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Microbial Composting as a Sustainable Solution for Global Waste Management: A Comprehensive Review

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Abstract:
This review examines microbial succession–driven composting as a sustainable and economically viable approach for organic waste degradation. Persistent global waste management challenges, intensified by urbanization, industrialization, and population growth, necessitate scientific strategies employing microorganisms such as Bacillus and Pseudomonas. Specific microbial strains enhance composting efficiency, reduce emissions, and improve compost quality.
The continuous rise in municipal solid waste presents serious environmental, health, and economic concerns, highlighting the need for efficient waste treatment methods. Microbial practices, including composting and anaerobic digestion, play a vital role in waste recycling and valorization. The review also traces the evolution of waste management practices and the influence of global trends on waste generation and disposal.
Rapid urbanization and industrialization have intensified environmental pollution, underscoring the importance of bioremediation, where microorganisms offer cost-effective solutions for industrial waste degradation. The escalating global waste burden demands immediate attention, with sustainable waste management practices essential for promoting a zero-waste economy. Overall, the review emphasizes composting and microbial interventions as key components of an integrated approach to achieving environmental sustainability.

Keywords: Composting, Microbial succession, Waste management, Sustainable solutions, Municipal solid waste, Bioremediation.

Introduction:

Composting, driven by microbial succession, efficiently degrades organic waste, offering economic benefits. Global waste management challenges persist, demanding strategic approaches. Urbanization, industrialization, and population growth strain the environment. Scientific waste management, leveraging microorganisms like Bacillus, Corynebacterium, and Pseudomonas, is crucial for sustainability. Specific strains enhance composting efficiency, emissions, and end-product quality. Tailored waste degradation approaches are essential. Municipal solid waste growth poses environmental, health, and economic challenges. Microbial practices like composting enhance efficient waste treatment. Anthropogenic waste, managed effectively, ensures a cleaner environment. Historical waste management methods evolve with global trends. Environmental pollution, driven by rapid urbanization and industrialization, necessitates bioremediation. Microorganisms contribute to industrial waste decomposition, offering cost-effective solutions. The rising municipal solid waste globally warrants attention. Waste and pollution, linked by human activities, emphasize the need for effective waste management practices, involving reduction, recycling, segregation, treatment, and disposal for a sustainable future.

Review:

Composting, driven by microbial succession, efficiently degrades organic waste, offering economic benefits. Challenges in global waste management persist, with varied practices and certifications. Composting phases include mesophilic, thermophilic, and cooling, with factors like C/N ratio, pH, moisture, aeration, temperature, particle size, and microbial dynamics crucial for optimal results. Microbial additives, including fungi and bacteria, significantly impact composting efficiency, emissions, and end-product quality. Specific strains enhance enzymatic activity, stability, and humification. Tailored approaches and strategic management are essential for effective waste degradation and sustainable composting practices.(Rastogi et al., 2020)

Urbanization, industrialization, and population growth stress the environment, prompting irreversible damage. Scientific waste management is crucial for sustainable development. Microorganisms like Bacillus, Corynebacterium, staphylococcus, Streptococcus, and Pseudomonas enhance bioremediation and biodegradation for eco-friendly waste management. Plant-associated bacteria support phytoremediation. Micro fungi, mycorrhiza, yeasts (e.g., Trichosporon cutaneum), and algae (e.g., Prototheca zopfii) contribute to pollutant degradation. In xenobiotic compound (XC) biodegradation, oxidoreductases, oxygenase's, and dehalogenases transform contaminants, with specific microbes like Bacillus sp. and Rhodococcus degrading benzene and PCBs. Plastics, heavy metals, rubber, and agricultural waste also involve microbial processes for effective disposal. Petroleum-induced hydrocarbon contamination is addressed by Sphingomonas, Mycobacterium, and fungal organisms. Microbial biotechnology in waste management is vital for environmental sustainability, employing diverse microorganisms for efficient degradation and transformation processes.(Mondal, S., Palit, D., 2019)

The continual growth of municipal solid waste poses global environmental, health, and economic challenges. Microbial practices, such as composting and anaerobic digestion, efficiently enhance waste treatment, recycling, and valorization (Mathews & Gowrilekshmi, 2016). These practices contribute to building a sustainable, cost-effective, and efficient zero-waste economy (El Asri et al., 2022).

