Eco. Env. & Cons. 28 (January Suppl. Issue) : 2022; pp. (S340-S344)
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ISSN 0971–765X

http://doi.org/10.53550/EEC.2022.v28i01s.047

Review of landfill studies on physico-chemical characters, associated microflora and their Dynamics

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(Received 18 August, 2021; Accepted 22 September, 2021)

ABSTRACT

With rapid urbanization, landfills or the fixed sites where solid wastes from the adjacent areas are dumped have become an inevitable part of urban life. But landfills give rise to various types of hazards like methane emission due to anaerobic decomposition of wastes, ground and surface water contamination due to release of leachates containing toxic substances and also pathogenic microbes. The inevitability of the landfills and the associated hazards calls for better understanding of the landfills. Microbes or the natural decomposers degrade the biodegradable components of the solid wastes, but the heterogeneous nature of the solid waste, the rate of deposition, the physicochemical conditions, non-biodegradable components disrupts the normal biogeochemical cycles and as a result the landfills turn into an environmental and health hazard. Short-term enhanced degradation can help in reducing long-term environmental impacts and also help in efficient management of the landfills (Warith, 2002). The dynamics of the biotic and abiotic components of the landfills remains far from being fully understood. Better understanding of the microbially mediated processes in the landfills has become necessary as there are not many alternatives to disposing solid wastes all across the globe.

Keu words : *Anaerobic decomposition, Landfill, Microflora*

Introduction

Solid wastes generated by anthropogenic activities have become a cause of concern due to its massive quantity and shrinking space in the urban settings. In the rural areas and in the earlier times, the nature of wastes and the rate of deposition were different than that at present. Waste could be managed at individual household level. But with rapid urbanization, availability of space is decreasing, and waste generation per individual is increasing. Moreover, non-biodegradable components in the solid wastes are increasing with changing lifestyles. In the urban areas, landfills have become the most used and the cheapest means of disposal of solid wastes. Although nature can decompose and recycle most of the substances, but the non-biodegradable substances, rate of deposition and the physico - chemical conditions inside the unmanaged landfill, creates a myriad of environmental and health hazards. A proper understanding of the composition and the processes that take place within a landfill can help in proper management of landfills. This paper aims to understand the the physicochemical conditions of the landfills, the hazards associated with it, and the role of microbes in the landfills through review of research works associated with the landfills.

The environmental and health hazards of landfills have been reported by many researchers. Decomposition process in a landfill releases liquid leachates and various gases like methane that have heavy detrimental effect on the environment (Barlaz and Ham, 1993). Municipal solid waste produced by household wastes is the third major source of an-

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thropogenic methane emissions and constitutes 11% of global methane emissions (Singh *et al*., 2018). The chemicals released from a landfill can percolate down posing a serious threat for groundwater and also surface runoff water, that can contaminate water bodies (Szymanski *et al*., 2018; Mor *et al.,* 2006). The landfill leachates are highly toxic and can produce carcinogenic and genotoxic effects in humans through food (Mukherjee *et al.,* 2014). With increasing attention of the researchers, huge volume of knowledge has emerged from the landfill studies ranging from physico-chemical characters to microbial diversity.

Physico-chemical characteristics of landfill

For better management of the landfills, understanding the general physico-chemical characteristics becomes necessary. Various studies from different parts of the world, have reported about the physico-chemical properties of the landfills. The moisture content in a landfill, gradually decreased with time and age of the landfill and it varied from 30% to 68.9% (Feng *et al*., 2016; Jani *et al*., 2016; Rupani *et al.,* 2019). pH during the initial phase of composting ranges between 5–5.5 and the young landfill leachate had low pH values while the old leachates had slightly basic pH (7.5-8.5) (Rupani, 2019; Wei *et al.,* 2010). COD values ranged from 18g/l - 21 g/l and BOD from 11 g/l -14 g/l. Maiti *et al*. (2016) observed COD to be 4191.66± 2282.19 mg/l. The young landfill leachate is commonly characterized by high biochemical oxygen demand (BOD) (4000–13,000 mg/l) and chemical oxygen demand (COD) (30,000–60,000 mg/l), the old leachates were characterized by a relatively low COD (<4000 mg/l) (Wei *et al.,* 2010). Various heavy metals have been observed in the landfills and are one of the major factors responsible for landfill toxicity. Jani *et al.* (2016), found higher concentrations of zinc, copper, barium and chromium in landfill soil. Heavy metal contents in composts from cities were found to have higher content of Zn, Cu, Cd, Pb, Ni and Cr (Saha *et al*., 2009). The excess heavy metal concentration is due to the presence of batteries, electronics, cosmetics and so forth. The most common metal components are cadmium, chromium, nickel, zinc and lead which varies depending on the amount of heavy metal materials in the waste (Rupani *et al.,* 2019). Maiti *et al*. (2016) reported heavy metals lead and mercury higher than the permissible limits in their study.

