Chapter

Studies, Efforts and Investigations on Various Aspects of Solid Waste Management with Emphasis on Developing Countries

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Abstract

Solid waste can be broadly classified as putrescible and non-putrescible based on its biodegradability. Municipal solid waste contains food waste, papers, plastic, paints, heavy metals and rubber. Industrial solid waste may contain waste adsorbent, waste catalyst sludge, solid residue of by-product, residue of reactions and hazardous materials also. Dewatering, centrifugal filtration, drying and incineration are usual steps used for solid waste treatment in industries. Biodegradable solid waste, being rich in organic content, can be used to synthesize various useful organic compounds. Vermicomposting is an effective method for converting organic waste into nutrient-rich fertilizer. Food and vegetable waste can be processed to obtain useful products. Inorganic domestic waste and electronic waste may contain valuable heavy metals like gold and platinum. E-waste and industrial waste containing hazardous waste need to be classified and treated carefully. Non-biodegradable waste like plastic and rubber can be reused or recycled. Non-government organizations in developing countries are playing key role in creating awareness among people about solid waste. Recycling in industries is promoted by government through various schemes and initiatives. This chapter briefly explains initiatives and investigations aimed at increasing adoptability and efficiency of various solid minimizations, reuse, recycle methods and technologies used for synthesis of value-added products.

Keywords: recycle, decomposition, fermentation, synthesis, yield, recovery

1. Introduction

Solid waste can be broadly classified as putrescible and non-putrescible, based on its biodegradability. Putrescible waste contains organic matter. This waste is suitable for digestion and land disposal. Non-putrescible waste is generally non-biodegradable waste which cannot be digested. Municipal solid waste contains food waste, papers, plastic, paints, heavy metals and rubber. Municipal waste needs to be classified based on biodegradability for further treatment. Local civic bodies are now putting stringent norms for classification of solid waste. In India green and blue containers are provided to households to separate this waste and source. Industrial solid waste may contain, waste adsorbent, waste catalyst sludge, solid residue of by-product, residue of reactions, etc. This solid waste may contain hazardous material also. Dewatering,

centrifugal filtration, drying and incineration are usual steps used for solid waste treatment in industries. Bio-degradable solid waste, rich in organic content can be used to synthesize various useful organic compounds. Non-biodegradable waste like plastic, rubber can be reused or recycled. Reduce, reuse and recycle are nowadays trending concepts in solid waste management. Non-government organizations (NGOs) in developing countries are playing key role in developing awareness among people about proper segregation and collection of solid waste. Recycling industry is promoted by government through various schemes and initiatives. This chapter briefly explains initiatives and investigations aimed at various solid minimizations, reuse and recycle methods and methods used for synthesis of value-added products from solid wastes. Initiatives taken by governments; non-government organizations are briefed in the chapter. Also, investigations carried out by scientific community to treat and recycle solid waste are reviewed. The chapter contains efforts taken for solid waste recycle and reuse in Asian countries, though it contains some significant efforts in other developing countries also. This review is based on available literature, research papers and available reports on solid waste management.

2. Methodology

Solid waste contains bio-degradable and non-bio-degradable material. Non-bio-degradable material cannot be digested and hence reuse or recycle of this type of waste is becoming important area of investigation. Countries like China, Taiwan and Malaysia are taking initiatives to reduce plastic waste by reuse and recycle principle. First three sections (Sections 3–5) of the chapter are devoted to plastic and non-bio-degradable waste. In remaining sections, reuse, recycle, recovery and energy generation methods for biodegradable waste are explained with the help of available literature and research papers. Domestic and municipal solid waste treatment needs to be more familiar with people. For this, efforts are being taken by government authorities by adopting regulations and stricter norms. These regulations along with awareness created by social groups and organizations can improve waste management scenario in developing countries. Another aspect of solid waste treatment discussed in this chapter is investigations carried out by researchers to optimize the waste reuse and recycle technologies. This aspect is briefed with the help of research papers published by investigators from these developing countries.

3. Plastic bags

Plastic bags are used for containing and transporting goods. Also, they are used for vegetables, groceries and other domestic items as a container. Plastic, which sometimes is non-replaceable, is very important material if used sensibly. The plastic bags are very thin and flexible. The disposal of these plastic bags is creating huge problems in developing countries. If these bags are recycled, the disposal problem would not arise. But lack of awareness and willpower has played a great roll in plastic ban. Nowadays the governments have banned the use of plastic bags above certain thickness. Even many other civic bodies are banning plastic use. Studies show that increase in reuse of plastic can reduce the eco-impact of plastic to a great extent [1]. In developing countries, blockage of drainage due to plastic causes calamities such as flood. Also, it can be a reason for mosquito breeding. Lack of sophistication of the recycle and waste treatment facility develops concern about manufacture and use of plastic [2]. Many developing countries in

Africa have adopted use of glass container instead of plastic. They are promoting use of cloth bags instead of plastic bags [3, 4].

