

## CHAPTER 2

### LITERATURE REVIEW

#### **2.1 Healthcare waste**

Healthcare waste management is always an important topic of consideration for every country. However, more attention should be given to such a crucial issue in various countries. A serious problem is a need for waste management strategies, firm policies, adequate knowledge with awareness, strict regulation, and sufficient funds. (Khan *et al.*, 2019). The International trade agreements must escalate the economic benefits, but they are not suitable for health (David Birnbaum, 2016). The amount of waste generation in India varies from 0.5 to 2 kg per bed and per day, and it counts to 0.33 million per year; it is an enormous amount of waste to be controlled judiciously (Patil *et al.*, 2001). More than six lakhs of hospital beds in India, over twenty-three thousand Health Centers, and registered nursing homes. Landfill location selection for healthcare waste disposal is vital because Improper management of healthcare waste forces the urban community and water resources at risk, which can bring up many social and environmental costs for municipalities (Torkayesh *et al.*, 2021, Yazdani *et al.*, 2020). Some hospitals and dispensaries need to be registered, and many health centers are involved at every corner of urban and semi-urban areas (Swain *et al.*, 2017). In the case of quality management in hospitals, leadership plays a crucial role (Babu *et al.*, 2020). An increase in population also contributes to the high chance of increasing diseases. The usual disposal and treatment techniques used in developing countries are open dumping and improperly designed landfills with health hazards to humans and society. A significant challenge is the lack of awareness and general alertness (Mmerekhi *et al.*, 2017). An intelligent healthcare waste disposal system is one criterion for managing healthcare waste and contains circular economy benefits (Chauhan *et al.*, 2021).

#### **2.2 HCWM in Various Countries**

After the first act, China paid less attention to waste management: waste management acts 380. According to this act, centralized waste removal is obligatory (Yong *et al.*, 2009). Proper waste segregation is unavoidable, and if there is a failure in parting, it will be highlighted by the Healthcare waste pointers (Santos *et al.*, 2018). If the workers are not adequately trained, they will not understand the exercise code's prominence, and there is always a risk of life to workers, patients, and other people (Mbongwe *et al.*, 2008). During COVID-19 and Post COVID situation, disposal of healthcare waste has become crucial. In a case study in the Tamil Nādu state of India, various disposal methods are compared, and incineration is the best method for the current scenario. Still, it also has destructive environmental impacts (Manupati *et al.*, 2021). The policy framework to target political, legal, and environmental issues must be the main focus of worldwide governments and health officials to ensure cleaner production in healthcare services (Thakur *et al.*, 2021).

A similar study was performed in Ghanaian hospitals about healthcare waste management. The results prove that healthcare professionals in private hospitals have more awareness about healthcare waste, and the disposal of materials available is high in non-government hospitals compared to government and semi-government (Stephen *et al.*, 2020). Patient safety is also a concern because the patient is most likely to be in the toxic environment of the waste. So, hospital staff must be aware (Ferrer *et al.*, 2018, Gupta *et al.*, 2021). A case study has been performed in Greece to know patient satisfaction. The results show that there is a high satisfaction for medical and nursing services but a low level of satisfaction for administrative services in the hospital related to improving the efficiency of the healthcare system. This way, administrative services must be enhanced to strengthen healthcare waste management (Drosos *et al.*, 2018).

Many countries have already imposed strict regulations on healthcare waste disposal. However, various barriers and problems still need to be solved, restricting the adequate disposal of healthcare waste. The Healthcare sector works in multidimensions like safety, care, quality, etc., and an excellent organizational

structure helps improve employee relationships. A good relationship helps organize hospital tasks, just as healthcare waste management. (Rahul *et al.*, 2021). In India there is inequality in access to healthcare services because of unequal resource allocation, insufficient infrastructure, and the high cost of health services (Ashutosh *et al.*, 2019). Healthcare waste management needs to be addressed in the circular economy transition due to its single-use mindset, which is dangerous and toxic (Ranjbari *et al.*, 2022). The Proper disposal of healthcare waste is challenging, so healthcare waste management is also receiving considerable attention after implementing Biomedical waste management and handling rules in 1998.

