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Analysis of Bio-Medical Waste Management

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Abstract: **The discussion between COVID-19 and biomedical waste management is the focus of this review study. Healthy places worldwide have been transformed into distressing environments due to the ongoing COVID-19 pandemic, which has resulted in substantial death tolls due to its rapid spread. Lockdowns have become a continuous response in nearly every corner of the globe. Among the issues that have arisen thus far, one notable challenge emerges in densely populated cities: the improper handling of medical waste—a systemic review study of the relationship between COVID-19 and biomedical waste management. I gathered Sixteen articles and newsletters related to COVID-19 and biomedical waste management through various search portals.**

Index Terms **- COVID-19, biomedical waste management, pandemic, medical waste**

I. INTRODUCTION

Numerous waste products emerge due to human activities, and the safe disposal of such waste is imperative. Industrial, sewage and agricultural waste threaten water, soil, and air, potentially harming the environment and human well-being. Classification of solid waste varies according to its origin [1], encompassing categories like (a) household waste, (b) industrial waste, and (c) biomedical waste, also referred to as hospital waste or infectious waste. Hospital waste is regarded as hazardous due to its content of toxic substances. This waste is engendered during human and animal diagnosis, treatment, immunization, and research endeavors within these fields.

Liquid waste can be divided into two components: (a) discarded liquid reagents/chemicals and (b) the drainage of cleaning and washing water [2]. Until recently, medical waste management was not generally considered an issue. In the 1980s and 1990s, concerns about exposure to human immunodeficiency virus (HIV) and hepatitis B virus (HBV) led to questions about potential risks inherent in medical waste. Thus, hospital waste generation has become a prime concern due to its multidimensional ramifications as a risk factor to the health of patients and hospital staff and extending beyond the boundaries of the medical establishment to the general population [3]. Hospital waste encompasses all discarded materials, whether biologic or non-biologic, that are not slated for further use. Within this framework, medical waste constitutes a subset arising from patient diagnosis, treatment, immunization, and associated biomedical research. Biomedical waste (BMW) emerges across diverse settings, including hospitals, research institutions, healthcare teaching facilities, clinics, laboratories, blood banks, animal housing, and veterinary institutes. Biomedical waste, or infectious or medical waste, is defined by its generation during activities such as diagnosis, testing, treatment, research, or the production of biological products for humans or animals. Examples of biomedical waste encompass syringes, live vaccines, laboratory samples, body parts, bodily fluids and waste, sharp needles, cultures, and as per the Medical Waste (Management and Processing) Rules 2008, the segregation of "medical wastes from other wastes is obligatory at all stages, encompassing generation within hospitals, collection, and transportation, necessitating separate processing based on their respective classifications." The ongoing COVID-19 pandemic has transformed formerly healthy environments into nightmarish scenarios characterized by significant death tolls due to its extraordinarily rapid spread. Lockdowns have become a recurring phenomenon, spanning nearly every corner of the globe. Amid the multifaceted problems posed by the pandemic, a pronounced concern in densely populated cities revolves around properly handling medical waste. Wuhan, China, the initial epicenter grievously impacted by the pandemic, is an illustrative example. This city, inhabited by 11 million individuals, witnessed its hospitals generating over 240 tons of medical waste daily during the peak outbreak phase, a stark increase from the 40 tons produced before the epidemic, according to China's Ministry of Ecology and Environment's emergency office. To address this monumental surge in medical waste, the central government responded by deploying 46 mobile medical waste treatment facilities to Wuhan and constructing a new plant with a 30-tonne capacity within a mere 15 days in March.

Biomedical waste is considered hazardous due to its potential to harbor virus particles, which can be concealed within human tissues, items contaminated with blood, such as bags, needles, syringes, or other sharp objects, as well as bodily fluids, such as dressings, plaster casts, cotton swabs, and beddings tainted with blood or bodily fluid. Experts emphasize that medical waste diverges from other categories like household or industrial waste. It can directly infect individuals through skin contact or via ingestion and inhalation, involving items like inhalers or ventilation pipes.

Inhalation with objects like inhalers or ventilating pipes can expose individuals to contagions. Many infectious viruses, including HIV and Hepatitis (B and C), have the potential to originate from such waste, posing risks to those not afflicted by these diseases. Notably, antibiotic-resistant germs and viruses, such as COVID-19, can proliferate through medical waste, disseminating efficiently. The hazardous nature of biomedical waste stems from its capacity to conceal potential virus particles within human tissues, encompassing items tainted with blood like bags, needles, syringes, and other sharp objects, as well as bodily fluids, such as dressings, plaster casts, cotton swabs, and beddings contaminated with blood or bodily fluid [1].

