Chapter

Biodegradable Waste

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Abstract

Biodegradable wastes are waste materials easily degraded or broken down naturally by factors such as biotic (bacteria, fungi, plants, animals, etc.) and abiotic (pH, temperature, oxygen, humidity, etc.). This process enables complex substances to be broken down into simpler organic compounds which subsequently fade into the soil. This is a natural process that could be prolonged or rapid and poses little risks to the environment. These waste materials could be termed green waste; including food waste, paper waste, and biodegradable plastics such are found in municipal solid waste. Other examples of biodegradable wastes include sewage, manure, sewage sludge, human waste, waste from various slaughterhouses, hospital waste, dead animals, and plants. Biodegradable waste could be said to be recyclable or reused; furthermore, bio-waste recycling may also directly contribute to climate protection. They are generally known as useful waste. Recycling is one of the current waste management strategies having great benefits for the environment.

Keywords: recycling, biodegradable, biotic, bio-waste, environment

1. Introduction

Waste can be said to be an inevitable constituent arising as a consequence of domestic activities or industrial action. They have little or no value, due to the fact that they generally have no alternative use. Lack of adequate waste disposal system generates a great challenge for both the environment and human life. Waste can be divided into biodegradable and non-biodegradable waste. Non-biodegradable wastes are inorganic sources of waste that are not easily decomposed by natural agents, they can remain on the planet for hundreds of decades. They are sources of great damage to the ecosystem examples include plastics, batteries, glass, metal, medical waste, etc. However, many of them can be recycled to produce new products.

Biodegradable wastes are waste materials easily degraded or broken down naturally by factors such as biotic (bacteria, fungi, plants, animals, etc.) and abiotic (pH, temperature, oxygen, humidity, etc.). The process is such that complex organic matter is broken down into simpler organic compounds such as carbon dioxide, water, methane, or simple organic molecules by microorganisms and other living things, acting in composting, aerobic digestion, anaerobic digestion, or similar processes [1].

This is a natural process that could be prolonged or rapid and poses little risks to the environment. These waste materials could be termed green waste (any biological waste that can be broken down into compost); including food waste, paper waste, and

biodegradable plastics such are found in municipal solid waste. Other biodegradable wastes include human waste, manure, sewage, sewage sludge, and slaughterhouse waste [1].

However, if these biodegradable wastes are not properly managed they could become sources of pollution, thereby impacting the health of the environment negatively. Current clean-up strategies including recycling biodegradable waste have endeavored to mitigate the detrimental impacts of such waste on the environment. This review chapter addresses the current methods (Recent Advances) in biodegradable waste management, which when adequately implemented, can reduce the impact of such waste on health and environment.

2. Types of biodegradable waste

Biodegradable waste can be commonly found in municipal solid waste as green waste, food waste, paper waste, and biodegradable plastics. Other biodegradable wastes include human waste, manure, sewage, and slaughterhouse waste.

1. Green Waste: This can also be referred to as "biological waste", it is known as any organic waste that can be composted. Its constituent is usually refusing from gardens such as leaves or grass clippings, and industrial or domestic kitchen wastes. Materials such as pine, hay, dried leaves, or straw are not considered green waste, they are termed "brown wastes" being rich in carbon, on the other hand, green wastes contain concentrations of nitrogen. Green waste can also be used the increment efficiency of several composting operations and can be introduced to soil to sustain local nutrient cycling. Many communities, especially in the United Kingdom, have initiated green waste recycling and collection programs in order to reduce the quantity of biodegradable materials in landfills [2].

2. Food Waste: There is rapidly increasing attention given to sustainable food and biodegradable waste management (FBWM) in the municipal solid waste management system, due to environmental challenges. The enormous amount of FBW generated in Japan, for instance, is a result of their preference for raw food; such as raw egg, raw vegetables, or raw fish or meat (sashimi, sushi, etc.). Fresh fruits in particular, as well as other food, population growth, and improvement in lifestyle and standards of living, have invariably introduced several logistical problems that result in massive amounts of FBW [3, 4].

