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Integrated Decision-Making Framework for Waste Management in COVID-19 Pandemic: An Indian Perspective

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Abstract

In terms of environmental and socioeconomic problems, the COVID-19 pandemic has resulted in a global crisis. It has changed the generation of waste and its disposal in both quantity and quality, posing fundamental challenges to policymakers in making decisions that will ensure long-term environmental management. The current study has reflected the existing difficulties of the waste management system in combating increased waste generation along with disposable PPE (Personal Protective Equipment). The risk of COVID-19 infection from contaminated waste is high, particularly in developing countries where waste management measures are sadly inadequate. As a result, the importance of developing waste management strategies would help address the environmental, social, and economic difficulties in the face of the global financial crisis through analysis of various case studies across countries. It would help to incorporate the proposed strategies across municipal bodies in developing countries to achieve sustainability and introduction of new policy frameworks in order to manage waste effectively across municipalities.

Keywords: COVID-19 Pandemic, Waste Management, Personal Protective Equipment, Sustainability

Introduction

The novel COVID virus has infected the entire planet resulting in over 197 million cases and over 4 million deaths. Infected cases in the top five countries, such as the United States (35.5 million), India (31.5 million), Brazil (19.8 million), Russia (6.2 million), and France (6 million) (Data as of July 30, 2021). In this unprecedented emergency, ensuring health of the people with current healthcare workers and providing jobs has become a top priority for many government organizations worldwide to protect public interests. The global pandemic has persistently changed the quantitative and qualitative characteristics of wastes and their treatment, posing a significant risk to sanitation workers. A considerable increase in various healthcare wastes in fighting against the novel virus, such as gloves, masks, and PPE, has only augmented the danger of viral transmission when contaminated with regular municipal solid waste (MSW).

Moreover, the pandemic resulted in stringent lockdowns, resulting in psychosocial changes among the masses, such as the desire to buy and store more food and other domestic goods, resulting in an increase in domestic waste, posing a severe challenge to waste disposal densely. The imposition of lockdowns and closing of eating establishments has increased the demand for transporting food, vegetables, and other essential daily items, resulting in the growth of various plastic wastes such as "High-Density Polyethylene", "Low-Density Polyethylene", "Polypropylene" and "Polyethylene Terephthalate". For the waste management industry, recycling and proper disposal of such plastic trash have become a mammoth job. Informal garbage pickers, particularly women, play an essential role in the manual processing of wastes in developing nations like India, particularly in the rural sector, and are thus more susceptible to infection. As a result, providing enough insurance coverage and other socioeconomic support has emerged as a major problem in the COVID dilemma. Throughout the urgent need for waste management cycle, from preparedness and readiness to response and eventually recovery from COVID, effective governance and policy framework will play an important role. Starting with source segregation,

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storage, collection, transport, treatment, and final disposal, proper healthcare waste management must follow waste management hierarchy, and 3R principles with integrated and holistic management.

According to the World Health Organization, waste management systems in health care administrations should consider intense heat treatment or chemicals in treating contaminated wastes. Virus transmission is always possible among employees engaging in waste disposal and treatment, especially in underdeveloped and developing countries. As a result, the current research has discussed several MSW mitigation pathways, such as decentralized waste administration and its integration into existing frameworks. Despite the fact that most governments made some steps to ameliorate the problem, most are still unable to manage even the waste generated by healthcare in normal times. The increase in volume of healthcare waste generated as a result of these limited technical options and capacities, imposed additional pressures on both local and national governments. The study has also acknowledged several problems that need to be addressed to realize ways and means to combat global difficulties, particularly from the perspective of developing nations. It has made recommendations for solid waste management strategies and a need to establish better waste management policies. It has also attempted to find new strategies related to infrastructure development in dealing with the current and future situation.

Literature Review

Countries across the globe had to incorporate various waste management strategies due to a sudden outbreak of COVID as the virus was successful in putting tremendous pressure on existing facilities of waste management. While hospitals were fully loaded with patients, most of the infected population had to quarantine themselves at their homes. It has been found that a COVID patient is capable to generate 3.4 kg of medical waste every day (ADB, 2020).