Amid the COVID-19 emergency, the prudent management of household waste assumes paramount importance. Medical waste, including masks, gloves, used or expired medications, and other contaminated items, can be mixed with regular household waste. However, these items should be treated as hazardous waste separately. Safeguarding against contamination, they should be stored apart from other domestic waste streams and collected by specialized municipal or waste management entities [2].

II. OBJECTIVES

a) The decision to utilize an appropriate technique for biomedical waste management is made.
b) We are analyzing the impact of coronavirus on the production of biomedical waste while upholding the integrity of the specifications

III. LITERATURE REVIEW

1. *Managing Health Care Solid Waste During the COVID-19 Pandemic: A Brief Mini-Review [2]*

Healthcare facilities, medical laboratories, and biomedical research establishments generate healthcare waste. Mishandling this waste presents substantial risks of disease transmission to waste pickers, waste workers, healthcare professionals, patients, and the broader community due to exposure to infectious agents—inadequate waste management releases harmful contaminants into society. Nevertheless, the contamination involving highly transmissible agents like the COVID-19 virus has induced significant instability in managing healthcare waste and subsequent recycling, primarily due to the sheer volume of waste generated and its contagious nature. Numerous countries have implemented safety protocols to counteract this contamination and regulate healthcare waste; however, the adequacy of these measures varies based on each country's specific context. Additionally, the World Health Organization (WHO) has established guidelines for healthcare waste management, aiding in managing highly contagious healthcare waste arising from the ongoing pandemic. Effective healthcare waste management has the potential to mitigate the dissemination of the COVID-19 virus and enhance material recyclability, thus minimizing the need for landfills. By disinfecting and segregating healthcare waste, sustainable management is facilitated, enabling their repurposing for valuable applications.

This review delves into diverse strategies for managing healthcare solid waste in various countries. It addresses the challenges encountered in this realm and proposes potential solutions for surmounting these obstacles. Furthermore, the review offers valuable insights into managing healthcare solid waste amid the COVID-19 pandemic and outlines prospective paths for progression.

2. *Bacteriological Profile of Biomedical Waste: Guidelines for Management [12]*

Biomedical waste (BMW) is generated across various settings, including hospitals, research institutions, health care teaching institutes, clinics, laboratories, blood banks, animal houses, and veterinary institutes. Recent attention in India has been directed towards hospital waste management, particularly following the enactment of the BMW (Management and Handling) Rules, 1998. A study was undertaken at Sharda Hospital in Greater Noida to explore the bacteriological profile of BMW and investigate the practices employed for its management and disposal, adhering to standardized procedures. In the course of this study, a total of 500 samples of biomedical waste were collected for bacterial culture. Among these, 136 samples exhibited bacterial growth. Notably, the predominant bacteria isolated from these cultures were Pseudomonas species. Furthermore, this study proposes optimal practices for managing biomedical waste.

3. *Assessing Bio-Medical Waste Before and During the Novel Coronavirus Disease Pandemic Emergency in India: A Gap Analysis [5]*

Given the global spread of the Coronavirus disease (COVID-19), India grapples with the same crisis. Given India's pre-existing insufficient waste treatment infrastructure and the sudden eruption of the COVID-19 virus, the proliferation of Bio-medical waste (BMW) has emerged as a significantly heightened concern, necessitating the secure disposal of an elevated volume of garbage. This study thoroughly evaluates India's BMW situation before and during the COVID-19 pandemic. Furthermore, the gaps in the execution of BMW regulations in India are underscored by this article. In addition to reports and data explicitly sourced from the Central Pollution Control Board (CPCB), various government and non-government organizations inform the basis of this study's analysis. The study's findings underscore the inadequacy of COVID-19 waste management across many States/Union Territories (UTs) in India. The nation has generated a cumulative total of 32,996 metric tons of COVID-19 waste between June and December 2020. During this period, Maharashtra emerged as the highest average generator of COVID-19 waste (789.99 metric tons per month), 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), West Bengal (303.15 mt/month), and others respectively. The study emphasizes the identification of numerous gaps concerning compliance with BMW management regulations. For instance, among the 35 States/UTs, only eight received authorization per BMW management regulations for their healthcare facilities (HCFs). Despite government restrictions, 23 States/UTs continue to employ deep burial methods for BMW disposal. The present research advocates for, according to high-priority status, those States/UTs that, on average, generated 100 metric tons of COVID-19 waste monthly in the preceding seven months (June–December 2020). These states require specialized attention to implement BMW regulations and enhance their BMW treatment capacity.

