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Review Paper

Solid and Liquid Wastes: Avenues of Collection and Disposal

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Abstract

For high moisture and organic nutrients-rich Indian wastes, predictably with high methane potential, anaerobic digestion appears to be most suitable option, providing renewable biogas as a substitute for fossil fuels and organic manure as an equally important by-product for soil enrichment. Admittedly, the existing anaerobic technologies are suited to homogeneous wastes, while the same ones for processing heterogeneous solid urban wastes need to be modified by trial and error in the absence of alternative technologies.

Keywords: waste, waste management, anaerobic digestion, pollution, organic waste, composting

Introduction

The term 'waste' refers to solid or liquid matter which has no longer any economic value. With industrialization and urbanization, ensuing growth in urban solid and liquid wastes is a relatively recent development in India. During mid-seventies, urban per capita solid waste generation was 250–350 gm/day[1], whereas it has increased to 320–530 gm/day in late eighties; total sewage generated in India was about 30 billion liters/day in 1997 and recent figures indicated additional 50-70 % increase[2]. The quantity of waste generated per capita is estimated to increase at a rate of 1-1.5% annually in India[3,4]. Such enormous increase in waste (solid) should impose the cumulative requirement of land to around 1400 km^2 by 2047 in India[5]. Large quantity of waste in solid and liquid form is generated by food processing industries, agro-based industries, sugar mills, breweries, distilleries, tanneries[4] and pulp/paper[6] industry as summarized in table-1. Organic fraction of such solid waste has a large energy potential (20-25 MJ/m^3)[7].

It is estimated that i. the industrial waste generated coming from agro-waste, food processing industries, dairies, distilleries, pressmud, tanneries, pulp/paper etc., provides scope to set up 12 million plants for generating 17,000 MW bioenergy and ii. under the Ganga Action Plan, 46,000 m^3 biogas can be produced daily from the sewage treatment plants in 21 Indian mega-cities by treating about 339 million liters/day municipal wastewater, equivalent to 99,450 kWh/day electrical energy[4]. From these estimates, it appears well settled that waste management challenges can only be met through marshalling the talents of competent environmental engineers and biological scientists through the design and application of cost-effective solutions[3,5].

Classification of Wastes

The word 'waste' and the act of 'wasting' are human inventions for short-term convenience. Otherwise, waste doesn't exist in nature. In terms of collection and disposal, they are liquid and solid wastes. While waste is classified differently in different contexts[3,7], in the context of theme of this review, the following classification appears appropriate.

Table-1
Industry-wise profile of waste[20]

Source of waste	Quantity	Energy recovery potential (MWe)[20]
Tannery	52,500 m^3 waste water /day	140
Pulp /paper industry	1600 m^3 waste water/day	
Dairy industry	50-60 million liters/day	
Willow dust	30,000 tones/year	-
Municipal liquid	12,145 million liters/day	100
Distillery	8,057 m^3/day	300
Municipal solid	27.4 million tones/year	900
Pressmud	9 million tones/year	220
Food/fruit processing industry	4.5 million tones/year	40

Biodegradable waste: Typically, it originates from microbial, plant and animal sources, which may be broken down by other living organisms; garden or park waste, grass, flower cuttings and hedge trimmings; animal carcasses, parts thereof from slaughter houses not intended for human consumption; leftover and spoiled food from household kitchens, restaurants, central kitchens and catering facilities; biodegradable plastics, residues from food/fruit/vegetable processing industry; human excreta, cattle dung, sewage, etc. Industrial wastes from edible oil production, breweries, wineries, distilleries, dairies, cheese processing, organic chemicals etc. While these wastes may appear physically different, they tend to be fairly homogeneous in biochemical composition (carbohydrates, fats and proteins) for anaerobic digestion for biogas production by virtue of their high methane potential.

Hazardous/toxic waste: This category includes waste medicines, dispensary waste, paints, chemicals, light bulbs, fluorescent tubes, spray cans, fertilizers/pesticide containers, batteries, shoe polish etc.

Recyclable waste: It comprises of paper, glass bottles, ceramics, cans, metal scrap, certain plastics, etc.

Inert waste: It consists of construction and demolition waste, dirt, rocks, debris etc. with relatively lower environmental impact by virtue of its non-biodegradability.