Anthropogenic activities generate diverse waste. Effective management ensures a cleaner environment and societal well-being. GIS and remote sensing aid waste control. Historical methods reflect evolving practices. Global trends show high-income earners produce more waste. Composting reduces food waste, creating manure and biogas. Agricultural waste acts as organic manure. Advanced recycling tackles electronic and scrap metal waste. Industrial waste demands varied disposal. Medical waste risks groundwater contamination in unlined pits. Composting utilizes aerobic microorganisms, with the product undergoing curing, blending, and marketing. Wastewater analysis measures organic matter concentration, strength, and acidity.(Jinjiri et al., 2018)

Waste management has ancient roots, with 500 BC Athens regulating waste disposal. Modern challenges stem from municipal solid waste, a byproduct of human activities, including rising electronic waste. Global waste management grapples with hazardous chemicals, urging the adoption of beneficial methods. Classical waste classification covers degradable, recyclable, inert, electrical, composite, harmful, and toxic waste. India's 60% waste reuse, but plastic recycling ratios vary globally. Developed nations follow integrated waste management programs. France favors incineration, the UK relies on landfills, and Hanoi lacks sorting, directly dumping waste. Microbes contribute to municipal waste bioconversion, offering eco-friendly solutions and potential for plastic degradation.(Singh et al., 2020)

Environmental pollution, intensified by rapid urbanization and industrialization, threatens ecosystems globally. Over 1 billion pounds of toxins are released annually, generating 140 billion metric tons of agricultural waste. Plastic pollution, exceeding 500 billion to 1 trillion bags, poses a severe threat. Bioremediation, using microorganisms, emerges as a cost-effective solution. Ex-situ methods involve bio-piling and composting, while in-situ techniques like biosparging and bioventing optimize microbial activity. Heavy metals like Cadmium, Copper, and Lead endanger ecosystems, but microorganisms offer potential solutions through bioaccumulation and detoxification mechanisms. In dye and pesticide pollution, microorganisms employ enzymes to degrade the pollution levels. Microbes also contribute significantly to the remediation of petroleum hydrocarbons and chlorinated compounds. Lignocellulosic waste remediation benefits from microbial activities, fostering soil health and productivity. (Tegene, 2020)

Industrial decomposers, typically bacteria or fungi, break down specific organic waste in various industries, aiding waste management and reducing environmental impact. Industrial decomposition faces challenges of contamination with plastics, metals, and chemicals. Industrial microbiology applies microorganisms for useful product production, bioremediation, and more. Microbes in food, pharmaceuticals, and biofuels showcase their versatility, genetic adaptability, and cost-effectiveness. Microorganisms are vital in biofuels, bioremediation, and pharmaceuticals, offering renewable, low-emission solutions.(Zakari, n.d.)

The escalating production of municipal solid waste (MSW) poses environmental threats globally. Urban mining, retrieving resources from urban waste, gains significance. The high MSW output of over 4 billion tonnes annually, half being MSW, requires attention. China, a major contributor, produced 215 million tonnes in 2017. MSW, predominantly managed through incineration and landfill, challenges ecosystems and resources. Waste policies, waste charges, and economic development impact waste generation. Education's role in waste reduction is debated. Utilizing the STIRPAT model, this study analyzes factors influencing MSW generation in China, considering regional heterogeneity for a comprehensive perspective on sustainable waste management.(Cheng et al., 2020)

Guide on managing industrial waste, addressing harmful consequences of increased demand. The author covered sectors like pharmaceuticals, textiles, petroleum, soap, and more. (Wang et al., 2005). Waste and pollution are intrinsically linked, with human activities introducing harmful substances into the environment, causing health hazards, ecological harm, and structural damage. Over the past 150 years, waste management has emerged, transferring consumer waste responsibilities to practitioners. Consumers often disregard their waste fate, contributing significantly to pollution. Waste classification traditionally hinges on physical state-gaseous, liquid, or solid waste. This discussion delves into public health and environmental safety in solid waste management practices. It includes diverse activities like reduction, recycling, segregation, treatment, and disposal, with origins in simple methods like landfill and burning, lacking health-safe solutions historically.(Hamer, 2003)

Discussion:

The discussion emphasizes the critical role of composting, driven by microbial succession, in efficiently degrading organic waste with economic benefits. Despite this promising solution, global waste management faces diverse challenges, necessitating strategic approaches. Urbanization, industrialization, and population growth intensify environmental strain, emphasizing the need for scientific waste management leveraging microorganisms like Bacillus, Corynebacterium, and Pseudomonas for sustainability. Tailored waste degradation approaches are crucial, particularly with the continuous growth of municipal solid waste posing environmental, health, and economic challenges. Microbial practices, such as composting and anaerobic digestion, are highlighted for their efficiency in waste treatment and recycling. The discussion underscores the significance of waste management practices, including composting, to address environmental pollution, waste classification, and the interconnected challenges posed by various waste streams for a sustainable future.

Conclusion:

In conclusion, composting emerges as a potent solution, driven by microbial succession, for efficiently degrading organic waste with economic benefits. However, global waste management faces persistent challenges, exacerbated by urbanization, industrialization, and population growth. Strategic, scientific waste management, and harnessing microorganisms, are imperative for sustainability. Tailored waste degradation and effective municipal solid waste management are crucial for addressing environmental, health, and economic concerns. Historical practices evolve with global trends. As environmental pollution surges due to rapid urbanization, bioremediation becomes imperative, with microorganisms offering cost-effective solutions. The escalating global municipal solid waste issue demands urgent attention. The interconnection of waste and pollution underscores the critical importance of reduction, recycling, segregation, treatment, and disposal practices for a sustainable future.

References:

1. Cheng, J., Shi, F., Yi, J., & Fu, H. (2020). Analysis of the factors that affect the production of municipal solid waste in China. Journal of Cleaner Production, 259, 120808. https://doi.org/10.1016/j.jclepro.2020.120808
2. El Asri, O., Fadlaoui, S., & Afilal, M. E. (2022). Applications of Microbes in Municipal Solid Waste Treatment. In Inamuddin, M. I. Ahamed, & R. Prasad (Eds.), Application of Microbes in Environmental and Microbial Biotechnology (pp. 587–607). Springer Nature. https://doi.org/10.1007/978-981-16-2225-0_21
3. Hamer, G. (2003). Solid waste treatment and disposal: Effects on public health and environmental safety. Biotechnology Advances, 22(1), 71–79. https://doi.org/10.1016/j.biotechadv.2003.08.007
4. Jinjiri, B. A., Garandawa, M., Sabo, R., & Mustapha, A. U. (2018). An Overview of Microorganism in Waste Management and Control. International Journal of Scientific and Research Publications (IJSRP), 8(12). https://doi.org/10.29322/IJSRP.8.12.2018.p84100
5. Mondal, S., Palit, D. (2019). Effective Role of Microorganism in Waste Management and Environmental Sustainability. In: Jhariya, M., Banerjee, A., Meena, R., Yadav, D. (eds) Sustainable Agriculture, Forest and Environmental Management. Springer, Singapore. https://doi.org/10.1007/978-981-13-6830-1_14
6. Mathews, S., & Gowrilekshmi, R. (2016). Solid Waste Management using Effective Microorganism (EM) Technology. International Journal of Current Microbiology and Applied Sciences, 5(7), 804–815. https://doi.org/10.20546/ijcmas.2016.507.093
7. Rastogi, M., Nandal, M., & Khosla, B. (2020). Microbes as vital additives for solid waste composting. Heliyon, 6(2), e03343. https://doi.org/10.1016/j.heliyon.2020.e03343
8. Singh, S., Parihar, S. S., Singh, R., & Saxena, A. (2020). THE ROLE OF SOIL MICROORGANISM IN MUNICIPAL SOLID WASTE MANAGEMENT. 7(3).
9. Tegene, B. G. (2020). Mode of Action, Mechanism and Role of Microbes in Bioremediation Service for Environmental Pollution Management. Journal of Biotechnology & Bioinformatics Research, 2(3), 1–18.
10. Wang, L. K., Hung, Y.-T., Lo, H. H., & Yapijakis, C. (2005). Waste Treatment in the Process Industries. CRC Press.
11. Zakari, H. (n.d.). The Role of Industrial Decomposers in Sustainable Waste Management and Environmental Protection.