IV. PROBLEM DESCRIPTION

Disposing of waste from the hospital to the standard treatment facility encompasses architectural design considerations. This application detects package movement by tracking offline, ensuring no debris is improperly discarded into public garbage bins. This, in turn, safeguards both individuals and the environment from pollution. The subsequent section outlines the steps occurring within the proposed Android application. The Architectural Design encompasses the following modules:

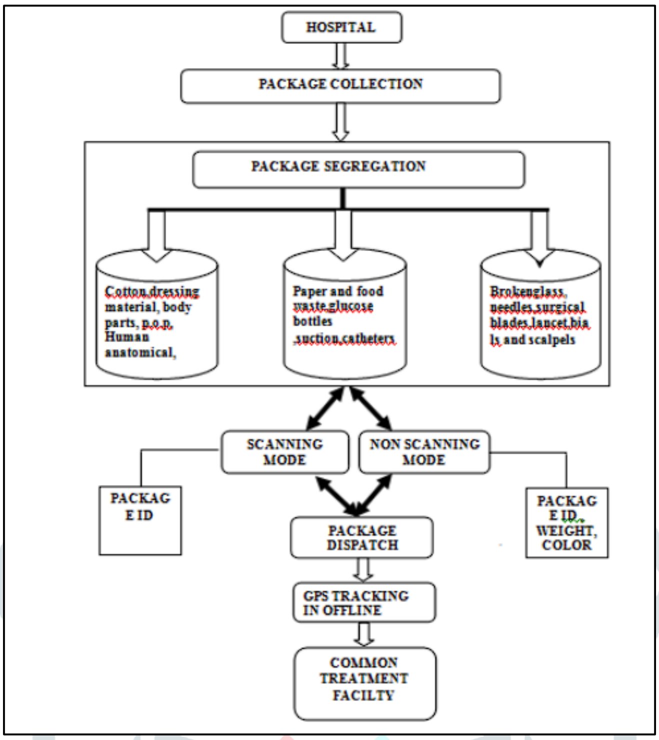

Fig 1: Proposed Architectural Design

a). Initial Validation:

Various forms are employed for the execution of input design, including login, collection, dispatch, and receipt capture. During scanning, two distinct input modes are used: scanning mode and non-scanning mode. In scanning mode, the inputs (package ID) are automatically populated into corresponding forms based on the barcode. Conversely, in a non-scanning manner, the information (package ID, color, weight) requires manual input.

b). Admin Login Form:

During the initial usage, the application will request login details, which will then be stored. After the first use, the application will not require login details, enhancing the accessibility of the application.

c). Package Collection:

In the Collection phase, the housekeeping staff will be equipped with Android tablets or Android phones to record the waste collected from various generation points, such as departments and wards. This process includes capturing the waste segregation type and weight. Subsequently, the managed packages will be transferred to a shared storage area. Provisions to capture the following details at hospitals are,

- **Ward name**
- **Package id**
- **Package color**
- **Weight**

d). Package Dispatch:

During the Dispatch phase, the hospital staff regularly dispatch the collected packages from the shared storage area to the Common Treatment Facility (CTF). The hospital staff in charge of this process will capture the following details at the hospital during the package dispatch:

- **Truck number**
- **Package id**
- **Weight**

Fig 2: Segregation of waste in packages

The illustration above depicts the container's dispatch from hospitals to the standard treatment facility truck. The bio-medical waste tracking Android application will automatically populate the hospital name and dispatch user ID using the login details.

e). GPS SYSTEM:

The waste package disposal movement from the hospital to CTF is carried out by truck, which involves the above process and will be tracked using GPS in our Android application. The GPS device named Track-on is used in this application, which contains a SIM card number. To activate the device, it will text that number, which tracks the truck and sends the response message every 5 seconds offline to the mobile phone.

V. PROPOSED METHODOLOGY

The utilization of a BIOBIN is incorporated within the proposed system to gather data and notify the relevant individuals engaged in the waste management process. This setup encompasses the subsequent components: Smart BIOBIN, ultrasonic sensors, servo motor, and Node MCU.

