VOLUME 8 ISSUE 2 2022

ISSN 2454-3055

INTERNATIONAL JOURNAL OF ZOOLOGICAL INVESTIGATIONS

Forum for Biological and Environmental Sciences

Published by Saran Publications, India

International Journal of Zoological Investigations Vol. 8, No. 2, 912-920 (2022)

International Journal of Zoological Investigations
Contents available at Journals Home Page: www.ijzi.net
Editor-in-Chief: Prof. Ajai Kumar Srivastav
Published by: Saran Publications, Gorakhpur, India

ISSN: 2454-3055

Biomedical Waste: Sources, Composition, Categories and Global Scenario with Reference to India- A Review

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Received: 4th November, 2022; **Accepted:** 10th December, 2022; **Published online:** 21st December, 2022

https://doi.org/10.33745/ijzi.2022.v08i02.108

Abstract: In reducing health problems and eliminating potential risks to people's health, health-care services inevitably create waste that may itself be hazardous to health. Waste produced in healthcare activities carries a higher potential for infection and injury. Therefore, safe and reliable methods for handling of medical waste are essential. Inadequate and inappropriate handling of health-care waste may have serious public health consequences and a significant impact on the environment. Effective confinement of Biomedical waste (BMW) and safe handling measures provide significant health protection. This review focuses on BMW with respect to: (1) definition; (2) sources; (3) classification; (4) sub-types of hazardous waste; (5) categories; (6) composition and (7) global scenario and status in India.

Keywords: Biomedical waste, Health care facilities, Health hazard, Infection, Sustainable management

Citation: Jawale Ratnamala S.: Biomedical waste: Sources, composition, categories and global scenario with reference to India- A review. Intern. J. Zool. Invest. 8(2): 912-920, 2022.
https://doi.org/10.33745/ijzi.2022.v08i02.108

Introduction

Waste is a material or product that is unwanted or have been discarded, rejected or abandoned. It includes materials or products that are recycled, converted to energy, or disposed (Latimer, 2015). The production of waste is an inevitable consequence that is coupled with anthropogenic activities, economic development, and urbanization (Bhatia and Paul, 2017). The waste generated consists of four major categories such as municipal solid waste (MSW), industrial waste, agricultural waste and hazardous waste (Haque *et al*., 2021).

Tiseo (2021) reported that Canada is the biggest producer of waste and produced an estimated 1.33 billion metric tons (mt) of waste per year, with 1.12 billion metric tons of this generated by industrial waste. Worldwide, top ten countries with estimated annual waste per capita (in mt) during 2019 are Canada (36.1), Bulgaria (26.7), United States (25.9), Estonia (23.5), Finland (16.6), Armenia (16.3), Sweden (16.2), Luxembourg (11.8), Ukraine (10.6) and Serbia (8.9).

Basel Convention announced that the hospital solid waste (HSW) is the second most dangerous waste after nuclear and radioactive wastes. The changing trends of human lifestyle, consumption habits, use of harmful compounds, and urban activities have affected the quantitative and qualitative characteristics of MSW (Ozeler *et al*., 2006; Ansari *et al*., 2019). Zhang *et al*. (2010) stated that the hazardous and complex wastes in MSW such as materials generated in hospitals is the major threat to the public health and the environment.

The world is generating more and more waste and hospitals and health centres are no exception (ICRC, 2011). Hospitals are a place where patients' problems are diagnosed, analyzed and treated. During these activities generation of solid waste is unavoidable (Altin *et al*., 2003). Health care facilities (HCF) generate many types of liquid, solid and gaseous waste in large quantities which may cause negative impact on workers in health institutions, society and public health if not properly managed (Aymen and Bajari, 2018).

Hospitals and nursing homes generate increasing amount of BMW in an unscientific manner. The garbage and filth generated in hospitals causes adverse effects on the body of health care workers, public and flora and fauna of the area (Javid and Sharma, 2019). Kanyal *et al*. (2021) stated that hospitals produce waste, which is increasing over the years in its amount and type. Javid and Sharma (2019) noted that BMW, which includes waste from hospitals, nursing homes, medical research centres, clinics, and medical shops, is variable in characteristic and composition. BMW is hazardous to the exposed population if not managed properly.