   Over the years, food and biodegradable waste have become a serious challenge and concern for both the general public and the government [5–7]. However, this waste presents a great opportunity if it is put to better use.

   It is worth noting that food waste constitutes a fraction of the biodegradable waste which historically has gained less attention, in spite of the fact that it is the most likely waste stream that could contaminate other waste fractions. Moreover, it has been the major contributor to methane production in landfill [8].

3. Paper Waste: Paper waste causes severe problems in so many offices and industries over the world. Due to printing mistakes, billings, junk mails, and packaging, such paper could comprise approximately 70% of the total waste of a company. The recycling of paper is done by taking it to the recycling plant where

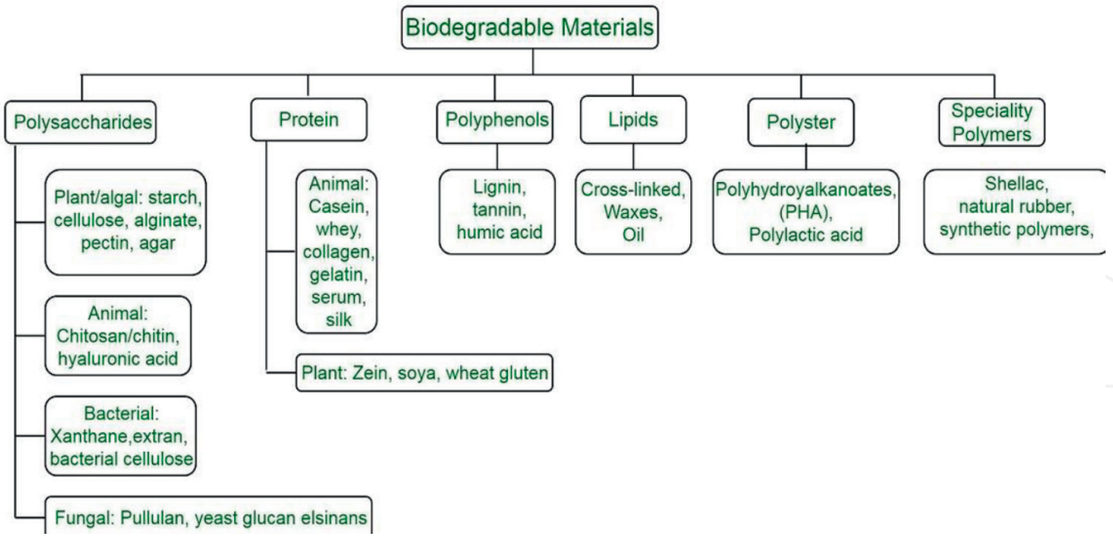

Figure 1.
Biodegradable materials classification. Source: [9].

it is firstly separated and then the separated paper is cleaned and washed with soap in order for it to be broken down. After it is broken down, it is then exposed to heat after which it breaks down into cellulose. Recycling is an essential method to reduce pollution and cut back on waste accumulation. Notebooks, old newspapers, and used envelopes can be recycled. However, paper contaminated with food, stickers, and carbon paper cannot be recycled (**Figure 1**).

4. Biodegradable plastics: They are plastics commonly produced with petrochemicals, microorganisms, renewable raw materials, or combinations of all three. Biodegradable plastics can be decomposed by the activity of living organisms, usually microorganisms, into carbon dioxide, water, and biomass. Two types of biodegradable plastic are known: oxo-biodegradable (OBP) and hydro-biodegradable (HBP). They both begin degradation via a chemical process oxidation and hydrolysis respectively, which is then followed by a biological process. They both emit carbon dioxide as they degrade but the latter can also emit methane as well, it is also not recyclable unlike the former which is recyclable.

   These biodegradable plastics are used in various areas in our daily lives including: They make compostable waste collection bags, and trays, punnets for meat, vegetable, and fruits. The use of bioplastics to make pins, plates, screws, and materials for capsules and pills. They are also used for tea bags, air pillows, pencils, pens, bottles, mulch film, and sharpeners [10].