1). Node MCU:

The IoT platform primarily features an ESP-12 module, incorporating a microcontroller with 16 digital I/O pins and one analog input pin. Additionally, it includes a compatible USB interface for plug-in purposes, along with a flash memory capacity of 4 MB. The module's compact size is advantageous, allowing it to integrate into various IoT projects seamlessly.

2). Servo Motor:

A servo motor is affixed to this sensor, enabling the lid's movement. This servo motor operates as a DC motor employing the Pulse Modulation principle. The rotation angle of the servo motor is determined by the duration of the pulses administered to its signal pin.

3). Ultrasonic Sensor:

Functioning as a distance-measuring apparatus, an ultrasonic sensor operates based on the principles of ultrasonic waves. This device emits an ultrasonic wave and subsequently captures the echo of the emitted wave from the target object. It calculates the distance between the sensor and the target object by analyzing the time disparity between the emission and reception of the signal.

Formula to estimate the distance is given by:

$$L = \frac{1}{2} \times T \times C$$

Where L represents the distance between the sensor and the intended device, T represents the difference in time, and C represents the speed of light.

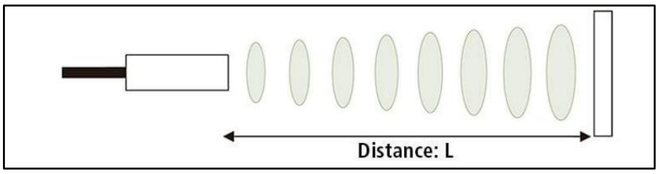

Fig 3: Working of Ultrasonic Sensor

VI. TREATMENT AND DISPOSAL TECHNIQUES FOR BIOMEDICAL WASTE

Several effective methods have been employed for the treatment of infectious waste. The ensuing approaches delineate potential treatment options accessible at your facility. The plans encompass Autoclaving, Incineration, Thermal inactivation, Gas/Vapor Sterilization, Chemical Disinfection, and more.

1). Sterilizer:

Sterilizers represent enclosed chambers that apply heat, pressure, and sometimes steam over a specific duration to sterilize medical equipment. For nearly a century, autoclaves have been utilized to sterilize medical instruments for subsequent reuse. Their application involves eradicating microorganisms that might be present in medical waste before its disposal in conventional landfills. Autoclaves can process a significant portion, up to 90%, of medical waste and can be easily adapted to suit the requirements of various medical institutions [15]. Small, countertop autoclaves are frequently employed for sterilizing reusable medical instruments, while larger counterparts are used to manage substantial quantities of medical waste. Steam sterilization is most effective with low-density materials like plastics, metal pans, bottles, and flasks [16]. However, high-density polyethylene and polypropylene plastics should not be subjected to this process, as they impede steam penetration into the waste load. Placing plastic bags within rigid containers before steam treatment to avert spillage and drainage obstructions is advisable. Before placing them in the steam sterilizer, bags should be unsealed, and caps or stoppers should be slightly loosened. Meticulous attention is required to segregate infectious waste from other hazardous materials. Contagious waste that combines non-infectious hazards should not undergo steam sterilization [17]. Moreover, waste containing anti-neoplastic drugs, toxic chemicals, or substances prone to steam-induced volatilization should not be subjected to steam sterilization.

2). Cremation:

This phenomenon is substantiated by an elevated temperature inducing dry oxidation. This process aims to convert organic and combustible waste into inorganic and non-combustible forms, reducing volume and weight. These alterations render the waste unrecognizable, reusable, or viable for disposal in external landfills [18]. Nevertheless, incineration is accompanied by certain drawbacks, including substantial capital and operational expenses associated with modern technologies. Despite these drawbacks, the advantage of incineration lies in its exemption from the pretreatment requirement. It is particularly suitable for waste possessing a low heating value, surpassing 2000 Kcal/Kg for a single chamber and 3500 Kcal/Kg for a double-chamber configuration. Effective incineration necessitates the waste to maintain a moisture content of less than 30% and exhibit combustibility [19].

3). Heat deactivation:

Heat deactivation encompasses subjecting waste to elevated temperatures to eradicate infectious agents. This approach is typically employed for treating substantial quantities [20]. The process involves containing liquid waste within a vessel, which is then heated through heat exchangers or a steam jacket enveloping the ship. The temperature and duration of treatment are contingent upon the types of pathogens present in the waste. After treatment, the treated contents can be discharged into the sanitary sewer system while adhering to State, Federal, and local regulations. This method requires higher temperatures and prolonged treatment cycles than steam treatment.