4. Waste plastic

Waste plastic and rubber can be used in road construction [5]. Semi-dense bitumen concrete can be prepared and used for road construction. Waste plastic material such as high-density polyethylene (HDPE-2), low-density polyethylene (LDPE-4), poly propylene (PP-5) and polystyrene (PS-6) can be used for obtaining different products [6]. Slurry formation, liquefaction, recovery and condensation are the steps in the process. Use of superplasticizer can enhance the properties of waste plastic in road construction [7]. Biomedical plastic waste finds application in road construction. Compared to normal the bituminous mix, bio-medical plastic waste coated mix had better properties [8]. Pyrolysis oil can be derived from the waste plastic and can be used to derive diesel. Studies indicate that this diesel is suitable for use in engine [9]. Use of plastic waste in the flexible pavements increases strength and durability [10, 11]. Bitumen requirement can be reduced by 8–12% by using plastic waste for pavement material [12]. Thermal cracking of waste plastic can convert them into usable oil form [13]. Also, plastic bottles can be used for the construction of house. It is observed that these houses are bioclimatic. It means that when it is cold outside is warm inside and vice versa [14].

5. E-waste

Discarded, obsolete, end of life electrical and electronics equipment forms Electronic waste (E-waste). Heavy metals such as lead, cadmium, chromium, mercury, barium is present in E-waste [15]. The E-waste recycling needs quantitative measures for recycling and reuse of E-waste [16]. Illegally imported E-waste from developed countries is additional E-waste problem faced by India like countries [17]. There is need for increasing awareness about health effects of E-waste and importance of recycling. Inventorization and unhealthy conditions of informal recycling, inadequate legislation, poor awareness and reluctance on part of the corporate to address solid waste issues are drawbacks of waste minimization programs in India [18]. Waste materials from discarded computers, televisions, stereos, copiers, fax machines, electric lamps, cell phones, audio equipment and batteries can be hazardous to health. For example, lead can leach out from the E-waste materials, and enter into human bodies through oral route [19]. According to Kumar and Shah, the crude recycling activities cause irreversible health and environmental hazards [20]. So, there is need of refinement of the process adopted for recycle. According to Kumar and Karishma, India is fifth largest producer of E-waste in the world. In India only recycling of E-waste is 10% of recycle business [21]. About 65% of E-waste is generated in urban Area in India [21]. About 21% of this E-waste is plastic. E-waste is fastest growing waste stream in the world [22, 23]. Around seven lakh tons of E-waste were produced in India in 2016 [24]. Individual and government contributions can help to tackle this E-waste problem [25]. It is important to bridge the gap between the formal and informal divide in E-waste management in India [26]. E-waste recycling provides jobs to thousands of people in India. There needs to be coordination between formal and non-formal sectors for proper treatment and recycling of E-waste. There is need for the collection, segregation and primary dismantling of non-hazardous fractions of E-waste. Compatible and efficient technology for E-waste was a matter of concern for India and many

developing countries. According to Vats and Singh, informal recyclers are treating 95% of the E-waste generated with hazardous practices [27].

6. Food waste utilization for product synthesis

Food waste can be used for synthesis of various useful chemicals. Source separated food waste can be used for synthesis of ethanol with thermophilic enzymes [28]. Food waste biomass can be used in treating wastewater. Anaerobic digestion of this waste upon acidogenesis produces volatile fatty acids [29]. Ethanol cultivated biomass can be used effectively for the effluent of the food waste digestion. Food waste can be processed in long-term operation of a laboratory anaerobic reactor in mesophilic conditions for anaerobic fermentation to produce biogas and useful products [30]. Shukla et al. have explored the possibility of biohydrogen production from food waste [31]. Degradation of food waste and energy recovery through biogas production are twin benefits of the anaerobic digestion [32]. Factors such as organic loading rate, temperature, time, pH, carbon to nitrogen ratio play vital role in the process. With increase in methanogenic bacteria, the methane percent in biogas increases significantly [33]. An investigation by Akpan indicated that producing ethanol from food waste is more economical than producing it from other waste organic sources like old newspapers [34]. For synthesis of biohydrogen from waste, methods such as the methods like electrolysis of water, steam reforming of hydrocarbons and auto-thermal processes can be used [35]. According to Kapdan and Kargi, use of photosynthetic algae is one of the important methods for hydrogen synthesis from waste [36]. Investigations are reported on synthesis of bioplastic from food waste. Ingredients from food waste such as starch, cellulose, fatty acids, sugars and proteins can be used for bioplastic synthesis [37]. Many investigations are reported on hydrolysis of food waste and subsequent ethanol formation [38, 39]. Various investigations are reported on synthesis of lactic acid, vinegar and citric acid from waste materials including food waste [40–43].

