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Mahmoud Nasr
Abdelazim Negm *Editors*

Solid Waste Management

Advances and Trends to Tackle the SDGs

Springer

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Solid Waste Management and Sustainability: Recommendations and Conclusions

Solid Waste Management and Sustainability: Introduction and Updates

Mahmoud Nasr and Abdelazim Negm

Abstract

Large amounts of solid waste have been generated due to the recent acceleration of urbanization and population growth, possessing considerable limitations to waste management systems and infrastructure. This book represents different types of solid wastes collected from domestic/households, agricultural/agro-industrial, and industrial sources. It illustrates the commonly used waste management methods, including physical, chemical, physico-chemical, thermal, thermochemical, biological, and biochemical techniques. Information about solid waste management and sustainability is connected to the 17 United Nations' Sustainable Development Goals (UN SDGs). The barriers, challenges, and opportunities associated with fulfilling the sustainability concept in waste management are defined. The book's outputs support the involvement of stakeholders, policy-makers, and public and private sectors in maintaining sustainable solid waste management strategies.

Keywords

Agro-industrial wastes · Domestic wastes · Feasible approach · Sustainability concept · Waste management update

1 Introduction

The acceleration of urbanization and population growth has recently been associated with an exponential increase in the amount of solid waste generated (Sonu et al. 2023). This increased pattern poses substantial challenges to waste management systems and infrastructure worldwide (Cucchiella et al. 2014). As such, the unmanaged dumping of solid waste negatively impacts the dominance of zooplankton, phytoplankton, and fish (Lopez et al. 2018). Various microorganisms (e.g., bacteria, fungi, cyanobacteria, and algae), in addition to plants and animals, are oppositely impacted by uncontrolled solid waste disposal (Santulli et al. 2023).

Some solid wastes can be utilized to maintain environmental and socio-economic benefits (Wang et al. 2023a). For instance, agricultural and forestry

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wastes represent biomass feedstock resources that could remediate polluted sites and act as an input (or a source) for energy production (Mengqi et al. 2023). This renewable resource should be characterized to determine the value-added materials and numerous residues under thermochemical conversion processes (e.g., pyrolysis, gasification, and combustion) (Ahmad et al. 2023). The appropriate characterization of this biomass includes surface morphology, pore-size distribution, ash fusion and deformation temperatures, calorific values, and thermogravimetric analysis (Palansooriya et al. 2023). These characterization techniques assist in selecting a specific biomass for the most suitable application (H_2, CH_4, or ethanol production) (Srimalanon and Kachapongkun 2023).

Valorization technologies in solid waste management can be classified into biochemical conversion (Subbarao et al. 2023) and thermal conversion (Thi et al. 2024). Biochemical conversion technology represents the microbial breakdown/degradation of organic portions (e.g., food residues, kitchen wastes, agricultural crops, and livestock manure) in solid wastes, generating biogas and digestate (van Midden et al. 2023). Anaerobic digestion utilizes microorganisms to convert biodegradable and moist waste (biomass) such as food waste and livestock sludge into biogas (mainly CH_4) (Eraky et al. 2023). This biogas can be used to produce energy, reducing the dependence on fossil fuels (Themelis 2023). Anaerobic digesters accept various organic-based substrates coming from the industrial, agricultural, and commercial sectors (Shi et al. 2021). Agricultural waste is one of the broadly employed substrates for anaerobic digestion applications (Torres-Lozada et al. 2023). Anaerobic digestion can be classified as either dry or wet, according to the amount of water (moisture) in the slurry, manure, and sewage sludge (Emmanouilidou et al. 2023). For instance, dry-based anaerobic digestion includes a lower amount of liquid digestate compared with the wet-based one. Some biorefinery technologies are used to recover nutrients from liquid digestate (Wang et al. 2023b). Moreover, solid digestate can be employed as compost, acting as an organic conditioner in the soil matrix (van Midden et al. 2023). Composting denotes a series of biochemical reactions conducted by the microbial community under controlled aerobic conditions (Syarifinnur et al. 2023). This process raises the decomposition rate of organic substances, yielding C, H_2O, minerals, and nutrient-rich stabilized compost (Palansooriya et al. 2023). Composting temperature highly affects the mineralization of simple compounds (e.g., amino acids and sugars), degradation of complex organic constituents (e.g., cellulose, hemicellulose, lignin, and fats), and pathogenic microorganisms' deactivation (Awino and Apitz 2023).

This chapter generally covers the main topics discussed in the book titled "*Solid Waste Management: Advances and Trends to Tackle the SDGs*." These topics include the recently employed methods of solid waste management to meet the sustainability concept. As such, the biological and thermochemical techniques of solid waste conversion were explored in terms of fulfilling the three pillars of sustainability.

2 Bibliometric Analysis of Solid Waste Sustainability

The bibliometric study analyzes data on the published articles about "Solid," "Waste," and "Sustainability." The required information (number of articles, journal titles, subject areas, affiliation, and citation analysis) was collected from the SCOPUS databases in the 2015–2022 period. Table 1 lists the essential parameters and results of this search strategy. The published articles address pollution reduction by physicochemical, advanced oxidation, thermal, separation, and biological safer and cleaner technologies. The main objective of these articles is to avoid the detrimental impacts of chemical contaminants and materials on the receiving environment (soil, water, and atmosphere). The outputs of the articles are essential for a multidisciplinary and diverse audience of scientists, policymakers, the broader public, and the environment-caring stakeholders.