4). Chemical disinfection:

Chemical disinfection employs gaseous or vaporized chemicals as agents for sterilization. Among these, ethylene oxide emerges as the most frequently utilized agent; however, its application warrants careful consideration due to its status as a suspected human carcinogen. It should be noted that the potential for worker exposure exists, as ethylene oxide might be absorbed onto the surfaces of treated materials, posing risks during sterilizing materials [20].

5). Chemical sterilization:

Chemical sterilization emerges as the preferred approach for treating liquid infectious waste. Several factors need to be considered, including the type of microorganism, degree of contamination, presence of proteinaceous material, type of disinfectant, contact time, and other relevant aspects such as temperature, pH, mixing requirements, and microbial biology [20]. The ultimate disposal of chemically treated waste. Infectious waste that has undergone effective treatment no longer poses a biological hazard and can be mixed with ordinary solid waste for disposal, provided that the waste doesn't present other risks governed by federal or state regulations. The EPA recommends:

- Engaging with state and local authorities to identify approved disposal methods.
- Discharging treated liquids and pathological waste (after grinding) into the sanitary sewer system, subject to approval from the local sewer authority.

Health hazards associated with biomedical waste:

Improper management of biomedical waste leads to significant environmental issues encompassing air, water, and land pollution. Pollutants can be categorized as biological, chemical, and radioactive. Environmental problems stem from both the generation of biomedical waste and its subsequent handling, treatment, and disposal processes [9].

Air Pollution can manifest indoors and outdoors, originating from various types of biomedical waste, including biological, chemical, and radioactive forms. Indoor air can become laden with pathogens, either as spores or directly contributing to air pollution within healthcare institutions. Outdoor chemical pollutants primarily result from open burning and incineration [21]. Open burning of biomedical waste is particularly harmful and should be strongly discouraged.

Water Pollution represents another significant concern stemming from biomedical waste. The improper garbage dumping into low-lying areas, lakes, and water bodies can result in severe water pollution. Pathogens present in the trash can contaminate ground or surface water. Harmful chemicals, including heavy metals, can further contribute to water pollution [22].

Land Pollution is associated with the final disposal of biomedical waste. Even the liquid effluent following treatment, when spread on land, can lead to pollution. Open dumping of biomedical waste significantly contributes to land pollution [22].

Challenges of biomedical waste management in India:

(Bio-medical Waste (Management and Handling) Rules. Ministry of Environment and Forests Notification, New Delhi. 1998)

- The requirement to treat 420,561 kg per day of biomedical waste in compliance with Bio-Medical Waste Rules.
- The need for a manifold increase in Common Bio-Medical Wastes Treatment Facilities (CBMWTFs). The current 157 facilities must be sufficient to manage all generated biomedical waste.
- The establishment of CBMWTFs under public-private partnership arrangements.
- Promotion of new technologies for the destruction of toxic biomedical waste.

VII. WHICH TREATMENT IS PREFERABLE?

Incineration represents a high-temperature dry oxidation process that transforms organic and combustible waste into inorganic, non-combustible matter, leading to a notable reduction in waste volume and weight. This approach is typically chosen for addressing waste that needs more potential for recycling, reuse, or disposal in a landfill site. The process flow is depicted schematically. The combustion of organic compounds predominantly yields gaseous emissions like steam, carbon dioxide, nitrogen oxides, certain toxic substances (such as metals and halogenic acids), and particulate matter. This process also generates solid residues in the form of ashes. If the control of combustion conditions is insufficient, toxic carbon monoxide may also emerge. The ash and wastewater derived from the process encompass toxic compounds, mandating their treatment to avert detrimental impacts on health and the environment. Energy-recovery facilities are commonly integrated into most contemporary, large-scale incinerators. In regions with colder climates, steam and hot water generated by incinerators can serve urban district heating systems, while in warmer temperatures, incinerator steam is harnessed for electricity generation. Small hospital incinerators utilize the recovered heat for preheating the waste before incineration. Biomedical waste poses a significant challenge on its own. The transition of developing nations into developed ones has increased demand for healthcare services, rapidly driving biomedical waste generation. In the context of India, biomedical waste presents a substantial concern. Insufficient awareness and the absence of stringent regulations have led to instances where hospitals discard waste into the ground or water bodies.