Solid waste management

Municipal solid waste (MSW) includes predominantly solid/semi-solid domestic and commercial wastes collected by a municipality within a given area. Its composition varies widely from season to season and place to place. In fact, the composition of waste depends on several factors viz. population, climate, culture, lifestyle, food habits. The biodegradable fraction of majority of waste is quite high (35-75%) and plastic contents is usually low (1%). Chemical analysis of waste has shown i. 0.56 - 0.71 % total nitrogen, ii. 0.52 – 0.82 % phosphorous, iii. 0.52 – 0.83 % potassium and iv. 25 – 40 % C:N ratio[8]. Heaps of un-disposed wastes, rotting around industrial sites, both sides of highways, market places and area-wise corners in the towns/cities represent ugly sights, apart from causing health and pollution problems due to putrefaction and leading to proliferation of vectors and pathogens, as also greenhouse gaseous emissions.

Collection: In industrialized countries, solid waste in urban areas is often collected from homes by kerbside collection using purpose-built waste collection vehicles; in rural areas, residents are required to convey their household wastes to collection sites known as transfer stations. Its collection from several sites in smaller amounts is otherwise a bigger problem. In small localities, mechanical systems use a proprietary vacuum-based collection device, known as Envac, which conveys refuse via underground conduits to collection/treatment site.

Transport: Biodegradable solid waste disposal is a mixed bag of problems and opportunities. Transportation cost to disposal sites outside prescribed city limits being high, short-circuiting the transport, often the waste is dumped in an open space on the side of highways, shifting pollution load from city to emerging residential areas. The manner in which waste is transferred from waste-bins to trucks leaves lot of aerosols and dust-laden with pathogens. The spills or leakages during the journey to dumping yard spreads lot of microbes are spread on ground and air, the waste being carried open to sky.

Separation: The separation of heterogeneous solid wastes into relatively homogeneous entity prior to category-wise disposal further adds to the cost. Owing to its biodegradability and high methane potential, it can be looked upon as a promising feedstock for biogas generation[7]. This economic incentive opens an effective way to handle localized specific wastes, contributing to their environment-friendly disposal. An appropriate way to avoid potential health hazards of no or delayed disposal is to intercept a biodegradable waste at the point of generation before being mixed with non-biodegradable wastes. Kitchen and vegetable/fruit market wastes are largely suited for this purpose. These wastes can be collected and treated at source.

Agency for disposal: Waste disposal is either carried out by a department of the municipality, or typically by a private company under contract. Industrial waste being generated from a variety of commercial manufacturing processes to new products from a set of input materials, its disposal is the responsibility of the industry. If it is not dealt in this manner, biodegradable waste contributes to greenhouse gas emissions and by implication climate change[3,5,7].

Disposal: Disposal is considered a part of public health and sanitation function of municipalities. The waste was allowed to be consumed by stray cattle, incinerated, dumped in a landfill, composted or anaerobically digested and recycled to enrich the soil.

Cattle feed: Like other wastes, biodegradable waste can be fed to animals. In India, swine, stray cattle (especially non-milch cows, pigs and assess) have worked as natural scavengers, by design or default.

Incineration: Once upon a time, incineration appeared to be an attractive option for disposal. It emitted many toxic chemicals and gases viz., carbonyls, volatile organic carbonyls, polyaromatic carbonyls etc. to the detriment of pure air and respiratory problems of infant and old. However, in retrospect, incineration of organic waste, rich in moisture appears to be an ill-conceived program in mega cities as a result of high consumption of energy, creation of pollution load, corrosion of equipment and economically being non-sustainable due to high organic moisture content of waste[9,10].

Landfill: Several countries have employed landfill for disposal of wastes in the past and continued it for a long time. The degradable fraction of the waste in the landfill gives rise to leachate and biogas[11]. The By volume, disposal through landfill has been the largest contributor to methane gas production in several countries in the world since last six decades. It causes noxious odor as it decomposes, attracts flies and vermin and thus, has the highest potential to add Chemical Oxygen Demand

(COD) to the leachate. While biogas generation and collection in initial and end stages being sporadic, little and economically non-viable, North America and Canada collected biogas from many landfill sites only during the peak period, abandoning them to Nature's mercy, causing major pollution due to CH_4 and CO_2[12]. Literature is replete indicating that landfill technology is indeed outdated[13]. Therefore, the European Union (EU) Landfill Directive and Waste Regulation, like regulations in other countries, enjoins diverting organic wastes away from landfill disposal.