3. Harmful effects of biodegradable waste

Biodegradable wastes may pollute and impact the environment in the following ways:

- A large amount of microbial flora around the wastes is produced which may increase the risk of communicable diseases in humans, plants, and animals caused by microbes.

Biodegradable Products	Period
Cotton rags	1–5 months
Paper	2–5 months
Rope	3–14 months
Orange peels	6 months
Wool socks	1–5 years
Cigarette butts	1–12 years
Plastic-coated paper milk cartons	5 years
Leather shoes	25–40 years
Nylon fabric	30–40 years
Plastic 6-pack holder rings	450 years

Source: [9].

Table 1.
Length of time for some commonly used products to biodegrade when they are scattered about as litter.

- Bad odor on burning may be produced due to the emission of certain gases.
- Waste collection may lead to dungeons of garbage thus promoting the carriers and vectors like mosquitoes and rats to spread communicable diseases.
- Lack of biodegradable waste handling may lead to an adverse effect on climate. For instance, methane emission from anaerobic fermentation may result in the production of landfill gas (**Table 1**).

4. Management of biodegradable wastes

Waste management could be said to be procedures and measures necessary to manage waste from its commencement to its disposal stage [11]. This involves the collection, transport, treatment, and eventually waste disposal, at the same time monitoring and waste management regulation process and laws governing waste, economic mechanisms, and technologies. Waste management can also include the reduction of waste production.

Waste management is usually aimed at reducing the adverse effects of waste on human health, the environment, planetary resources, and esthetics. A great deal of waste management addresses municipal solid waste, which is largely generated by household, commercial and industrial activity. It is worth noting however that waste management practices are not consistent among countries (developing and developed nations); regions (rural and urban areas), and residential and industrial sectors can all take distinct approaches [12].

Ankidawa and Emmanuel [13], stated that biodegradable materials constitute approximately 70% of the urban waste stream in evolving economies. Disposal of refuse in an indiscriminate manner is a frequent occurrence in many villages and big cities across some developing countries, these waste decay, as well as the generated odors, pollute the environment where they are disposed of. This will subsequently lead to runoff of these decayed refuse into rivers and streams, by such means altering the quality of water sources from lakes, rivers, streams, etc. which could be deleterious to humans if ingested [13].

4.1 Waste handling and transport

Solid waste handling can be said to include the storage, collection, transportation, treatment, utilization, processing, or disposal of solid waste, or could mean any combination of such activities. Methods of waste collection vary widely among various regions and countries. For instance, the world was estimated to generate about 2.2 billion tonnes of solid wastes just in the year 2020 [14]. Of these generated wastes, a great percentage will be basically municipal solid waste (MSW). Certainly, the biosphere system will not be able to absorb and recycle such a large amount of wastes. Hence priority has to be given to the management of MSW for proper treatment and disposal in order to avoid a negative impact on the environment as well as on human health.

The domestic waste collection involves the handling in the local waste handling facilities. Domestic waste collection services are often provided by local government authorities, or by private companies for industrial and commercial waste. In some places in the underdeveloped countries, areas, especially those in less developed countries, do not have formal waste-collection systems.

Waste transportation means the movement of waste over specified areas by trains, tankers, barges, trucks, or other forms of vehicles. Train wrecks or traffic accidents can result in waste spills and releases of pollutants that may contaminate the air, soil, and water. There is also the possibility of waste being released while loading or unloading during transportation. Many citizens are concerned about the transportation of the waste through their communities and the risks involved. Some are as well bothered that the municipal waste from urban areas may be contaminated with substances that could contaminate local drinking water supplies or toxic chemicals.

Finally, the preparation of an Impact Assessment of a potential legislative proposal is of optimum importance. The objective is to look into various ways by which biodegradable waste is managed for instance in the EU, and to provide appropriate policy assessment options, such as the economic, social, and environmental impacts, as well as prospective opportunities/risks.