The economy of the countries played an important role in handling COVID wastes. Different countries used different strategies in their capacity to manage waste and curb virus transmission among workers:

- *China:* The epicenter of COVID, Wuhan city in China, generated almost six times the waste it generated before pandemic. The medical waste was treated in incineration plants which used to work 24/7 before the outbreak. As soon as local authorities realized an increase in medical wastes, they approached to companies which were specialized in waste management, and were successful in building treatment facilities that could handle 20 tons/day (Wei, 2020). The local authorities also deployed mobile incinerators to safely dispose the increasing number of PPEs, gloves, masks and other single use protective gears. Hospitals delegated segregation and disposal of wastes to waste handling workers. They also used chlorine solution (0.5%) for disinfection and doubled bags were used in packing of the wastes and store temporarily before final disposal.

  Autoclaving was also used for disposal of a specific kind of waste in a licensed landfill. Industrial furnaces and cement kilns were used as an alternative facility for disposing healthcare wastes. Only designated vehicles were used for the transportation of medical solid waste and data were correctly documented. To reduce the risk of illness, locations which had added the load were closed, disinfected, and separated from drivers (ADB, 2020).
- *Europe:* European Union (EU) gave certain guidelines where COVID wastes was identified as infectious waste. Incineration was used for waste disposal and wastes was stored in packed bags in restricted areas where only authorized personnel were allowed. Disinfectant was used on outer and inner surfaces in order to avoid possible transmission of the virus. (Cremonesi et al., 2020; Waste-Mangement, 2020).
- *Philippines:* It used efficient use of transportation system to collect waste and dispose them to treatment facility by having certain checkpoints to keep track of the collection vans and they also maintained a compliance report (EMB, 2020).
- *India:* In India, the Central Pollution Control Board (CPCB) of India which comes under the Ministry of Environment, Forest and Climate Change laid certain guidelines for various stakeholders. COVID-19 Hospitals are required to collect COVID waste in separate color-coded bags which are double layered. The bins must carry a special COVID mark with foot operating lid. The waste must be stored in a temporary storage room before handing over

to CBWTF (Common Biomedical Waste Treatment Facility). Waste containers, bin and trolleys were disinfected with sodium hypochlorite solution daily. Protection masks, gowns and other disposable protection gears were collected in yellow bags. The workers at CBWTF sanitized themselves and were equipped with protection gears for their safety. An application was made by CPCB for data collection and COVID waste disposal. Landfills and incineration plants were used for the COVID waste disposal.

- *Japan:* It also laid guidelines for segregation of wastes and sealing of the containers very tightly. Dedicated vans transported wastes in order to prevent scattering and spilling of wastes within a facility. Access to storage rooms was given to only authorized personnel. Clear labelling of wastes was done for infectious wastes at storage rooms.
- *Kenya:* Reusing of reusable items was done only after proper disinfection. Bags were tied when they were two-third full, and finally placed in the designated area for collection. Storage of wastes was done only in specific areas where access was restricted to only authorized personnel.

In all the above waste management strategies, medical waste requires efficient management on a regular basis with increased frequency. The collection of waste and segregation, along with unique identification tags followed by transportation and disposal needs to be done efficiently.

Protection of healthcare workers along with disinfection, and training is very essential for proper healthcare waste management (UN, 2020). Contaminated wastes from confirmed COVID-19 patients were collected with safety precautions and stored in special bags with correct labelling. Healthcare waste collectors must be fully equipped with PPE, such as boots, long-sleeved gowns, heavy-duty gloves, masks, goggles, and face shields, and they must wash their hands with sanitizer or disinfectant after disposing of the trash (WHO, 2020b).

Though many countries have different classifications for healthcare solid waste, most countries prefer WHO criteria. In order to handle healthcare waste efficiently, segregation is critical (Omar et al., 2012). As a result, if recyclable garbage is separated from other non-hazardous waste in an efficient manner, waste will be reduced greatly (Mosquera et al., 2014; Windfeld & Brooks, 2015). To separate infectious trash, carefully labelled containers with the type and weight of the waste are utilized. Following the removal of sharps and fluids, infectious waste is usually stored in plastic bags, plastic-lined cardboard boxes, or other leak-proof containers that fulfil particular performance specifications. Color-coding is used to make it easier to distinguish between different forms of garbage. In most nations, infectious trash is frequently contained in red or yellow bags. Bags of black or transparent material are used to collect general healthcare waste.