Reactions in a landfill

Barlaz and Ham, (1993) have described how the landfills pass through different phases and the role of microbes in methane emission. The landfills undergo four phases of decomposition, (1) an initial aerobic phase, (2) an anaerobic acid phase, (3) an initial methanogenic phase, and (4) a stable methanogenic phase. An additional aerobic or humic phase of decomposition has been proposed (Christensen and Kjeldsen, 1995) When refuse is buried in a landfill, a complex series of biological and chemical reactions occur as the refuse decomposes. After decomposition of waste proceeds, the rate of oxygen diffusion exceeds the rate of oxygen depletion due to microbial activities and there is shift of landfill from anaerobic system to aerobic system.

Microbes associated with landfills

The knowledge about microbial communities have increased many fold because of the availability of culture independent methods of studying microbes. Municipal solid waste landfills which have become an unavoidable part of urban society have been studied by various researchers to assess their ecological impact. Due to technological advancement and attention of the researchers, a huge volume of knowledge has accumulated from all over the world about the microbiome concealed in a landfill. Studies on susceptibility of bacteria to heavy metals that contribute to toxicity in a landfill has shown that most bacterial species are more susceptible to chromium toxicity than other heavy metals like lead or mercury (Jayanthi *et al*., 2016). Huge diversity of organic substrates present in a landfill and infinite microniches created by interactions among the different factors make landfills a highly complex system. How the diversity changes temporally and spatially under regular disturbances and interactions among the different species needs further studies. The microbial communities within a landfill take up diverse roles and occupy a huge diversity of micro niches. It is difficult to make generalisations about microbial diversity of landfills as the factors affecting diversity are unstable and show temporal and spatial variation. Microbial diversity in a landfill varied with organic matter, and moisture content of the stored waste (Wang *et al.,* 2016). Although the pattern was not clear, but a funtionally diverse group of bacteria like cellulolytic bacteria, sulfate-reducing bacteria, sulfate-oxidizing bacteria and xenobiotic organic compound degrading microbes were observed in landfill (Song *et al.*, 2015). Wang *et al.*, (2017), analysed spatial variation of the microbial diversity at different depths of land fill and found that Firmicutes, Proteobacteria, and Bacteroidetes were the dominant phyla, and the dominant genera included *Halanaerobium, Methylohalobius, Syntrophomonas, Fastidiosipila, and Spirochaeta*. In the top layers, Methylohalobius (methanotrophs) were more abundant while the methane producing *Syntrophomonas* and *Fastidiosipila*, were more abundant in the middle and bottom layers of stored waste. Song *et al.* (2015) studied the temporal variation of land fill microbiome at initial methanogenic phase and stable methanogenic phase. In the initial methanogenic phase, archaea (Methanomicrobiales) comprised 97.6% of total archeal population and this reduced to 57.6% in stable methanogenic phase. Another archea Halobacteriale was 0.1% in the initial methanogenic phase and was 20.3% in stable methanogenic phase. Among the bacteria, abundance of Firmicutes was 21.3% in the initial methanogenic phase and was 4.3% in the stable methanogenic phase. The bacteroidetes which were 11.5 % in the initial phase, and dominated of the stable methanogenic phase with 49.4% abundance. Members of *Bacillus, Fibrobacter*, and *Eubacterium* were found in the initial methanogenic phase, while the stable methanogenic phase harboured groups of *Microbacterium*. Krishnamurthi *et al*. (2012) reported dominance the phylum Firmicutes (86.6%), followed by Actinobacteria (9.6%) and Proteobacteria (3.7%) in the landfill microbial diversity analysis. More than 17 species of the genus *Bacillus* belonging to Firmicutes were reported, while Archeal diversity was limited to the orders Methanosarcinales and Methanomicrobiales of the phylum Euryarchaeota. Groups of clostridia known to contain mesophilic cellulolytic species like *C. coccoides*, *C. lentocellum C. leptum* groups and *Clostridium thermocellum* could be identified in landfill (Van Dyke and Mccarthy, 2002). Kalwasiñska and Burkowska (2013) showed that the bioaerosol emitted by the municipal facility is the source of hemolytic bacteria (≤300 CFU m^{-3} of air), as well as of pathogenic bacteria (*Pseudomonas aeruginosa* and *Bacillus subtilis*).

Conclusion

Today landfills are an undesirable but inevitable part of urban life. If left unmanaged, landfills can give rise to myriads of environmental problems like methane emission, ground water contamination and also health hazards through leachates releasing carcinogenic substances and harmful microbes. Advancement in technology and attention of the researchers have facilitated better understanding of the landfills and have highlighted the seriousness of threats they pose in the long run. When global warming is a major threat to Earth, methane producing Methanogenic bacteria like Methanomicrobiales, *and Syntrophomonas* have been reported from various landfills.

Various researchers have established the effect of landfills on ground and surface water. Pathogenic bacteria *Pseudomonas aeruginosa* and *Bacillus subtilis* have been reported in the air samples collected near landfills. Some of the common microbial phylum observed in landfill were Firmicutes, Actinobacteria, Proteobacteria, Bacteriodetes. Since microbes play a major role in degradation of landfill wastes, it becomes imperative to understand the microbial dynamics over time and space in order to mitigate the different hazards and also in proper management of the landfills.

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