4.2 Segregation/separation of wastes

Waste or garbage most likely could be in the form of vegetable peels or fruits, wrapping materials, discarded objects, wasted food as household garbage, domestic sewage or chemicals, and fertilizers discarded and washed into rivers, etc. All these highlighted wastes can be segregated or separated into two basic components, as biodegradable and non-biodegradable components.

Contingent on the type of wastes, two garbage bins one for biodegradable wastes and the other for non-biodegradable wastes are usually advocated. This will help in easy sorting and recycling of wastes to make beneficial products. Green bins are designated for biodegradable wastes like fruit peels and vegetables, tea leaves, spoiled food, tissue paper, eggshells, hair, leaves, etc. Blue bins are designated for recyclable wastes like plastic waste, glass bottles, chocolate wrappers, old batteries, polythene bags, etc. However biodegradable waste could be managed by employing the following techniques:

I. Composting

Since biodegradable or organic wastes like vegetable peels, waste food, leaves, dead flowers, and eggshells can be recycled, they are converted into manure by burying them in compost pits. Composting can be said to be the act of burying

recyclable organic wastes like leaves, waste food, vegetable peels, etc., in a compost pit. It is known to be a simple and almost effortless process of recycling. These wastes are biodegradable, this is a result of the action of small organisms like bacteria and fungi. It is also of importance to note that asides from bacteria and fungi acting in the compost, an earthworm called red worms (or red wigglers) can also act on wastes in the compost and degrade them.

Hence, composting, and the recycling of organic waste, including food waste and vegetation, decreases the amount of waste to be taken to the landfill, this is a sector that is growing rapidly. Ideally, compost residue has been reported to be a humus-like material, rich in organic matter, stable and sanitized, that is free from offensive odors arising from the composting process of segregating the biowaste collected [15]. Generally, recycling is thought to be beneficial to the environment, since leaving organic waste to decompose in landfills has a negative impact both economically and environmentally. Household waste that is commonly collected for recycling is the waste for composting, followed by paper and then glass [16] [**Table 2**]. Although metal cans make up only 1% by weight of the material collected to be recycled, recycling them however offers high energy as well as material savings. Organic matter of biodegradable wastes is degraded microbiologically during composting, generating products containing stabilized carbon, nitrogen, and other nutrients in the organic fraction, however, the stability depends on the compost maturity [17].

II. Vermicomposting

The type of composting that is a result of decomposition via different species of worms, especially worms like the red wigglers, white worms, and other earthworms is called vermicomposting. They create a mixture of decomposing food waste or vegetables, vermicast (worm casting), and bedding materials. The worms usually break down the organic matter into nutrient-rich manure which increases soil fertility. Vermicompost can be said to be made in 3–4 weeks and it seems like loose soil-like material.

Vermicast, an end-product of the breakdown of organic matter by earthworms could also be referred to as worm castings, worm manure, worm humus, or worm feces. It has been demonstrated that these excreta contain lower levels of contaminants and a higher nutrient content than the organic materials before vermicomposting [18]. Furthermore, vermicomposting is a superb organic fertilizer that is rich in

Material	% of household waste	Energy	Emissions	Raw material save/tonne recycled
Paper	18	28–70% less	95% less air pollutants	
Glass	7	18% less	30% less	1.2
Plastic	7	Up to 66% less		1.8
Cans (Fe)	3	70% less	86% less	2
Can (Al)	3	95% less	95% less	4

Source: [16].

Table 2.
Impact of recycling for different materials.

nutrients and soil conditioner, contains water-soluble nutrients and is an excellent, nutrient-rich organic fertilizer and soil conditioner [19]. It is also used in sustainable organic farming and gardening. It is worth noting that vermicomposting can be applied as well for sewage treatment. A variation of the process is vermidigestion or vermifiltration which is used to eliminate pathogens, organic matter, and oxygen demand from wastewater or directly from blackwater or flush toilets [20, 21].

III. Landfills

Sanitary landfills are generally used to dispose of non-hazardous solid wastes in an approach that reduces damage to human health and the environment. Before the evolution of sanitary landfills, solid wastes were frequently piled up on the ground in open-burning dumps, attracting rodents and insects as well as causing esthetic and public health issues.