In the present study, an overview of BMW with respect to definition, sources, classification, sub-types of hazardous waste, categories, composition and global scenario with reference to India is considered.

Definition of Biomedical waste:

Waste generated in hospitals is referred to as BMW (Chandrappa and Das, 2012), or medical waste (Aymen and Bajari, 2018) or health-care waste (HCW) (Ansari *et al*., 2019) (Table 1).

Schedule I of the BMW Rule comprises of human anatomical waste, animal waste, microbiology and biotechnology wastes, waste sharps, discarded medicines and cytotoxic drugs, soiled waste, solid waste (wastes generated from disposable items other than the waste sharps), liquid waste, incineration ash and chemical waste (Chandrappa and Das, 2012).

The present paper provides an overview on the major issues and debate, gaps in knowledge and way to bridge the gap related to BMW with respect to definition, sources, classification, sub-types of hazardous waste, categories, composition and global scenario with reference to India.

Review method adopted was based on the scientific literature survey from databases such as Medline, Embase, PubMed Central, ScienceDirect, Proquest and Medscape. The keywords used for reviewing the literature were the ones that refer to the issues concerning the BMW. For literature search, keyword "biomedical waste" is combined with: sources, composition, categories and global scenario with reference to India.

Sources of biomedical waste:

The source of BMW is the place or the location at which BMW has been generated. The sources of BMW can be classed as major or minor according to the quantities produced.

Major sources of biomedical waste:

Major sources generates more amount of BMW (Table 2) and there is regular generation of BMW in the major source which includes government hospitals, private hospitals, nursing home and dispensaries.

Minor and scattered sources of biomedical waste:

Minor and scattered sources produce BMW (Table 3) in categories similar to hospital waste but with characteristic composition such as:

Table 1: Selected definitions of BMW

Reference	Definition of e-waste
Biomedical Waste (Management and Handling) Rules, 1998 of India	Any waste, which is generated during the diagnosis, treatment or immunisation of human beings or animals or in research activities pertaining thereto or in the production or testing of biologicals and including categories mentioned in Schedule I.
Regulation 1(2) of The Controlled Waste Regulations 1992 (SI1992/588) of United Kingdom	Any waste which consists wholly or partly of human or animal tissue, blood, other body fluids, excretion, drugs or other pharmaceutical products, swabs or dressings, or syringes, needles or other sharp instruments, being waste which unless rendered safe may prove hazardous to any person coming into contact with it, and any other waste arising from medical, nursing, dental, veterinary, pharmaceutical.
	Any similar practice, investigation treatment, care, teaching or research, or the collection of blood for transfusion, being waste which may cause infection to any person coming into contact with it.
Environmental Protection Agency (EPA) and Center for Disease Control and Prevention (CDC, 2003) Odumosu (2015)	Hospital waste refers to all waste, biological or non-biological, that is discarded and not intended for further use.
World Health Organization (WHO) (2014)	Waste generated within health-care facilities, research centres and laboratories related to medical procedures along with waste originating from minor and scattered sources, including waste produced in the course of health care undertaken in the home (e.g. home dialysis, self-administration of insulin, recuperative care).

Table 2: Major sources of BMW (Source: Odumosu, 2015)

Sources	Sub-sources
Hospitals	• Government hospitals and Private hospitals • Nursing homes and Dispensaries
Other health-care establishments	• Emergency medical care services • Health-care centres and dispensaries • Obstetric and maternity clinics • Outpatient clinics, Dialysis centres • First-aid posts and sick bays • Long-term health-care establishments • Transfusion centres • Military medical services
Related laboratories and research centres	• Medical and biomedical laboratories • Biotechnology laboratories and institutions • Medical research centres
Mortuary and autopsy centres, Animal research and testing	
Blood banks and blood collection services, Nursing homes for the elderly	
Acupuncturist, Paramedic and ambulance services	