Table 1 Bibliometric analysis data on solid waste sustainability

Parameter	Data/observation
Database	SCOPUS
Query string	TITLE-ABS-KEY (solid AND waste AND sustainability)
Period time	Year of publication 2015–2022
Language	English
Number of documents	3576 document results
Document type	Article (2393) Review (432) Conference Paper (378) Book Chapter (272) Book (30) Others (71)
Top 10 subject area	Environmental Science (2156) Engineering (1030) Energy (889) Social Sciences (500) Chemical Engineering (372) Business, Management and Accounting (334) Materials Science (320) Agricultural and Biological Sciences (259) Chemistry (243) Computer Science (221)
Top 10 journals	Journal of Cleaner Production (180) Sustainability Switzerland (176) Waste Management (144) Science of the Total Environment (96) Journal of Environmental Management (94) Resources Conservation and Recycling (81) Waste Management and Research (73) Bioresource Technology (58) IOP Conference Series Earth and Environmental Science (52) Environmental Science and Pollution Research (50)
Top 5 affiliations	Universiti Teknologi Malaysia (42) Chinese Academy of Sciences (40) Universidade de São Paulo (37) Ministry of Education China (36) University of Tehran (32) Universiti Malaya (31) Universidade Estadual Paulista Júlio de Mesquita Filho (27) University of Johannesburg (26) Universiti Sains Malaysia (26) National University of Singapore (26)
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3 Clustering of Most Common Keywords Associated with Solid Waste Management and Sustainability

VOSviewer was utilized to present a clear understanding of solid waste management and sustainability. The main topics covering the waste management approach can be described as follows (Fig. 1):

- Use of machine learning and artificial intelligence for optimizing solid waste gasification and pyrolysis systems
- Bibliometric studies on the characterization of solid waste structure

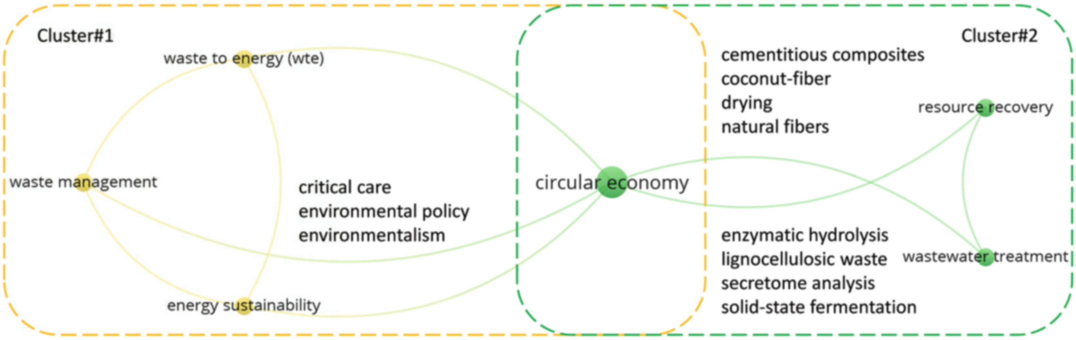

Fig. 1 Clustering of keywords obtained from bibliometric analysis data on solid waste sustainability

- Occurrence and monitoring technologies for treating landfill leachate
- Valorization of food processing wastes and by-products for biochar production
- Promotion of net-zero emissions from waste recycling industries
- Green material (e.g., waste-based and sustainable concrete): evaluation of strength and durability of concrete containing different agricultural waste materials as an additive
- Assessment of natural resource security in the water, energy, and food nexus under the umbrella of solid waste management
- Toward sustainability through the circular economy of plastic packaging waste management options
- Vermicomposting as a sustainable, cost-efficient, and environment-friendly approach to organic waste management
- Composting and fermentation for organic waste management and profitable use
- Sustainable management of e-waste (e.g., laptops, printers, cellular phones, freezers, microwaves, refrigerators, computers, and air conditioners) in developing countries
- Role of smart technologies for implementing industry 4.0 environment in product lifetime extension, supporting the transition to the green economy
- Green strategies for converting agricultural waste to biofuels, maintaining environmental sustainability

4 Physical-Based Conversion Using Cavitation

Cavitation-assisted methods can be used prior to anaerobic digestion to maintain sustainable management of food waste (Sonu et al. 2023). The completion of the cavitation process is influenced by some physical factors (or mechanical impacts), such as shock waves, microjets, and shear stress. These factors are generated due to the rupture of cavitation bubbles, which destruct material structure and reduce solid particle size. This route increases the total porosity of agricultural waste feedstock, facilitating the release of cellulose substrate and the associated nutrients and readily biodegradable organic matter into the medium. The success of the particles' disintegration by cavitation depends on the efficient cleavage of the strong hydrogen bonds between complex protein molecules, generating simpler ones that are soluble in the solution. Furthermore, extremely high temperatures and pressures are accompanied by the creation of a series of chemical reactions, yielding multiple reactive species. These species, including •OH and H• radicals and H_2O_2, cause strong oxidation of organic compounds and enhance lignin depolymerization. Cavitation could also facilitate enzymatic transesterification for biodiesel production, depending on the interaction between oil (or fat) and monohydric alcohol (e.g., methanol) in the presence of a catalyst. The biomass used for cavitation includes agricultural residues of acacia nilotica branches, bagasse, bamboo dust, coconut coir, cotton