The international biohazard emblem is painted in a contrasting color on infectious waste containers. Containers for sharp kind of disposal are usually sturdy, leak-proof, break-resistant, and puncture-resistant. Secondary leak-proof containers are preferred to prevent leakage from primary containers during transportation. Appropriate efforts should be implemented to establish the optimum placement and labelling of these containers to improve segregation efficiency and avoid improper container use. In regions where both types of waste are created, it is common practice to install normal trash containers next to infectious waste containers, resulting in effective and better segregation. It's also a good idea to have a sufficient number of waste bins. In regions where several containers are located, posters with illustration schemes for correct segregation are occasionally mounted to walls; these might serve as reminders to health workers about the reasons of utilizing specific containers for specific trash.

Overall, optimising healthcare resources has the potential to reduce waste generation across the globe (Rodríguez-Pardo et al., 2020). During the COVID-19 pandemic, an effective management approach for healthcare solid waste was followed:

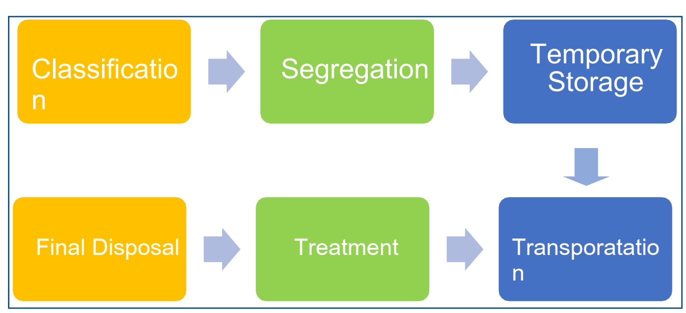

Fig. 1: Effective Waste Management Approach for Solid Healthcare Disposable Waste

A good healthcare waste management system must promulgate policies and guidelines that clearly define the roles and responsibilities of stakeholders, development of waste management strategies and evaluation of waste management alternatives. The government bodies must consider establishing a waste management organization, staffing, financial resources, plan implementation, frequent training, monitoring, assessment, and continuous improvement for long-term waste management in healthcare. To establish and implement a waste management plan, a waste management committee should be constituted. In low-income communities, a committee to control the number of infections should be formed, with one person in charge of healthcare waste management in hospitals. It is critical to assess the plan on a regular basis, and all staff members involved in healthcare waste management should be informed of the processes and changes (Bharsakade et al., 2021; Thakur, 2021).

Many developing countries faced difficulties not only in formulating policies and issuing guidelines, but also in enforcing them once they have been prepared. As a result, a national healthcare waste management policy is required to guide political decision-making and organize government efforts and resources to ensure that the plans are implemented successfully. Some of the essential things to consider while developing healthcare waste management policies are as follows:

- Identification of country needs and gaps, taking into account the national adoption of international accords and conventions, sustainable development and the environment, and hazardous waste management safety.
- Regulations governing HCW management, including waste segregation, collection, storage, handling, treatment, disposal, and transportation of various waste types, as well as duties and training requirements.
- Practical/technical instructions and manuals that augment formal implementation requirements and are directly applicable to local management and employees.
- Up-to-date distribution of roles, resources, and duties, specifying measures to be taken by authorities, healthcare professionals, and waste removal crews.
- A contingency plan to ensure the continuity of healthcare waste management services in the event of an emergency. Because resources may be limited in an emergency, contingency plans should include alternate options for employees, vehicles, infectious waste, trash accumulation, washing, disinfection, and street cleaning.

The growing volume of healthcare solid waste and the increased transmission of infection is also a serious problem. During the COVID-19 pandemic, temporary healthcare waste treatment centers and temporary transportation facilities assisted in properly managing waste and preventing transmission. Waste collected from hospitals and other healthcare facilities can be transported directly or through temporary transit centers to temporary or existing treatment facilities. The processed trash can then be transported to waste disposal facilities. Because the number of illnesses does not remain constant, waste creation is uncertain (Yu et al., 2020). As a result, temporary waste treatment and transportation may aid in the efficient management of healthcare solid waste (Yu et al., 2020). Additional healthcare waste treatment capacity, as well as alternative technologies, may aid in proper waste management. These alternative technologies, including as autoclaves and high-temperature burn incinerators, may be useful in dealing with waste during a pandemic (Ilyas et al., 2020; WHO, 2020b). The use of SF-CO2 sterilizing technology can help to lower the danger of infection from medical waste (Hossain et al., 2011). Sterilwave, an ultra-compact technology, can also be used to treat healthcare waste since it successfully kills the COVID-19 virus on-site, preventing community transmission during healthcare waste management. This method can help to reduce waste weight, and treated garbage can even be managed as standard municipal waste (Bertin-medical-Waste, 2020). A transportable treatment device could also help with the additional strain of handling healthcare waste during a pandemic.