Table 3: Minor and scattered sources of BMW (Source: Odumosu, 2015)

Sources	Sub-sources
Small health-care establishments	• Physicians' offices, Dental clinics, • Acupuncturists, Chiropractors
Specialized health-care establishments and institutions with low waste generation	• Convalescent nursing homes • Psychiatric hospitals • Disabled persons' institutions
Non-health activities involving intravenous or subcutaneous interventions	• Cosmetic ear-piercing, • Tattoo parlours • Illicit drug users, • Institutions for disabled persons
Funeral services, Ambulance services, Home treatment,	
Chiropractors, Psychiatric hospitals	

- Health care provided by nurses: Infectious waste and many sharps.
- Physician's offices: Infectious waste and some sharps.
- Dental clinics and dentist's offices: Infectious waste and sharps, and wastes with high heavy-metal content.
- Home health care (dialysis, insulin injections): Infectious waste and *Classification of biomedical waste*:
- Odumosu (2015) documented that waste is categorized based on the risk it holds. Based on their form or state, sources and potential risk to the public, BMW is classified into "non-hazardous" and "hazardous" waste (WHO, 2014).

Non-hazardous biomedical waste:

- Also called "general health-care waste".
- Accounts 75% - 90% of the total BMW produced by health-care providers.
- Properties are similar with the domestic waste.
- Comes from the administrative, kitchen and housekeeping functions at health-care facilities.
- Also include packaging waste and waste generated during maintenance of health-care premises.
- Non-risky in nature.

Hazardous biomedical waste:

- Potentially hazardous and may pose a variety of environmental and health risks.
- Accounts about 10% - 25% of the total BMW.
- Also called "health-care risk waste".
- Two types: Infectious waste and other hazardous or with toxicity characteristics.

Infectious waste:

- Accounts about 15% - 18% of the total hazardous BMW.
- Consists of non-sharps, sharps, plastic disposables and liquid wastes.

Hazardous waste with toxicity characteristics:

- Accounts about 5% - 7% of the total hazardous BMW.
- Consists of radioactive waste, discarded glass, pressurized containers, chemical waste, cytotoxic waste and incinerator ash.

Sub-types of hazardous health-care waste:

Table 4: Sub-types of hazardous health-care waste (Source: WHO, 2014)

Type of waste	Description	Examples
Chemical waste	Waste containing chemical substances	• Laboratory reagents, Film developer. • Expired disinfectants or that are no longer needed. • Solvents.
Cytotoxic waste	Waste containing substances with genotoxic properties	• Waste containing cytostatic drugs - used in cancer therapy. • Genotoxic chemicals.
Infectious waste	Waste suspected to contain pathogens and that poses a risk of disease transmission	• Waste contaminated with blood and other body fluids. • Laboratory cultures and microbiological stocks. • Waste including excreta. • Materials that have been in contact with patients infected with highly infectious diseases in isolation wards.
Pathological waste	Human tissues or fluids	• Human tissues, organs or fluids. • Body parts and fetuses. • Unused blood products.
Pharmaceutical waste	Waste containing pharmaceuticals	• Expires pharmaceuticals or no longer needed. • Items contaminated by or containing pharmaceuticals.
Radioactive waste	Waste containing radioactive substances	• Unused liquids from radiotherapy or laboratory research. • Contaminated glassware, packages or absorbent paper. • Urine and excreta from patients treated or tested with unsealed radionuclides; sealed sources.
Sharps waste	Used or unused sharps	• Hypodermic, intravenous or other needles. • Auto-disable syringes. • Syringes with attached needles. • Infusion sets and scalpels. • Pipettes, knives, blades and broken glass.
Wastes with high content of heavy metals	Wastes with high content of heavy metals	• Batteries, broken thermometers. • Blood pressure gauges. • Pressurized containers. • Gas cylinders, gas cartridges. • Aerosol cans.

Categories of biomedical waste:

Table 5: Categories of BMW (Source: Hasan *et al*., 2015).

