waste (tones per day)
January	74
February	53
March	75
April	139

Conclusion

Handling hospital waste demands constructive understanding between both waste producers and waste managers. Health care personnel need to be trained from time to time by organizing trainings and awareness programmes. Waste management implementation should be supported, and adequate funding should be allocated on time. The finest hospital waste handling strategies strive to keep away from waste production and most importantly retrieve most of the waste, rather than dispose it off. The elementary hypothesis of acceptable hospital waste behaviour is built on the notion of 3Rs i.e. reduce, recycle, and reuse. Outdated facilities should be upgraded in order to reduce hazardous gas emissions and generate clean energy from waste. Individual participation is required. Because a high portion of waste generated in Indian hospitals (approximately eighty five percent in India) is from the common category (nontoxic and harmless), the healthcare centers definitely have to maintain continuous contact with municipal authorities in order that the aforementioned group of waste is removed on daily bases from the healthcare centers for landfill or another treatment. Collaboration with PCB to seek cost-effective and ecologically sustainable technologies for the treatment of biomedical and other harmful wastes. To look for appropriate materials to utilize as bins for biomedical waste that requires burning, autoclaving, or microwaving.

Competing Interests

Authors have declared that no competing interests exist.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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