Furthermore, landfills are usually large areas used for waste disposal. It is another method known to manage a vast amount of biodegradable waste. In a landfill, garbage is buried in such a way that it does not affect the environment negatively. Garbage buried inside landfills can be left there for a prolonged period as it decomposes very slowly. A landfill, when full, can be converted into a park. An example is Indraprastha Park.

Landfills have been traditionally used in handling large quantities of solid waste, being a low-cost method of waste management. As a result of rising in costs and reduction in land availability, many cities are focused on ways to reduce the quantity of solid waste dumped in landfills. For instance, in some cities, the government charges people for collection of garbage based on the size of the container collected. Hence, the bigger the can, the higher the cost.

This is planned to raise people's cognizance of the quantity of solid waste being generated as well as proffer an incentive for recycling. Programs to recycle plastic, paper, metal, and glass are currently being executed in various cities and countries with grand success. With the implementation of such programs, landfill areas can be anticipated to be readily available for a longer period of time. A case study is with the scenario in India, the management of waste is critical. The country holds 20% of the world's population and has only 2% of land space. There are inadequate spaces and locations to store waste. As a result, the primary focus should be on waste recycling and its reuse [22].

5. Uses and application of biodegradable waste

Anaerobic digestion used to treat biodegradable waste produces digestate a nutrient-rich solid material and biogas containing carbon dioxide and methane. However, for the biogas to burn to produce electricity, there is a need for further processing. This generated electricity can be used to power the plant. Alternatively, it could be used as a transport fuel. Biodegradable waste can also be used for composting or as a resource for electricity, fuel, and heat through the process of anaerobic digestion or incineration [23]. A classic example is that of Danish AIKAN and the Swiss Kompogas process of anaerobic digestion of biodegradable waste [24, 25]. While incineration can possibly recover the most energy, anaerobic digestion plants retain nutrients and make compost for soil amendment while still recovering some of the energy contained in the form of biogas. Kompogas for instance generated 27 million Kwh of electricity and biogas in 2009. The oldest of

the company's lorries has achieved 1,000,000 kilometers driven with biogas from household waste for over 15 years [26].

6. Conclusion

Biodegradable wastes can be described as those wastes, whose source is typically of plant or animal origin that can be degraded by other living organisms such as microorganisms. They can be commonly found in municipal solid waste as green waste, food waste, paper waste, biodegradable plastics, etc. If not properly managed they could become sources of environmental pollution, resulting in sicknesses and diseases and possibly death to humans and other living organisms as well. There are various steps by which biodegradable waste could be managed such as the collection, transport, treatment, and eventually waste disposal.

Biodegradable waste is not accumulated but is used up in a short time, they become part of biogeochemical cycles and give back rapid turnover.

They can be used to produce renewable waste as a bio-energy resource (for instance biogas), manure, fertilizers, compost, and other substances after decomposition.

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Conflict of interest

"The authors declare no conflict of interest."

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References

[1] Rani R. Management of biodegradable waste. Journal of Biotechnology and Biomaterials. 2021;**11**(6):132. ISSN: 2155-952X

[2] Williams ID, Kelly J. Green waste collection and the public's recycling behaviour in the Borough of Wyre, England. Resources, Conservation and Recycling. 2003;**38**(2):139-159. DOI: 10.1016/s0921-3449(02)00106-4. ISSN 0921-3449

[3] Ministry of Agriculture, Forestry and Fisheries. Annual report on food, agriculture and rural areas in Japan FY 2007. Ministry of Agriculture, Forestry and Fisheries. 2008. Available from: http://www.maff.go.jp/e/annual_report/2007/pdf/e_all.pdf [accessed: 2015-09-20]

[4] Takatsuki H. Waste problems and our lifestyle. Waste Management. 2013;**33**:2145-2146

[5] Gentil EC, Gallo D, Christensen TH. Environmental evaluation of municipal waste prevention. Waste Management. 2011;**31**:2371-2379