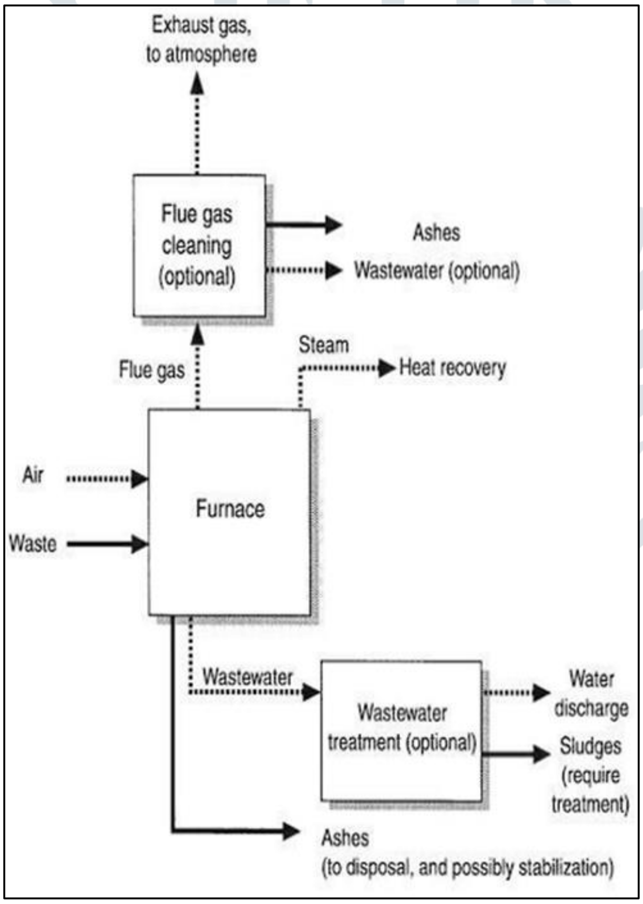

Fig 4: BWM Relevance to Civil Engineering

This practice is highly hazardous due to infectious and harmful substances like blood, tissue, organs, syringes, and needles. As responsible citizens and civil engineers, we must discover effective methods for properly treating biomedical waste. Civil engineers should focus on designing structures that adequately treat such destruction, thereby minimizing its impact on land or water bodies. Our role involves transforming waste into reusable products. Biomedical waste management is closely tied to waste management, which inherently relates to environmental engineering as it targets the environment's safety. Environmental engineering aims to ensure sustainable societal development while judiciously using land, water, and air resources. These aims are attained by effectively managing these resources to minimize environmental pollution and degradation.

VIII. CONCLUSION

In the face of the ongoing COVID-19 pandemic, where the world has been thrust into a harrowing reality of rapid transmission and unprecedented challenges, innovative solutions are crucial to alleviate its devastating impact. One standout innovation is the Smart BIOBIN, a groundbreaking IoT-enabled device engineered for efficient waste collection. This intelligent system not only addresses the pressing concern of safeguarding the health of sanitation workers by reducing risk and harmful effects but also holds the potential to disrupt the chain of COVID-19 transmission. By employing real-time alerts and data collection, the BIOBIN ensures the proper handling of medical waste and contributes to breaking the cycle of infections. Furthermore, the Smart BIOBIN extends its influence beyond immediate waste management. Its capabilities are leveraged to establish a cloud-assisted database, enabling sophisticated regression analysis to predict future waste deposition patterns. This data-driven approach is instrumental in determining optimal waste disposal methods. As we grapple with the pandemic's repercussions, the BIOBIN emerges as a beacon of innovation, offering a holistic solution that not only protects sanitation workers but also aids in controlling the pandemic's spread. However, it's essential to recognize that even with such advanced solutions, the gravity of COVID-19 still needs to be improved. The pandemic's toll on communities worldwide, transforming once-thriving locales into grim landscapes of lockdowns and high death tolls, cannot be underestimated. A significant underlying issue is the improper handling of medical waste, which can compound the crisis in densely populated areas. The preferred technique for addressing this challenge is medical waste incineration, known for its efficacy in managing infectious, chemical, and pharmaceutical waste while ensuring high levels of disinfection. In conclusion, the Smart BIOBIN exemplifies the power of innovation in crisis response. As we navigate these turbulent times, it stands as a beacon of hope, demonstrating how technology can be harnessed to mitigate immediate threats and forge a more resilient and secure future.

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