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# Transforming Hazardous Bio-Medical Waste Ash Through Sustainable Biological Treatment

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**Abstract:**

Medical waste, characterized by its toxic and infectious nature, poses significant hazards to the environment and human populations. In contrast, nature demonstrates self-cleansing abilities in healthy ecosystems, perpetuating sustainability. To address the environmental impact of medical waste, adopting Clean Production and Zero Waste systems can effectively reduce, reuse, and recycle waste, contributing to a more sustainable environment. However, hazardous waste from healthcare establishments presents unique challenges in proper treatment and disposal. India, in particular, faces significant biomedical waste management challenges, especially in rural areas with inadequate infrastructure.

This research paper reviews the current scenario of biomedical waste management in India, with a focus on incineration as a disposal method. Incineration, while reducing waste volume, releases toxic gases and heavy metals, posing health and environmental hazards. Alternative technologies, such as immobilization, wet chemical treatment, and microbial-based remediation, are being explored to make toxic residues inert and suitable for safe disposal or reuse. The reuse of incinerator ash in construction and agriculture is also being investigated.

The study isolates metal-tolerant microorganisms and assesses their potential for remediating metal-contaminated waste. Promising results show that certain microorganisms can significantly reduce alkalinity, hardness, and chloride content in biomedical waste ash, making them potential candidates for remediation. Moreover, the mixture of biomedical waste ash with soil exhibits positive results for plant growth, particularly in a 4% ash-soil mixture.

The research highlights the importance of proper waste management practices and the exploration of environmentally friendly alternatives to incineration. It emphasizes the significance of adopting cleaner technologies and leveraging microbial activities for sustainable waste management and environmental protection. Future research should focus on optimizing treatment conditions to enhance heavy metal removal efficiency further. By promoting sustainable waste management practices, the healthcare sector can contribute to a safer and healthier environment.

Key Words: Biomedical Waste, microbes, heavy metals

**Introduction:**

Medical care is an essential aspect of human life, ensuring health and overall well-being. However, the generation of medical waste poses significant hazards due to its toxic and infectious nature, threatening both the environment and human populations. In contrast, nature exhibits remarkable self-cleansing abilities, where waste in healthy ecosystems becomes nourishment for the next cycle, perpetuating sustainability.

To address the environmental impact of medical waste, adopting a Clean Production approach and implementing Zero Waste systems can effectively reduce, reuse, and recycle a vast majority of waste, contributing to a more sustainable environment. However, hazardous waste from healthcare establishments, including infectious, biomedical, and radioactive materials, presents unique challenges in proper treatment and disposal. Mismanagement of such waste can lead to disease transmission, contamination of non-hazardous waste, and environmental pollution.

India faces a significant challenge with the vast quantity of biomedical waste generated each year. Historically, inadequate waste management practices, such as indiscriminately combining all waste streams and burning them in incinerators, continue to persist in several countries. Developing world hospitals and clinics, where waste is often discarded with regular trash, pose severe health risks to scavenger populations due to improper disposal of infectious waste.

The Bio-Medical Waste (Management and Handling) Rules introduced by the Ministry of Environment and Forests (MoEF) in 1998 aimed to ensure proper segregation, collection, transportation, and disposal of infectious biomedical waste to safeguard public health and the environment. However, challenges remain in implementing effective waste management systems, especially in rural areas lacking proper infrastructure.

Various waste treatment technologies, including thermal, chemical, irradiation, and biological processes, play a crucial role in managing medical waste effectively. Incineration, in particular, is considered favorable for volume reduction, but it also poses environmental and health risks, releasing dioxins, heavy metals, and other pollutants. The residues from incineration, such as ash, require careful handling as they are potentially hazardous and may contaminate water sources if not adequately managed.

To promote sustainability, it is essential to reduce the toxicity and quantity of medical waste. Proper waste management practices and segregation are critical, and alternatives to incineration must be explored to minimize environmental impacts and health risks associated with medical waste disposal. This research paper aims to review the current scenario of biomedical waste management in India, assess incineration as a waste disposal method, and propose alternative, environmentally friendly solutions for sustainable waste management in the healthcare sector.

**Review of Literature**

The literature review highlights the significant environmental concerns associated with incinerators as major sources of dioxins and heavy metals in biomedical waste disposal. While incineration can reduce waste volume, it releases toxic gases, dioxins, and heavy metals into the environment, posing health hazards. Several alternative technologies for waste treatment are being explored, including immobilization with cement, wet chemical treatment, and thermal processes like vitrification. These methods aim to make toxic residues inert and suitable for reuse or safe disposal. Additionally, microbial-based remediation approaches are being investigated to mitigate heavy metal contamination in waste materials. The reuse of incinerator ash in various applications, such as construction and agriculture, is also being explored. To address the potential health effects and environmental risks, proper leachate analysis and monitoring of chloride levels in water sources are crucial. Adopting cleaner technologies and leveraging microbial activities can contribute to sustainable waste management and environmental protection.