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### **2.3 Healthcare waste generation and Management Challenges:**

Medical wastes are regarded as a sub-group of hospital wastes resulting from health services and have the potential risk of infection (Prüss *et al.*, 2014). Medical wastes are generated daily by various hospitals,

clinics, research centers, pharmaceutical companies, pathologies, diagnostics, and other health care centers. According to WHO, 10%–20% of medical waste belongs to hazardous and infectious groups (Mohamed et al., 2009). Medical wastes are further divided into four categories: infectious wastes, sharp wastes, chemical and pharmaceutical wastes, and ordinary wastes (Tabrizi et al.,2018). Medical waste includes disposable syringes, bandages, cotton swabs, body fluids, human excreta, anatomical waste, applications, expired medicines, and other chemical and biological waste types. Medical wastes are most infectious and can spread diseases and different types of viral and bacterial infections among humans and animals if not appropriately managed scientifically. Evidence suggests that some hazardous agents, such as HIV, Hepatitis B, and Hepatitis C, are transferrable through medical wastes. Thus, hospital wastes may play a significant role in the pathogenesis, transmission of infection, and environmental contamination (Chaerul et al.,2008). Therefore, hospital wastes must be managed with extra precaution.

In the past, medical waste was often mixed with household waste and disposed of in municipal solid waste landfills (Jang et al.,2006). This may contaminate water bodies and adversely affect the health of humans and animals living in the surrounding areas. A typical hospital waste consists of bandages, linen, and other infectious waste (30-35%), plastics (7-10%), disposable syringes (0.3-0.5%), glass (3-5%), and other general wastes including food (40-45%) (Patil & Shekdar,2001). Increased use of face masks, hand gloves, and personal protective equipment (PPE) kits resulted in a sudden surge in medical waste during the outbreak of the COVID-19 pandemic (Yang et al.,2021). Irresponsible disposal of these protective gears can result in health hazards such as the transmission of infection. There is increased awareness about the importance of proper disposal of hospital waste in the post-COVID world (Sangkham, 2020).

The existing academic discourse lists various approaches for protecting public health through effective medical waste management. These methods can be summarized in a waste-management hierarchy, where the most desirable process occupies the top slot while the least desirable one rests at the base (Shaikh,

2017). ‘Desirability’ is defined in terms of the overall benefit of each method from their impacts on the environment, protection of public health, financial affordability, and social acceptability. Different waste management interventions must be analyzed for superiority based on these multiple criteria. This type of evaluation is termed health technology assessment (HTA) in public health parlance (Mishra & Singh,2022). The typical hospital waste-management hierarchy is depicted in Figure 2.1

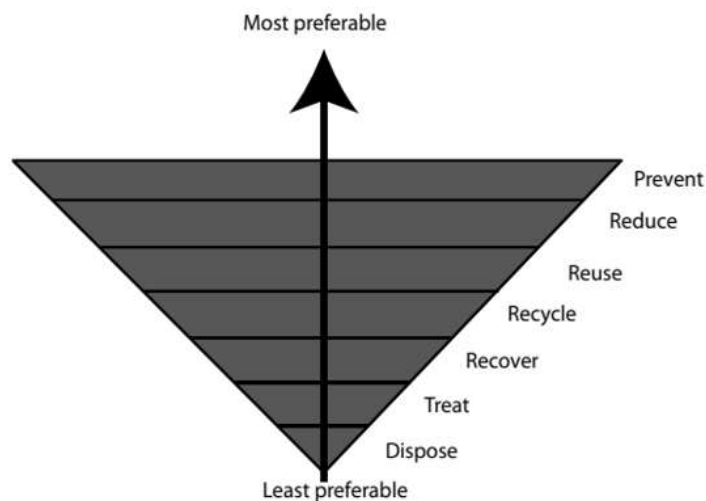


Figure 2.1: Hospital Waste Management Hierarchy (Source; Authors)

The hospital waste management (HWM) hierarchy is principally derived from the “3-Rs” concept of sustainable use of resources, where the three Rs stands for reduce, reuse, and recycle (Wichai-Utcha & Chavalparit, 2019). The idea emphasizes avoiding or recovering as much waste as possible in or around a healthcare facility rather than disposing of it by burning or burying it. The idea is to tackle waste “at source” rather than adopting “end-of-pipe” solutions. (Bao et al.,2021). A typical hospital waste management cycle involves separating, packaging, collecting, storing, transporting, and sterilizing wastes. A usual hospital waste management (HWM) cycle is depicted in Figure 2.2