Composting/vermi-composting: It is simple, technologically practicable and environmentally sustainable, practiced in India on large scale from time immemorial. At least 175 industrial units undertake composting on commercial scale, utilizing wide variety of locally available wastes to generate organic manure (compost, farm yard manure, soil conditioner) for sustainable agro-productivity from non-productive/degraded soils, besides being successfully used for higher productivity from organic farming, horticulture, aromatic/medicinal plants propagation, nurseries etc. However, the composting route results in uncontrolled release of CO_2 into the atmosphere without capturing energy from waste[14,15].

Anaerobic digestion: Of the above approaches, energy recovery through anaerobic digestion seems to be practicable because i. total quantity of waste is reduced by nearly 60-90%, ii. need for huge requirement of land is obviated, iii. cost of transportation of waste to landfill sites is minimized, iv. pollution of soil, water and air is arrested to minimum and v. recovering of methane as renewable energy source and effluent as organic manure appears attractive, eco-friendly, cost-effective and sustainable[16].

Effluent treatment

Effluent collection: Liquid waste, on an average, contains 90-95 % water, pathogens, non-pathogens, algae, invertebrates, fishes, frogs, soluble/suspended organic matter, soluble/insoluble in organics, gases etc. It is adversely affected in quality by anthropogenic influence, discharged by domestic, agricultural, commercial and industrial applications. Sewage is a sub-set of waste water, a major source of pollution, especially in urban areas. It is mainly a liquid waste containing some solids, typically consisting of faces and urine from toilets, laundry waste from households and industry, washing water from processing and cleaning and other materials which go down the drains. It contains a wide range of potential contaminants, released at various concentrations, disposed off usually via a pipe/sanitary sewers/storm drains /cesspool emptiers.

Effluent constituents: Its composition varies widely; it may contain water (> 95%), pathogens (bacteria, fungi, viruses, prions and parasitic worms), non-pathogens (> 100,000 / ml for sewage), army of small creatures (protozoa, insects, arthropods, small fish, etc.), suspended organic particles (faces, hairs, food, vomit, paper fibers, plant material, humus, etc.), soluble organic material (urea, fruit sugars, soluble proteins, drugs, pharmaceuticals, etc.) insoluble inorganic particles (sand, grit, metal particles, ceramics, etc.), soluble inorganic materials (ammonia, road-salt, sea-salt, hydrogen sulfide, thiocyanates, thiosulfates, etc.), and gases (hydrogen sulfide, carbon dioxide, methane, etc.[17,18].

Sewage may drain directly into major watersheds with minimal or no treatment. When untreated, it has serious implications on the quality of environment and health of aqueous biota and human beings. While some chemicals, especially heavy metals and pesticides pose grave risks even at low concentration and remain a threat for long periods due to their bioaccumulation in animal/human systems, pathogens cause a variety of debilitating ailments. In fact, it is on record that 70 % of ailments in India are rooted in water-borne contaminants[19].

Effluent disposal: There are numerous processes that can be used to clean up wastewaters, depending on the type and extent of contamination. Most wastewater is treated in wastewater treatment plants (WWTPs) through physical, chemical and biological processes. However, the use of septic tanks and other on-site sewage facilities (OSSF) are widespread in rural areas, serving 25-50 % of the homes in many countries. The largely employed aerobic treatment system is activated sludge process, based on maintenance and recirculation of a complex biomass composed by microbes, able to degrade the organic matter in the wastewater. Anaerobic processes are equally widely applied in the treatment of industrial wastewaters and biological sludge, yielding biogas, compost and reclaimed water for irrigation[17,18,19]. The present trend is preference to anaerobic digestion over aerobic degradation, since the former generates biogas and organic manure in cost-effective manner, whereas aerobic path is energy-intensive and inefficient.

Conclusion

For high moisture and organic nutrients-rich Indian wastes, predictably with high methane potential, anaerobic digestion appears to be most suitable option, providing renewable biogas as a substitute for fossil fuels and organic manure as an equally important by-product for soil enrichment. Admittedly, the existing anaerobic technologies are suited to homogeneous wastes, while the same ones for processing heterogeneous solid urban wastes need to be modified by trial and error in the absence of alternative technologies. Anaerobic digestion processes are equally widely applied in the treatment of industrial wastes and wastewaters yielding biogas and compost. Sewage services exist to manage sewage collection, treatment and recycling or safe disposal into the environment.

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