Waste category	Type of waste	Sources/Examples
Category No. 1	Human anatomical waste	Human tissues, organs, body parts
Category No. 2	Animal waste	Animal tissues, organs, body parts, carcasses, fluids, blood, experimental animals, waste generated by veterinary hospitals, colleges, discharge from hospitals, animal houses

Category No. 3	Microbiology and bio-technology waste	Laboratory cultures, stocks or specimens of micro-organisms, live or attenuated vaccines, human and animal cell culture and infectious agents from research and industrial laboratories, wastes from production of biologicals, toxins, dishes and devices used for transfer of cultures
Category No. 4	Waste sharps	Needles, scalpel, knives, blades, razors, scalpels, X-Acto knives, scissors, infusion sets, bone chips, saws, nails and broken glass.
Category No. 5	Discarded medicines and cytotoxic drugs	Wastes comprising of outdated, contaminated and discarded medicines. Anti-neoplasic and cytotoxic drugs, genotoxic chemicals.
Category No. 6	Solid waste	Items contaminated with blood and body fluids, including cotton, dressings, plaster casts, linen, beddings, etc
Category No. 7	Solid waste	Wastes from disposable items other than the waste sharps such as tubings, catheters, intravenous sets etc.
Category No. 8	Liquid waste	Wastes from laboratory and washing, cleaning, housekeeping and disinfecting activities
Category No. 9	Incineration ash	Ash from incineration of any biomedical waste
Category No. 10	Chemical waste	Film developer, laboratory chemicals, solvents, expired and no longer needed disinfectants, scrap amalgam, elemental mercury, undeveloped X-ray film, used X-ray fixer, condemned lead aprons lead foil and cleaning agents.

Composition of biomedical waste:

Table 6: Composition of biomedical waste

Reference	Composition of biomedical waste
Patil and Shekdar (2001)	• Infectious waste (30–35%) • Plastics (7–10%), Disposable syringes (0.3–0.5%) • Glass (3–5%), Other general wastes with food (40–45%)
Altin *et al*. (2003)	• Paper (16%), Textiles (10.2%), Cardboard (4%) • Plastics (41,2%), Food waste (17%)
Babu *et al*. (2009)	• Sharps (needles or scalpel blades) • Pathological wastes (anatomical body parts, microbiology cultures and blood samples) • Infectious wastes (body fluids, dressing, catheters and I.V. lines, radioactive wastes, mercury containing instruments and polyvinyl chloride (PVC) plastics)
Rodriguez (2013)	• Sharps, non-sharps, blood, body parts • Chemicals, pharmaceuticals, medical tools • Radioactive substances
Gawad *et al*. (2016)	• Foods (27%), plastic (22%), paper/cardboard (22%) • Glass (11%), metals (10%) and others 8%

Haque *et al*. (2021)	• Hazardous waste • Single-use plastic items • Personal Protective Equipment (PPEs) - face masks, hand gloves, rubber boots and white gowns, hand sanitizers • Medically used gears - syringes, test kits, plastic containers, bandages, tissues, etc.

Global scenario of biomedical waste generation:

The numbers of hospitals and nursing homes are increasing with the growth of the human population and subsequently generates large quantity of waste. The waste generated from different sources varies regionally, internationally and among hospital networks (Joshi, 2013; Javid and Sharma, 2019).

Altin *et al*. (2003) pointed out that in four hospitals in Sivas, Turkey, the daily waste generation rate was 985 kg/day and is projected to be 1267 kg/day in 2015. Babu *et al*. (2009) recorded quantity of BMW generated in kg/bed/day in various countries -- U.K. 2.5, U.S.A. 4.5, France 2.5, Spain 3.0 and India 1.5. The quantum of waste produced in a healthcare establishment depends on the income of the country, type of hospital, region, management practices, and types of patients (Himabindu *et al*., 2015).