Proper waste management in the healthcare industry may help to enhance the percentage of recyclable trash (Moreira & Gunther, 2013). Autoclaving can enhance the amount of recyclable material, which could assist reduce landfill trash during the COVID-19 epidemic (Zand & Heir, 2020a). An autoclave works on the idea of steam sterilization, which involves exposing infectious things like viruses and bacteria to direct steam at the right temperature and pressure for the right amount of time. As a result, autoclaving of healthcare solid waste can improve the efficiency of the recycling process by disinfecting the contaminated waste. During a pandemic, this recycling technique can help cut the cost of crucial safety items for healthcare. Disinfectants like sodium hypochlorite and alcohol, on the other hand, can inactivate the COVID-19 virus, which can persist for up to 9 days. As a result, disinfectants and 9-day storage of healthcare waste in a suitable containment facility can help to prevent the virus from spreading among healthcare waste handlers. Alternatively, hospital waste can be used to generate electricity.

During a pandemic, pyrolysis and combustion can be employed to create value-added goods from hospital waste. Organic waste can also be utilized to generate compost (Abylkhani et al., 2020) as well as other useful goods, such as biofuel (Velvizhi et al., 2020). Considering all of these possibilities, repurposing healthcare waste and establishing a monetization strategy during a pandemic can contribute significant value to the circular economy.

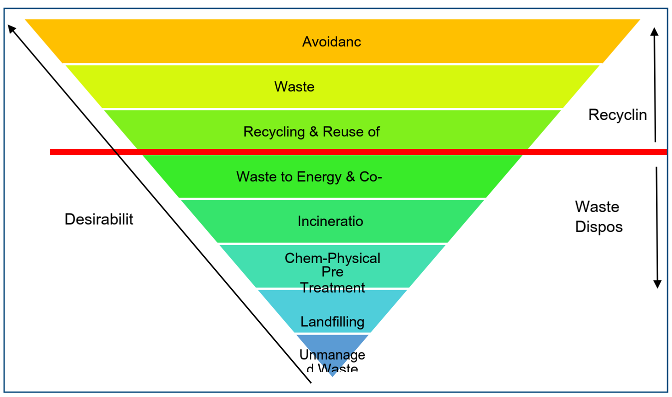

Fig. 2: Waste Management Hierarchy

Furthermore, MSW management is an essential service that must be available at all times during a pandemic. Disrupting MSW management services on a regular basis will result in further social and public health difficulties, which must be avoided. COVID-19 waste generated in homes and public places may be managed in accordance with current laws, legislation, strategies, and plans. In some nations, specific warnings and activities for such trash have been devised.

The merits and downsides of some of the most prevalent technologies for the treatment and destruction of healthcare waste, as well as a sustainable assessment of technology for choosing among them, are described here:

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- *Incineration:* It is a high-temperature, dry oxidation process that converts organic and combustible trash to inorganic, incombustible stuff and reduces waste volume and weight significantly. High-heat thermal reactions occur at temperatures ranging from 200°C to over 1000°C. Combustion, pyrolysis, and gasification are all processes that involve the chemical and physical destruction of organic material. Significant waste volume and weight reduction is an advantage using this method. No post-treatment is required for final disposal. However, there are disadvantages too, for e.g., Energy is in short supply and healthcare waste combustion creates mostly gaseous emissions, such as steam and carbon dioxide, potential carcinogen emissions, nitrogen oxides, a variety of volatile chemicals (e.g., metals, halogenic acid, incomplete combustion products), particulate matter, as well as solid remnants in the form of ashes, which must be handled with caution.
- *Autoclave:* Autoclaves have been used to sterilize medical devices for over a century, and they have recently been adapted for the treatment of infectious trash. An autoclave is made up of a metal vessel intended to endure high pressures, a sealed door, and a system of pipes and valves that allow steam to enter and exit the vessel. Soiled waste, bedding and personal items, protective equipment, clinical laboratory waste, reusable instruments, discarded sharps, and glassware are all acceptable. Low-heat thermal processes emit far less pollutants into the atmosphere than high-heat thermal processes. For autoclaves and other steam treatment devices, there are no specified pollutant emission restrictions. Waste does not need to be processed further and can be disposed of in a municipal landfill because it has been disinfected and is no longer harmful. Some countries, however, insist that the garbage be rendered unidentifiable before being shredded, however, this is dependent on the legal regulations. From lab autoclaves to massive autoclaves used in big waste treatment facilities, autoclaves are available in a variety of sizes. Volatile and semi-volatile organic compounds, chemotherapeutic waste, mercury, other hazardous chemical and radioactive waste, large and bulky bedding material, huge animal carcasses, and sealed heat-resistant containers are all ineligible for treatment. If there isn't enough ventilation near autoclaves,