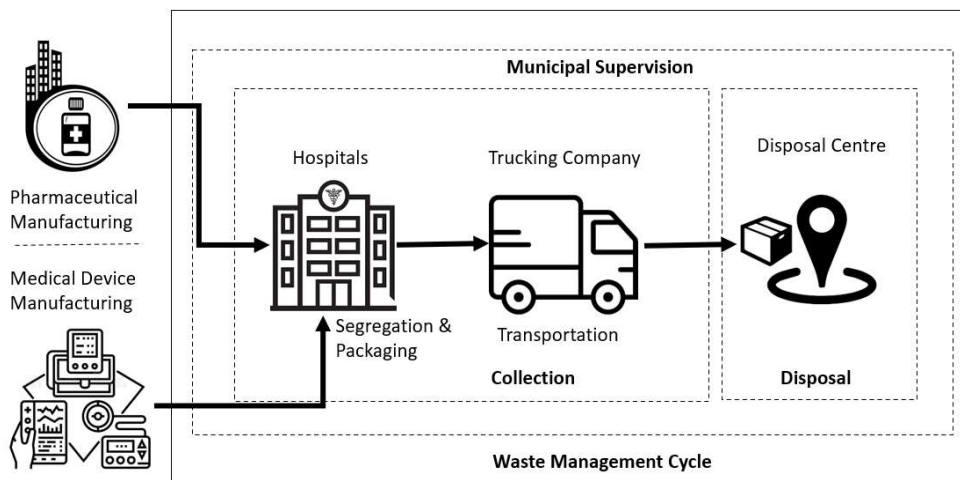


Figure 2.2: Hospital Waste Management Cycle (Source: Authors)

In resource-constrained countries such as India, healthcare expenditure is insufficiently low and is less than 2% of the gross domestic product (GDP) (Jakovljevic et al.,2020). Moreover, Varanasi falls under the less developed state of India, where healthcare infrastructure is further deficient. Unplanned urbanization coupled with increased consumerism is linked to increases in the per capita generation of waste (Goldman et al.,2021). Furthermore, rapid urbanization and population growth create larger population centers, making the collection of all waste and procuring land for treatment and disposal more and more difficult.

Waste management can consume a considerable portion of the budget of municipal bodies. On average, it accounts for 20% of low-income countries, 10% of middle-income countries, and 4% of high-income countries (4%) (WHO,2022). Budget resources devoted to waste management can be much higher in certain cities depending on population density and urban infrastructure availability. Expensive waste management usually competes for funding with other priorities such as clean water, education, and health care. Local authorities often administer waste management with limited resources and capacity for planning, contract management, and operational monitoring. The amount of private investment in hospital waste management

is alarmingly low because of the requirement of massive financial investment and limited opportunity to gain returns (dos Santos et al.,2020).

### 2.3.1 Integrated Healthcare Solid Waste Management:

The local governance bodies can resort to Integrated Solid Waste Management (ISWM), a recent practical approach to managing the growing challenge of Municipal Solid Waste (MSW). This method integrates all the system components (i.e., transfer, treatment, recycling, and disposal of wastes) to enhance sustainable waste management while reducing operational costs (Asefi et al.,2019). ISWM utilizes the learning from domains such as operations and technology management, financial management, and public policy to achieve the sustainable waste management goal (Shekdar, 2009). Figure 2.3 depicts the framework for Integrated Solid Waste Management.