Lakbala and Mahesh (2011) recorded that in the hospitals of Shiraz city of Iran, the average of waste generation rate was estimated to be 3.54 kg/bed/day which included 1.60 kg/bed/day non-infectious waste (general), 1.90 kg/bed/day infectious waste and 0.05 kg/bed/day sharp waste. Chandrappa and Das (2012) noted that the typical quantity of medical waste is 1.5 to 2.0 kg/bed/d for France, Belgium and England, 1.1 kg/bed/d for the USA, 0.01 to 0.2 kg/bed/d for Middle East, Asia and Africa, and 0.25 to 1.13 kg/bed/d for Latin America.

In hospitals of Sana'a city, Yemen, the daily average waste generated was 5615 kg/day of which 26% of the total waste was hazardous while 74% was a general (non-hazardous) waste. The average rate of the total waste generation was 3 kg/patient/day and 2.5 kg/bed/day (Gawad *et al*., 2016). According to Aymen and Bajari (2018), in Jordan, medical waste generation rate was estimate to be 2.66 kg/bed/day that is the total generation rate is 35 ton/day. The daily rate of generation of type two medical wastes was estimated to be 7 tons/days.

Ansari *et al*. (2019) showed that the highest and lowest reported hospital solid waste management (HSWM) belonged to Ethiopia (6.03) and India (0.24) kg/bed/day respectively. Haque *et al*. (2021) reported that China and other countries have seen a massive increase in the hazardous waste generation (about 600% increase in Hubei province) amount. High-income countries generate on average up to 0.5 kg of hazardous waste per hospital bed per day; while low-income countries generate on average 0.2 kg (WHO, 2021).

Present Status of biomedical waste in India:

Patil and Shekdar (2001) observed that in India, the annual generation of waste is about 0.33 million tonnes and the waste generation rate ranges between 0.5 and 2.0 kg/bed/day. In India, the waste generation rate ranges between 0.5 and 2.0 kg/bed/day (Babu *et al*., 2009). According to Mohankumar and Kottaiveeran (2011), India has 6 lakh hospital beds in 23,000 primary health centers and 15,000 private and small hospitals. Subrammani *et al*. (2014) noted that, in India, about 420,461 kg of BMW is generated per day, in which only 240,682 kg of waste per day is treated.

Bhatia and Paul (2017) noted that according to WHO Report (2017); in India, total quantity of BMW generated is 495.30 tonnes /day. Average per bed per day BMW generation is 0.277 kg/day. Das *et al*. (2020) concluded that In India, the annual growth rate of BMW is 7% with a projected

estimate up to 775.5 metric tons/day by 2022. Kanyal *et al*. (2021), recorded that India approximately generates 2 kg/bed/day of BMW.

According to Rajak *et al*. (2021), India has generated over 32,996 mt of COVID-19 waste between June and December 2020, of which Maharashtra (789.99 mt/month) is highest average generator of COVID-19 waste, followed by Kerala (459.86 mt/month), Gujarat (434.87 mt/month), Tamil Nadu (427.23 mt/month), Uttar Pradesh (371.39 mt/month), Delhi (358.83 mt/month) and West Bengal (303.15 mt/month). Bhalerao (2021) reported that India generated 56,898.4 tonnes of Covid-19 BMW between June 2020 and June 2021. Maharashtra (8,317 tonnes) topped in BMW generation and was followed by Kerala (6,442), Gujarat (5,004), Tamil Nadu (4,835), Delhi (3,995), Uttar Pradesh (3,881) and Karnataka (3,133).

Conclusion

Generation of hazardous waste from hospital and health-care facilities is rising and has been estimated to be more than double within next 10 to 15 years time. Management of BMW is an essential component of health facilities and it must be treated and disposed on priority basis. It must be understood and addressed by everyone working in health services. Environmental awareness and consciousness about BMW is taking roots in health sector and general public. New innovative technologies should be developed for sustainable management of BMW for environmental protection and to minimize health risk to human.

Acknowledgements

Encouragement and support provided by Principal, Veer Wajekar Arts, Science and Commerce College, Phunde, Uran, Raigad, Navi Mumbai, Maharashtra, India is gratefully acknowledged. Thanks are due to the Head, Department of Zoology and Faculty members for healthy cooperation and fruitful discussion on the present study. Their comments and suggestions have been critical in understanding the issue.

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