odor can become a problem. Low amounts of alcohols, phenols, formaldehyde, and other organic compounds may be released into the air by poorly segregated trash.

- *Microwave Treatment:* Microwave technology is mainly a steam-based procedure that uses moist heat and steam created by microwave energy to treat patients. Microwave energy with a frequency of roughly 2,450 MHz and a wavelength of 12.24 cm rapidly heats water in the trash. Soiled wastes, bedding and personal items, protective equipment, clinical laboratory waste, reusable instruments, waste sharps, and glassware are all suitable for this container. To prevent the release of aerosols during the feed process, a fully enclosed microwave device can be positioned in an open area and used with a HEPA filter. Except in the immediate proximity of the microwave unit, the odor has been decreased. A large-scale, semicontinuous microwave device can treat around 250 kg of food every hour (3,000 tons per year). Waste does not need to be processed further and can be disposed of in a municipal landfill because it has been disinfected and is no longer harmful. Some countries, however, insist that the garbage be rendered unidentifiable before being shredded, however, this is dependent on the legal regulations. From lab autoclaves to massive autoclaves used in big waste treatment facilities, autoclaves are available in a variety of sizes. Microwaves should not be used to treat volatile and semi-volatile organic compounds, chemotherapeutic waste, mercury, other hazardous chemical waste, or radioactive waste.

Most countries have made some efforts to implement relevant technology to handle healthcare waste generated by healthcare facilities. However, there is a significant problem in controlling healthcare waste created in homes. The majority of these wastes are dumped alongside other municipal solid wastes at open dumpsites.

Methodology

The study has considered secondary data, a systematic literature review, and a review of press stories. A thorough analysis of all scientific research and credible media on the subject has been undertaken in light of the present COVID-19 pandemic. It has focused on the waste management difficulties with BMW-COVID, including the environmental and health consequences of its mismanagement, as well as the state of collection and disposal reporting. BMW generation, treatment, and disposal statistics, as well as COVID-19 positive instances, were acquired from a variety of official websites, including the "Central Pollution Control Board," "State Pollution Control Boards," and the "Ministry of Health and Family Welfare," "Ministry of Health and Family Welfare" and "Ministry of Environment, Forest and Climate Change." A detailed state-by-state study was conducted on two levels: one for 13 states/union territories (UTs) and another for six states with a significant COVID-19 impact. The overall number of positive cases was considered when deciding on a state. To capture the ongoing scientific conversation on COVID-19-related BMW, a thorough assessment of research articles was conducted. A time constraint (January 2020–April 2021), English language, a combination of search terms (Biomedical waste/Hospital waste/Medical waste/BMW India/COVID-19), and availability in Web of Science and Scopus are some of the factors used to identify scholarly papers. As a result of the recent occurrence of COVID-19, all recent developments concerning BMW have been uniformly covered by all leading dailies in India and abroad, as determined by a screening of all online news platforms, including online editions of leading English dailies, web-based news portals, and online versions of monthly magazines. In addition to circulation data, ten expert views were gathered to determine the top five daily newspapers with online editions. The review will focus on the top five newspapers based on their scores. The Hindu, The Times of India, The Hindustan Times, The Indian Express, and The New Indian Express are picked. Google was used to select news stories for evaluation. COVID-19, BMW, Medical Waste India, Biomedical Waste, Hospital Waste, and India were among the search phrases/terms utilized, with COVID-19 and India appearing in all searches with any of the other terms. The first 50 news articles were examined for each search, and the relevant information was extracted from each of the five newspaper articles.