[6] Lebersorger S, Schneider F. Discussion on the methodology for determining food waste in household waste composition studies. Waste Management. 2011;**31**:1924-1933

[7] Wong L-F, Fujita T, Xu K. Evaluation of regional bioenergy recovery by local methane fermentation thermal recycling systems. Waste Management. 2008;**28**:2259-2270

[8] Gromez MGC, Grimes SM, Moore D. In-vessel composting of food waste – A catering waste management solution. CWRM. 2008;**9**(1):19-23

[9] GEEKSFORGEEKS. Biodegradable and non-biodegradable materials. 2022. Available from: https://www.geeksforgeeks.org/cdn.ampproject.org/biodegrdable and non-biodegradable materials [Accessed: 2022-08-19]

[10] Sciencing. What are the benefits of biodegradable plastic?. 2018. Available from: https://sciencing.com/benefits-biodegradable-plastic-22789.html [Accessed: 2022-08-20]

[11] United Nations Statistics Division. Environment statistics. Available from: unstats.un.org. Archived from the original on 17 March. 2017. Retrieved 3 March 2017

[12] Gary D. Waste management practices: Literature Review (PDF). Dalhousie University – Office of Sustainability. Archived (PDF) from the original on 1 February 2012. 2011. Retrieved 3 June 2022

[13] Ankidawa AB, Emmanuel N. Recycling biodegradable waste using composting technique. Journal of Environmental Science and Resources Management. 2012;**4**:40-49

[14] Christine Montgomery. World Bank, Solid Waste Management. 2022. Available from: https://www.worldbank.org. [Accessed: 2022-08-21]

[15] European Commission (EC). Working Document on Biological Treatment of Biowaste, 2nd Draft. 2001

[16] Postnote. Recycling household waste. Postnote recycling household waste. 2005;**252**:1-4

[17] Zwart K. Fate of C and N pools-experience from short and long term compost experiments. In: Anon, editor. Applying composts benefits and needs. Brussels Federal Ministry of Agriculture,

Forestry, Environment and Water Management, Austria and European Communities. 2003. pp. 77-86

[18] Ndegwa PM, Thompson SA, Das KC. Effects of stocking density and feeding rate on vermicomposting of biosolids (PDF). Bioresource Technology. 1998;**71**:5-12. DOI: 10.1016/S0960-8524(99)00055-3

[19] Coyne K, Knutzen E. The Urban Homestead: Your Guide to Self-Sufficient Living in the Heart of the City. Port Townsend: Process Self Reliance Series; 2008

[20] Xing M, Yang J, Wang Y, Liu J, Yu F. A comparative study of synchronous treatment of sewage and sludge by two vermifiltrations using an epigeic earthworm Eisenia fetida. Journal of Hazardous Materials. 2011;**185**(2-3):881-888. DOI: 10.1016/j.jhazmat.2010.09.103. ISSN 1873-3336. PMID 21041027

[21] Pilot studies for vermifiltration of 1000m 3day of sewage wastewater. Available from: www.academia.edu. Retrieved 2016-02-21. [Accessed: 2022-08-17]

[22] Khatabook. What is non-biodegradable waste?. 2021. Available from: https://khatabook.com/blog/what-is-non-biodegradable-waste/ [Accessed: 2022-08-17]

[23] National Non-Food Crops Centre. NNFCC report on Evaluation of Opportunities for Converting Indigenous UK Wastes to Fuels and Energy Archived at the Wayback Machine 20 July 2011. Available from: nnfcc.co.uk [Accessed: 2022-08-20]

[24] AIKAN website. Available from: aikantechnology.com [Accessed: 2022-08-20]

[25] Recycling chain Archived 2012-03-23 at the Wayback Machine. Available from: kompogas-utzenstorf.ch [Accessed: 2022-08-20]

[26] Gesundheit, Kraft und Energie für 2002. zuonline.ch. 3 January 2002. Archived from the original on 2 September 2002 [Accessed: 2022-08-20]