**Material and Methods**

Sample Collection

Soil samples were collected from an agricultural field located at VGU University.

Sludge samples were collected from a textile industry.

Ash samples were obtained from the Incineration point in Rajasthan, India. The ash samples were autoclaved prior to use to prevent interference with microorganisms during treatment.

Isolation of Metal Tolerating Micro-organisms:

Nutrient broth and Minimal media (M9) were used for isolating bacteria from the collected soil and sediment samples.

Dilutions ranging from 10-1 to 10-6 were prepared and spread on nutrient agar plates to ensure purity.

Pure cultures of each isolate were inoculated into M9 medium at pH 12, and the best-grown isolates were selected based on their growth characteristics.

Optimization of Metal Tolerance of Isolates in Enriched (NB) and Minimal Media (M9):

Isolates were sub-cultured and incubated on a rotary shaker.

Bacterial growth in M9 media was measured at OD600 using a spectrophotometer, and isolates with growth exceeding 0.50 were selected for further screening.

Screening for metal tolerance was done by growing isolates in M9 and nutrient broth media with 25, 50, and 75 ppm of different metal concentrations.

Identification of Selected Bacterial Isolates:

Selected isolates were characterized by colony morphology on nutrient agar, gram staining, and other morphological characteristics.

Additional biochemical tests were performed, including Gelatin Agar Medium, Starch Hydrolysis, Citrate Utilization, Catalase Screening, and Carbohydrate Utilization.

Physiological Testing:

The optimum pH for the growth of the strains was determined by incubating bacterial cultures with different pH levels.

Treatment of Ash Samples:

Specific microorganisms were applied to ash samples along with 0.1% molasses and glucose as carbon sources.

The samples were incubated at 37°C for 8 days.

Analysis of Ash Samples After Treatment:

Periodically, samples were tested for alkalinity, hardness, chloride levels, and heavy metal content (ICP-MS).

Ash leachate was analyzed by using an ash-to-water ratio of 1:10. The supernatant was used for the estimation of pH, alkalinity, and chloride content.

Physico-Chemical Characterization of Ash, Soil, and Their Mixture: The chemical characterization of fly ash and sewage sludge samples was done using standard methods, including pH, electrical conductivity, available nitrogen, available phosphorous, and organic matter measurements.

## Result and discussion

The study aimed to identify metal-tolerating microorganisms and assess their potential for remediating metal-contaminated waste. Initially, eight strains were isolated and tested for growth in Minimal medium (M9) with pH 12. Two isolates, Isolate 1 and Isolate 2, were selected for further experimentation based on their growth performance.

Isolate 1 displayed high tolerance to Aluminum (Al) and Silver (Ag) but lower effectiveness against Mercury (Hg) and Copper (Cu). Isolate 2 exhibited the highest growth with Iron (Fe) and Molybdenum (Mo), but poor growth with Copper (Cu) and Zinc (Zn). Both isolates demonstrated a decrease in growth as metal concentrations increased.

Isolate 1 was found to be Gram-positive, rod-shaped, and aerobically growing, with the ability to hydrolyze starch and gelatin. It exhibited positive results for citrate utilization and catalase production and could utilize various carbohydrates.

The leachate of Biomedical Waste Ash (BMW ash) showed high pH, alkalinity, hardness, and chloride levels, making it toxic due to the presence of heavy metals. Isolate 1 showed a significant reduction in alkalinity, hardness, and chloride content, making it a potential candidate for remediation.

Furthermore, mixing BMW ash with soil and testing the growth of ladyfinger plants revealed that a 4% mixture of ash with soil promoted plant growth, while higher concentrations inhibited germination and plant growth.

## Conclusion

In conclusion, understanding the composition and properties of incinerator ash is crucial for assessing its potential applications in waste treatment and utilization. The use of metal-tolerant microorganisms in the biological treatment of ash offers a safe, cost-effective, and eco-friendly alternative to chemical methods, thereby mitigating groundwater and surface water contamination risks.

The treated ash's favorable characteristics make it a viable option for agricultural purposes when mixed with soil at appropriate ratios. For instance, the successful germination of ladyfinger plants using a mixture of up to 4% soil and ash highlights its potential in enhancing plant growth.

To further enhance the removal of heavy metals from ash, future research could explore employing multiple strains of microorganisms, extending the incubation period, increasing biomass dosage, and optimizing pH and temperature conditions. These advancements hold the potential to significantly improve the efficiency of ash treatment and disposal, reducing its overall environmental impact.

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