Results and Discussion

Important takeaways from the medical waste management experience and lessons learned from different countries are as follows:

- Wuhan observed the development of a comprehensive disposal method that comprises a combination of centralized and on-site emergency medical waste disposal. This prompted the city's different emergency disposal equipment, such as incinerator plants, mobile treatment equipment, household incineration furnaces, and industrial kilns, to be used for medical waste disposal in all of the city's districts.
- Proper storage and reserved capacity of medical waste treatment facilities prevented the piling-up of waste during an emergency time like COVID-19.
- Changes in medical waste disposal technology was also observed - from decentralization to centralization, from irregular to regular management, and from mostly incineration to non-incineration disposal technologies such as autoclave steam, dry heat, chemical disinfection or microwave.
- Medical waste treatment facilities should be more automated and based on Internet of Things (IoT) technology, with a minimum number of workers involved. In the city of Wuhan, the entire process of medical waste disposal was made a real-time tracking and controlling procedure using IoT technology. IoT technology combined sensing of equipment information, location, scanning of devices and video surveillance. Internet access to each device ultimately helped in achieving the aim of making autonomous operations and using a minimum number of personnel for infectious trash.
- Larger mobile facility capabilities should be maintained, especially during a pandemic, which is especially critical for developing nations with insufficient medical waste disposal facilities. The mobile facilities are not only useful in an emergency, but they can also be used as a state's strategic backup capacity in the future.
- Recyclability and reduction of landfill should also be considered to aid sustainable management of healthcare solid waste during and after the COVID-19 pandemic. Government officials should investigate better waste-to-energy conversion methods to deal with the massive amount of MSW generated. Thermal waste treatment has resulted in over 90% volume reduction, enhanced mineralization, and the immobilization of dangerous chemicals. Developing a distinctive waste-to-energy concept, expert engineering, and large-scale investments, on the other hand, are all necessary.
- Even though many waste management facilities are experiencing workforce shortages due to the COVID epidemic, local municipal governments play a critical role in garbage collection, disposal, and treatment.
- In developing countries like India, the majority of MSW is currently disposed of in landfills. Incineration should be employed in locations where the covid pandemic is the worst because it is one of the most effective disinfection treatments. Infectious trash can be buried underground in a protected landfill in regions where centralized cleaning services are not readily available.
- Sanitation of COVID waste collection vehicles with a 1 percent sodium hypochlorite solution is also required. Health professionals and sanitization workers should use 70% alcohol sanitizer after properly removing PPE and facemasks.

Key Takeaways from India and Road Ahead

The Central Pollution Control Board of India (CPCB) developed its guidelines to ensure that biomedical waste generated during COVID-19 patient treatment, diagnosis, and quarantine is correctly disposed of. It is worth noting that India was one of the first countries to take this step. The CPCB's recommendations detail a step-by-step procedure for adequately disposing waste generated in COVID-19 isolation wards, sample collection centers and laboratories, quarantine camps, and home-care facilities. The laws also spell out what Common Biomedical Waste Treatment Facilities, State Pollution Control Boards, and Urban Local Bodies are responsible for. Some of the most important initiatives that various stakeholders in India have undertaken are as follows:

- To ensure zero leakage, collection should be done in double-sealed color-coded bags.
- A temporary storage facility should be created, and a designated biomedical waste collection container must be kept before handing it over to authorized personnel at the "Common Bio-medical Waste Treatment Facility" for treatment and disposal.

- The garbage generated in COVID isolation wards needs to be regularly tracked and disposed of in regular intervals.
- Mandatory notification to SPCBs and CBWTFs in the COVID-19 and COVID ICU ward operational areas.
- Biomedical waste sanitation workers should promptly ensure that COVID-19 trash is collected and transported to a temporary waste storage facility.
- Quarantine centers should hand over solid waste to garbage collectors who have been identified by the Urban Local Bodies (ULBs).
- If quarantine centers produce biological waste, it must be collected separately in yellow- colored bags provided by ULBs especially designed for biomedical trash collection. When COVID-19 garbage is received by CBWTF, it must be disposed of as soon as possible. Under the Bio-medical Waste Management Rules of 2016, the CBWTF may use any of the allowed processes - Incineration, plasma pyrolysis, autoclaving/hydroclaving, microwaving, and chemical disinfection are some methods.