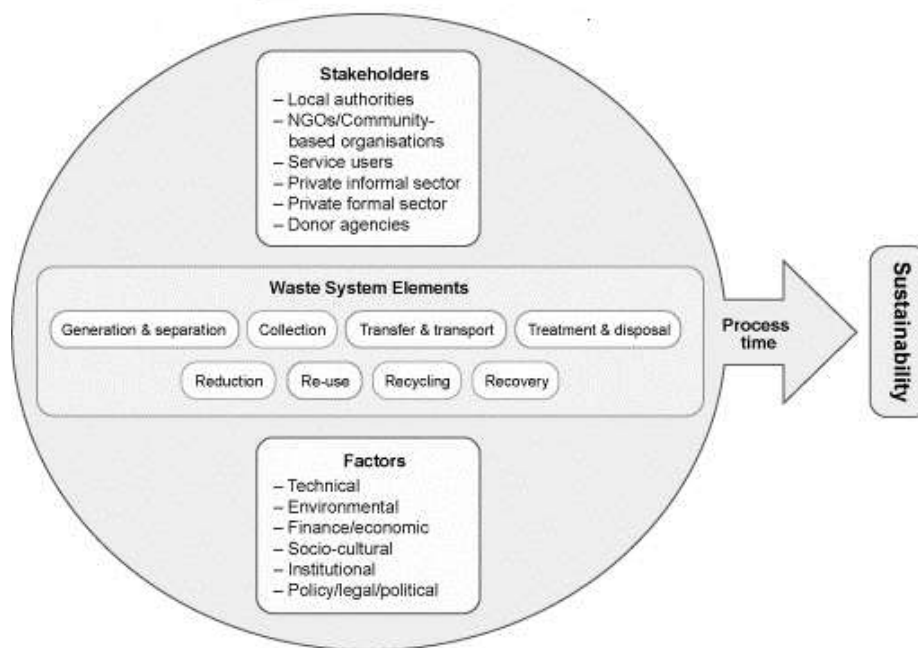


Figure 2.3: Integrated Solid Waste Management Model (Van de Klundert & Anschutz ,2001)

The concept of ISWM is based upon four basic tenets:

1. Equity: This tenet stresses that every section of society has a right to be served by a waste management system that protects their health and the environment.
2. Effectiveness: This principle means that all the waste is collected and disposed of safely.
3. Efficiency: An efficient waste management system is equal and practical while using the best resources at disposal.
4. Sustainability: A waste management effort is sustainable if appropriate to the local environment and can stay viable in the long run.

The advantages of ISWM are (1) reduction and reuse at source, (2) waste separation at source, (3) Recycling of waste, and (4) Recovery of organic waste (Tsai et al.,2020). The factors affecting the successful implementation of ISWM are (1) technical factors, (2) financial factors, (3) environmental factors, (4) Political and legal factors, and (5) Socio-cultural factors (Van de Klundert & Anschütz,2001).

Three facts about healthcare waste management can be stated from the above discussion. First, effective hospital waste management requires dedicated effort, and one shouldn't mix it with household waste management. Second, the waste management cycle should be made as efficient as possible to make it sustainable. Considering the local environment is critical to the success of an ISWM plan for hospital waste. Can managers at the helm of hospital waste projects in Varanasi take a leaf out of other cities? The following section tries to explore this suggestion.

### **2.3.2 Existing Approaches for Healthcare SWM:**

It takes careful analysis of the amount and types of waste generated to select appropriate management methods and plan for future demand. Although different municipal bodies try to optimize solid waste management, the service levels, environmental impacts, and costs vary dramatically (Hoornweg & Bhada-Tata, 2012). The traveling salesperson Problem (TSP) remains one of the most utilized methods for route planning in academic discourse. TSP is a widely used method to find the cheapest way to visit all waste

collection locations and return to disposal sites. The extension of TSP is Vehicle Routing Problem (VRP) which aims to minimize the routing costs. Since VRP is an NP-hard problem, heuristic algorithms are the most successful algorithms for finding the optimal route (Rybnytska et al.,2018). A study done in the Dutch municipality Wageningen uses VRP and tabu search to improve the routes. They further compare collection alternatives to select the best solution (Bing et al.,2014). Akbarpour et al. (2021) observe that the main problem with urban solid waste management is the cost of operations, which must be reduced. They propose a two-sub model to address this situation.

The first sub-model uses a vehicle routing problem (VRP) for routing fleets among generation waste to separation facilities. The second sub-model is designed to allocate resources from separation facilities to a set of recovery plants or landfill centers. A study in Tehran, Iran, utilizes an integrated Fleet Size and Mix-VRP framework to propose an efficient ISWM. They used the bi-objective Mixed-Integer Linear Programming (MILP) model to minimize the transportation cost in the entire waste management system and total deviation from the fair load allocation to transfer stations (Asefi et al.,2019). In their seminal work, Asgari et al. (2017) utilize a memetic algorithm for a multi-objective obnoxious waste location-routing problem. Another study in Beijing uses a multi-echelon logistics and disposal optimization model for municipal solid waste management. This linear programming model optimizes the municipal waste management system to obtain the minimum cost of operations (Schreiber & Yang, 2018). In a recent study, Yu et al. (2020) suggested a two-echelon multi-objective location routing problem model (2E-MOLRPM). They proposed an improved non-dominated sorting genetic algorithm with locally directed search. All these discussed pieces of literature focus on the efficiency of the waste management effort, while recent literature also focuses on sustainability as an essential objective. Babae & Aydın (2021), in their work, attempted to improve vehicle operations in waste management by considering environmental aspects and the possibility of outsourcing. Their study proposed a bi-objective MILP model to formulate the problem regarding the

sustainability aspect. Another study in India used a mathematical model to analyze incentive, subsidy, and reward-penalty mechanisms to improve the collection rate of recyclables and end-of-life products (Rathore & Sarmah, 2021). Moreover, to make these efforts sustainable, the logistics of these facilities need to be managed efficiently. To our knowledge, no such action has been published in the academic discourse. This case-based research attempts to fill this gap. The barriers related to healthcare waste management areas are described in Table 2.1