7. Aerobic treatment methods for food waste

Anaerobic methods reduce the sludge volume significantly and produce biogas fuel. Major disadvantage of this method is that it causes nuisance to nearby population [44, 45]. Aerobic thermophiling composting reduces odor problem [46]. pH, temperature, moisture content, organic carbon, volatile solids are vital factors during aerobic composting [47]. Also, C/N ratio and volume reduction are performance indicators of the process [48]. Obtaining optimal performance system is very vital in increasing acceptability of the waste treatment method [49]. Waste management strategy includes many steps such as disposal, treatment, reduction, recycling, segregation and modification [50].

8. Vermicomposting for domestic solid waste

Vermicomposting has advantages over aerobic and anaerobic digestion methods as it overcomes few drawbacks like odor, space and cost of these two methods. Vermicomposting is a method used to convert organic waste into fertilizers with the help of worms. Factors affecting the process are parameters like the growth rate (pH), number of worms, number of cocoons and worm biomass [51]. Bedding material has also influence on the process. Newspaper bedding was effective in the investigation carried out by Manaf et al. [51]. Studies have shown that

vermicomposting improves the soil structure, enhancing soil fertility, moisture holding capacity and in turn increase the crop yield [52, 53]. Vermicomposting derived liquid can be used for agriculture [54]. This liquid has very high nutrient value. Studies confirm that home composting has potential to reduce the greenhouse gas emission [55]. Investigation carried out by Kulkarni and Sose indicated that pH values between 6.4 and 7.6 are favorable for vermicomposting. 30–50% moisture is required for vermicomposting [56]. Optimum temperature lies between 25 and 30°C.

9. Paper waste

Paper waste can be used for applications like biofuel synthesis and ceiling boards, bioelectricity production, and fuel gas generation. Also, it can be used in mixed concrete. Papers are normally recycled. In order to prepare good quality paper only limited number of recycles can be done. So finally, it results into huge amount of waste, this waste sludge can be used in the concrete up to 30% concentration, as investigation revealed that up to 30% addition the concrete quality increases and it decreases after that [57]. Also, waste paper sludge can be used for biofuel synthesis. The sludge can be converted into simple fermentable sugar by microbial process [58]. The waste sludge can be mixed in 1:1 proportion with calcium carbonate additive to form good quality ceiling boards [59]. Detachment of ink from the-waste papers increases their drainability [60]. According to Allahvakil et al. [60], it is possible to modify the chemical or physical bonds with enzymes such as pectinase, cellulase and hemicellulose. This helps in detachment of ink from the paper. The waste papers can also be used as raw material for bioelectricity generation. Microbial fuel cell with Clostridium species can be used for the purpose [61]. According to research carried out by Mathuria and Sharma [61], a microwave plasma reactor can be used for conversion of waste papers to fuel gas. Waste paper sludge ash can be used for stabilization of clay soil. An investigation by Khalid et al. [62] indicated that the waste sludge ash up to 10% can exhibit excellent binding properties in the clay. According to Arshad and Pawade [63], the addition of waste paper also reduces the quantity of clay required.

10. Gold recovery from solid waste

Electronic and mobile component contain valuable materials like gold and platinum. Ammonium thiosulfate can be used for leaching gold from mobile circuit boards [64]. According to Chehade et al. [65], the printed circuit board contains about 0.15% of gold. Aqua regia can be used as a leaching agent for recovery of gold [66]. This process can be automized to provide solution to gold recovery [67]. Fibrous ion exchange resins can improve gold and platinum recovery. Catalyst industry waste contains gold, platinum and valuable metals [68]. About 3 vol% NaClO, 5 kmol/m^3 HCl and 1 vol% H_2O_2 can be used for leaching platinum compounds [69]. In case of hydrochloric acid (HCl), the recovery is 99%. Platinum and gold removal from the industrial waste is necessity from ecological and environmental point of view [70].