Because the task of safely disposing of and treating COVID-19-related biomedical waste is becoming increasingly complex, the Office of the Principal Scientific Adviser to the Government of India, in collaboration with Invest India, has recently announced the COVID-19 Biomedical Waste Treatment Innovation Challenge as part of the "Waste to Wealth Mission". The most important national policy efforts to promote resource efficiency and contribute to the transition to a circular economy are listed below. Here are some examples of policy interventions:

- Use various policy instruments to create a consistent set of resource efficiency incentives across the policy lifetime. Each of the significant stages of a product's lifespan should be handled by these policy mixes: material extraction, transportation, production, consumption, recycling, and final disposal. Evidence reveals that policies are now focused more on the post-consumption stages, and policy mixtures might be rebalanced to emphasize upstream in the production and consumption stages. Waste prevention, in particular, is underutilized in policy combinations.
- Implement policies that enhance resource efficiency throughout the product lifecycle. Environmental hazards must be addressed holistically to avoid problems being shifted throughout product lifecycles. Three policy options are described, each of which employs a distinct policy mix to improve resource efficiency at various stages of the lifecycle: EPR, green public procurement, and collaboration with businesses and other stakeholders are all examples of EPR.
- Treat resource efficiency as a cross-cutting and sectoral policy challenge, and incorporate it into cross-cutting and sectoral policies. As with other economic policy concerns, incorporating resource efficiency into cross-cutting and sectoral policies aid in the transition to a circular economy. By linking sectoral policies with resource efficiency goals can help to achieve policy coherence. Resource efficiency can also be integrated into cross-cutting policy domains such as innovation, investment planning, and education and vocational training. Mainstreaming requires effective governance institutions at a sufficiently high level of government.
- Better data and analysis will help to strengthen policy creation and evaluation. Material flow accounting and resource efficiency indicators are required for policy creation and implementation; yet, considerable data gaps obstruct their development. Better evidence on the macroeconomic advantages of resource efficiency and the costs of environmental externalities of present resource consumption patterns, according to the Guidance, should aid in making a case for resource efficiency policies. Policies and efforts that emphasize resource efficiency and tie waste management to other stages of a product's or material's life cycle illustrate the shift from a linear to a circular approach (design, production, consumption). The waste hierarchy, policy objectives or measures that promote eco-design, recycling, and reuse, targets for decoupling waste generation from economic growth, and extended producer responsibility (EPR) schemes are just a few examples of how circular economy principles can be incorporated into policy and legal frameworks.

Institutional Frameworks

The regulation of waste management necessitates a variety of activities from government institutions, including the creation of legal and policy frameworks, the setting of policy objectives, the implementation of those frameworks (including permitting and enforcement functions), data collection, monitoring, and evaluation, information and knowledge sharing, stakeholder consultation, and coordination.

The countries that were thoroughly examined have a diverse set of institutional frameworks for waste management policy. Nonetheless, all focal countries have some characteristics, such as a two-tiered or three-tiered governing system. National governments typically define high-level policy goals (such as national trash plans and strategies) and develop legislative frameworks.

In all focus nations, the ministry in charge of environmental policy is the key agency for waste policy. These ministries consult horizontally with other relevant ministries in the national government, such as those in charge of the economy or industrial development (on circular economy issues and industrial waste), agriculture (agricultural waste), and health (clinical waste, public health), to name a few. Different ministries are in charge of overall waste management policy and MSW policies in some nations.

Role of the Informal Sector

The informal sector plays a significant role in trash management in various nations. As observed in the Environmental Performance Reviews for Chile, Colombia, Estonia, Israel, Korea, Mexico, and Poland, informal sector engagement in recycling is daily in many countries, particularly in waste streams comprising high-value items. Informal recyclers contribute significantly to total recycling efforts in many circumstances. Indeed, the informal sector in Colombia performs half of all recycling activities, and around 14 000 people rely on it for their livelihood. In the lack of infrastructure for separate garbage collection, these operators can help reach recycling requirements. On the other hand, informal garbage collection can lead to unlawful waste dumping and reduce the cost-effectiveness of formal recycling programmes, such as EPR schemes.

Integrating these individuals into the formal waste management system can help to maximize garbage pickers' beneficial contributions to recycling goals while reducing the danger of adverse outcomes. During the protracted process of formalizing the city's rubbish pickers in Bogota, Colombia, some success in integrating the informal sector was evident. The process lasted over a decade and included legal objections from the informal sector against the city's plans to grant municipal garbage services on a competitive basis. As directed by the courts, the city entered into negotiations with the informal sector and produced a social and financial strategy for integrating waste pickers into the city's municipal waste management system. Providing financial incentives for waste pickers to participate in the formal system and formal acknowledgment of their involvement in waste management appeared to be crucial factors in integrating the informal sector. Setting the correct incentives for integration requires a thorough understanding of the industry and how it operates, as advised in the Korea study.