Table 2.1: Relevant Barriers with Description and Supporting References

<b>Number</b>	<b>Name of Barrier</b>	<b>Description of barrier</b>	<b>Supporting References</b>
<b>1(B1)</b>	Lack of Awareness	What are the Impacts of Healthcare waste on society?	C. L., & Jenkin, L. E. T. (2005), de Souza, R. M. (2018)
<b>2(B2)</b>	Lack of Training	How to handle healthcare waste?	J. N., Tripathy, S., & Panda, T. K. (2017), T. L., & Vaccari, M. (2016).
<b>3(B3)</b>	Insufficient staff working in HCWM	Less number of Staff for collection, transportation, and disposal	Delmonico, D. V. D. G., Santos, H. H. D., Pinheiro, M. A., de Castro, R., & de Souza, R. M. (2018)

<b>4(B4)</b>	Unavailability of segregation bins	Bins are not available for different types of waste.	Bdour, A., Altrabsheh, B., Hadadin, N., & Al-Shareif, M. (2007)
<b>5(B5)</b>	Lack of Top Authority's dedication towards HCWM.	There needs to be support from top management towards healthcare waste management.	Expert
<b>6(B6)</b>	No Segregation and Collection center	No Place for segregation and temporary storage	Muduli, K., & Barve, A. (2012), Swain, S., Muduli, K., Biswal, J. N., Tripathy, S., & Panda, T. K. (2017)
<b>7(B7)</b>	The incineration plant is not within the Hospital.	No Plant for proper disposal of all types of waste	Singh, A. (2019), Sarker, M. A. B., Harun-Or-Rashid, M., Hirosawa, T., Hai, M. S. B. A., Siddique, M. R. F., Sakamoto, J., & Hamajima, N. (2014)
<b>8(B8)</b>	Lack of Government	There is no support from the government to establish	

	Support and Policies	incineration plants and collection centers, and no such policies to support all these.	Expert
<b>9(B9)</b>	Lack of handling tools and precautions	No Availability of masks, gloves, and different handling tools	Aung, T. S., Luan, S., & Xu, Q. (2019), Caniato, M., Tudor, T. L., & Vaccari, M. (2016).
<b>10(B10)</b>	Reluctance to change and adoption	Not want to change their mind.	Muduli, K., & Barve, A. (2012), Swain, S., Muduli, K., Biswal, J. N., Tripathy, S., & Panda, T. K. (2017)
<b>11(B11)</b>	No coordination between the municipality, Pollution Control Board, and hospital authorities	Lack of communication between all authorities	Delmonico, D. V. D. G., Santos, H. H. D., Pinheiro, M. A., de Castro, R., & de Souza, R. M. (2018), Caniato, M., Tudor, T. L., & Vaccari, M. (2016)
<b>12(B12)</b>	Lesser Prioritization of	Not to consider Waste	Swain, S., Muduli, K.,

	Waste Management issues in policies of Health Care Units	management as a crucial part of the healthcare sector.	Biswal, J. N., Tripathy, S., & Panda, T. K. (2017)
<b>13(B13)</b>	No Strict implementation of disinfectant techniques	No Proper implementation of disinfectant techniques.	Bdour, A., Altrabsheh, B., Hadadin, N., & Al-Shareif, M. (2007), Swain, S., Muduli, K., Biswal, J. N., Tripathy, S., & Panda, T. K. (2017)
<b>14(B14)</b>	No adequate information regarding waste quantity and compositions	Adequate information regarding the quantity and types of waste is not available.	Bdour, A., Altrabsheh, B., Hadadin, N., & Al-Shareif, M. (2007), Singh, A. (2019).
<b>15(B15)</b>	Lack of Recycling Centers	Unavailability of recycling centers	Tudor, T. L., Noonan, C. L., & Jenkin, L. E. T. (2005), Muduli, K., & Barve, A. (2012), Chauhan, A., Singh, A., & Jharkharia, S. (2016)