11. Biogas production

Factors such as pH, organic loading, moisture content plays significant role in biogas production. Various types of biomass like fruit waste, domestic waste and crop residues can be used for biogas production. Pineapple waste biomass 48%

concentration in biogas was obtained in less than 50 days [71]. Cow dung is also very good source of biomass. Paper waste exhibits highest methane concentration in biogas, about 73% than other solid wastes such as cow dung, saw dust, rice husk and millet waste. However, hydrogen sulfide concentration is highest in this biogas [72]. A mixture of equal percentage of paper waste and biomass can be used for biogas production to increase quality of biogas. It is observed that the biogas production increases by 50% than paper waste alone. In case of orange peels, it is needed to pre-treat the peels as that content limonene, which is antimicrobial [73]. Many such investigations are reported on biogas synthesis from various type of solid waste [74–77]. Disposal of the final sludge from treatment plants needs to undergo drying and further incineration or dumping of dry biomass [78].

12. Bioconversion of waste feed stock

Putrescible solid waste like food and fruit waste, food grain waste, vegetable waste can be used for production of various products by employing bioconversion with suitable bacteria or microorganism [79]. Single cell protein can be obtained from orange peels and cucumber peel by using *Aspergillus niger* and *Saccharomyces cerevisiae* [79, 80]. These investigations suggested that glucose addition to the supplemented fruit hydrolysate medium. Solid state fermentation of orange peels with *Aspergillus niger* yields pectinase [81]. Content of ammonium sulfate, glucose and water in the culture medium affects the process [81]. Ethanol synthesis from fruit and other biodegradable waste is very common method of utilizing waste [82–87]. Number of other products such as citric acid, acetic acid, lactic acid, lactic acid, etc. can be obtained by using suitable microorganisms and operating conditions [84–87]. These conditions differ from product to product and waste type.

13. Hazardous waste

Hazardous waste poses serious problem to human being and environment. These hazardous wastes may contain biological waste, nuclear waste, heavy metals and flammable materials to considerable extent. Stricter laws and their implementation are required to save the environmental from the hazardous waste [88]. Proper classification and monitoring of hazardous waste can help to treat the waste efficiently [89]. Incineration and recycling are two most sustainable waste management practices [90, 91].

14. Conclusion

Bio-degradable solid waste, rich in organic content can be used to synthesize various useful organic compounds. Non-biodegradable waste like plastic, rubber can be reused or recycled. Reduce, reuse and recycle are nowadays trending concepts in solid waste management. Non-government organizations (NGOs) in developing countries are playing key role in developing awareness among people about proper segregation and collection of solid waste. Recycling industry is promoted by government through various schemes and initiatives. Local civic bodies are now putting stringent norms for classification of solid waste. In India green and blue containers are provided to households to separate this waste and source. Industrial solid waste may contain, waste adsorbent, waste catalyst sludge, solid residue of by-product, residue of reactions, etc. This solid waste may contain hazardous

material also. Dewatering, centrifugal filtration, drying and incineration are usual steps used for solid waste treatment in industries. In developing countries, blockage of drainage due to plastic causes calamities such as flood. Also, it can be a reason for mosquito breeding. Lack of sophistication of the recycle and waste treatment facility develops concern about manufacture and use of plastic. Following observations were made based on study of literature on solid waste treatment.

- Many developing countries in Africa have adopted use of glass container instead of plastic.
- Compatible and efficient technology for E-waste was a matter of concern for India and many developing countries.
- Various investigations are reported on synthesis of lactic acid, vinegar and citric acid from waste materials including food waste.
- Waste management strategy includes many steps such as disposal, treatment, reduction, recycling, segregation and modification.
- Various types of biomass like fruit waste, domestic waste and crop residues can be used for biogas production.
- Studies have shown that vermicomposting improves the soil structure, enhancing soil fertility, moisture holding capacity and in turn increase the crop yield.
- Paper waste can be used for applications like biofuel synthesis and ceiling boards, bioelectricity production, and fuel gas generation. Also, it can be used in mixed concrete.
- Hazardous waste poses serious problem to human being and environment. These hazardous wastes may contain biological waste, nuclear waste, heavy metals and flammable materials to considerable extent. Stricter laws and their implementation are required to save the environmental from the hazardous waste.
- Platinum and gold removal from the industrial waste is necessity from ecological and environmental point of view.

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