Role of the Private Sector

Municipalities frequently contract with private companies for municipal garbage collection, transportation, and treatment. Tenders are usually awarded to one contractor per municipality in order to obtain economies of scale and density. Industrial and hazardous waste generators frequently contract with private garbage service services. Investment in waste treatment facilities by the private sector is critical to the development of waste management infrastructure.

Public-private collaboration is critical for waste management and the transition to a circular economy on a larger scale. For example, in the Netherlands, the private sector is involved in the drafting of National Garbage Management Plans and has statutory duties for waste management. Similarly, the private sector is participating in the SMC Fundamental Planning process in Japan, and the SMC Law assigns responsibility for waste management and resource efficiency to the private sector. Because numerous economic sectors must be involved, stakeholder participation is required to ensure the complete implementation of these policies.

Governments can help businesses improve their waste management methods by forming information exchange networks. In Israel, a public-private partnership created a waste material exchange bulletin board, supporting high industrial waste recycling and recovery rates. The National Center for Cleaner Production and Environmental Technology in Colombia supports better environmental practices. The Centre enters into voluntary agreements with industry sectors and provides waste management technical help to businesses. It also runs a data system that facilitates the interchange of recovered materials across businesses. The Japanese government's Eco-Town Program aims to improve private sector's understanding of waste and resource efficiency. In the Czech Republic, the government supports trash reduction through conferences and a competition called Turning Waste into Resources, encouraging enterprises to recycle and utilize secondary raw materials. These actions are consistent with environmentally sound waste management, which recommends that countries encourage information sharing among private sector operators to promote waste avoidance and recovery operations. In general, obtaining and sharing valuable knowledge is essential for the transition to a circular economy.

Conclusion

Due to the high infection rate of the novel COVID-19 virus, the volume of healthcare waste is rapidly increasing. Workers in the waste management industry may become infected by virus-contaminated healthcare waste as a result of their close proximity to the trash and lack of safety precautions. As a result, the virus's transmission may accelerate over time. During the pandemic, the WHO has issued clear guidelines for managing healthcare waste. Varied countries have tried different approaches to appropriately manage healthcare waste. Effective safety measures and working techniques may make it possible to properly manage healthcare waste without spreading the infection to others. Better and healthier healthcare waste management can be achieved by disinfecting trash, followed by effective segregation and on-site treatment. Mobile treatment and interim storage techniques may help with long-term healthcare waste management while preventing the infection from spreading further. Proper healthcare waste management can also aid in the recycling of trash or the conversion of waste into useful items, such as energy. As a result, proper healthcare waste management can bring value to national economies, allowing for long-term growth. It will also aid in the reduction of the COVID-19 virus's spread.

Several government bodies were successful in strategizing the implementation of waste management and adopting various treatment practices. Various government bodies must now focus on redesigning MSW management systems to diminish waste burdens during and after the pandemic. However, establishing or reconstructing management frameworks that consider socioeconomic and environmental feasibility is critical. The current research aims to pave the road and open up a new prospect for future study in improving existing processing technologies and waste segregation methods. This outbreak has uncovered several problems in both developed and developing countries' management structures. As a result, the current research evaluation aims to reflect the need for a high-end management perspective in terms of a social and economic management system to deal with any future crises, including training of workers, mechanized mobile incinerators, and so on. Looking at the current situation globally, the pandemic is likely to stay till 2025, and as a result, a long-term strategy for solid waste management is essential. Instead of single-use masks, reusable masks can be sterilized and reused. To avoid waste accumulation, it should be utilized regularly. The most critical requirement is that citizens need to understand how to cope wisely with the current situation. The most important thing to remember is that garbage collection is not entirely the collector's responsibility; residents must be concerned about the safety of frontline employees as well. As a result, measures for reducing waste formation should be followed, such as allowing the garbage to rest for at least 72 hours before final disposal, sterilizing the disposal bag, and so on. We must ensure that discarded PPE is appropriately managed and does not add to riparian pollution at the place of disposal. On the other side, energy recovery from a plastic trash can aid in reducing plastic waste footprints. Despite the higher cost, using bioplastics instead of fossil-fuel-based plastic can be a long-term answer. As the environment has influenced garbage collection and disposal, governments have adopted fast and flexible waste disposal policies to prevent virus transmission through solid waste generated by households, COVID patients who are self- isolated, and hospitals.

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