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REVIEW ARTICLE

Treatment of landfill leachate by anaerobic digestion, biogas yield and co-digestion possibilities

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ABSTRACT

One of the significant concerns related to rapid urbanization in developing countries is solid waste management. In a developing country like India, municipal authorities are struggling to deal with solid waste management. Leachate, byproduct of landfill disposal is adding to its concern, by polluting ground water, surface water and adjacent soil quality. This study deals with the anaerobic treatment potential of landfill leachate. As anaerobic digestion treats the leachate as well as generates bio gas which has economical value. But due to its complex nature and heterogeneous properties biogas production is often not constant. Co-digestion with suitable material can provide a consistent source and undisturbed digestion. Various co-digestion potentials are described in this paper.

Keywords: Municipal solid waste, anaerobic digestion, landfill leachate, co-digestion

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INTRODUCTION

Across 95% of municipal solid waste collected around the world is disposed of in landfills (Gao et al., 2015). According to the Central Pollution Control Board (CPCB), India produced 152076.7 tonnes of municipal solid waste (MSW) per day (TPD) in 2018–2019, with an average waste of 0.11 kg per capita per day. Only 149748.6 TPD (80 %) was collected, 55759 TPD (22%) was handled or processed and roughly 50161.33 TDP (60–70 %organic component) was landfilled (SWACHH BHARAT MISSION MUNICIPAL SOLID WASTE MANAGEMENT MANUAL Part I: an Over view, 2016.). The organic compound content of the leachate produced by this form of MSW is high. This organic-rich landfill leachate has the potential to create a considerable quantity of biogas through anaerobic digestion.

Alternative fuels, such as biogas production from waste landfill leachate, might be a good alternative to fossil fuels, which are becoming increasingly expensive. The biogas generated can be utilised to power a generation. Biogas generates 2.14 kWh of power per m^3 (de Castro et al., 2020). For the treatment of leachate, anaerobic digestion can be utilised. Anaerobic digestion has potential remediate pollutants such as COD, BOD, TKN, pH, and others (Luo et al., 2020). Anaerobic digestion can

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remove 90% of organic matter and fulfil the conditions set out in the "Municipal Solid Wastes (Management and Handling) Rules, 2016" for the disposal of treated landfill leachates.

When landfill leachate is mixed with any other organic waste, the methane production rate rises, resulting in increased biogas production that can be utilised to generate electricity. Mono digestion of leachate yields 350 to 480 ml/g VS under conventional experimental conditions (Jaroenpoj and Eng, 2014), whereas mono digestion of rice straw yields 203 to 280 ml/g VS (Cruz-Santos et al., 2020). Biogas generates 2.14 kWh of power per m^3 (Suhartini et al., 2019). By combining landfill leachate with agricultural waste or any other easily bio degradable material, the bio-methanation process will be accelerated, resulting in increased methane generation. Co- digestion of landfill leachte with various material like pineapple peel (Jaroenpoj and Eng, 2014), sugarcane bagasse fly ash (Sudibyo et al., 2018), crude residual glycerine (de Castro et al., 2020) has shown good results for biogas production, whereas agricultural waste is abundantly available in India.

LITERATURE REVIEW

(Azlina et al., 2009) built laboratory-scale digesters to investigate the impact of leachate chemical oxygen demand strength on biogas (methane) production. The results revealed that the high and low strength samples worked similarly, but at differing rates of biogas generation. Although the biochemical oxygen demand in the effluent was reduced by up to 80%, the performance of other parameters such as chemical oxygen demand, total suspended solid, and volatile suspended solid, which contribute 33 to 46 percent, 21 to 37 percent, and 20 to 35 percent, respectively, was slightly reduced.

Jaroenpoj (2014) investigated the behaviour of landfill leachate co-digestion with pineapple peels, with an emphasis on biogas generation. Mono-digestion of leachate and pineapple peel, as well as their co-digestion with three different mixing ratios, were investigated in laboratory scale batch studies. The leachate was collected at the Rochedale Landfill site in Brisbane, Australia, while the inoculum and pineapple peel were obtained from the Golden Circle facility. Mono-digestion of leachate yielded 24 L kgVSconsumed-1 of methane and a 37 percent clearance efficiency of volatile solids (VS). The findings of mono-digestion of pineapple peel revealed a greater methane output of 317 L kgVSconsumed-1 and an 80 percent VS elimination efficiency.

Hashemi et al. (2015) used hydraulic retention durations of 23 and 12 hours to conduct an interventional investigation with a wide range of organic loading rates of 0.93–25 g l-1 day-1. Chemical oxygen demand (COD) was 1.85–25 g l-1 at the start. This research looked at pH changes, total, soluble (SCOD), rapidly biodegradable (rbCOD) chemical oxygen consumption, volatile fatty acid degradation, biogas output, and methane percentage. Depending on the loading rates used, the organic matter removal efficiency ranged from 76 to 81 percent. At a loading rate of 19.65 g l-1 day-1, the highest volumetric methane production rate of 5.7 l CH4 - l-1 day-1 was reached. During biodegradation, almost 85 percent of the organic matter was transformed to methane.

Mohamed et al. (2016) investigated batch anaerobic digestion of municipal solid waste at room temperature for 60 days using two distinct inoculums (cow dung and sewage sludge) at varied inoculum concentrations of 10%, 20%, and 30%. The biogas yields from the reactors using cow dung as inoculum were 337.365ml/gVS, 481.95ml/gVS, and 567ml/gVS, respectively; similarly, sewage sludge as inoculum yielded 214.775ml/gVS, 321.198ml/gVS, and 383.52ml/gVS. 65.45%, 80.06 percent, 86.655 percent, 60.25 percent, 65.89 percent, and 72.78 percent.

Yarimtepe et al. (2016) investigated the use of an ultrasonic method for leachate as a pretreatment before anaerobic batch reactors in order to boost hydrolysis rate and biogas output. When compared to raw leachate at 400 W/l, the ratio of sCOD/tCOD was raised by 32% after 45 minutes of sonication. These findings revealed that ultrasonic pretreatment has a considerable impact on the conversion of particle to soluble organic matter. Biogas generation and methane concentration rise by 33% and 15% in pretreated and raw leachate, respectively, during anaerobic batch experiments.

Sudibyo et al. (2018) investigated the use of natural zeolite and sugarcane bagasse fly ash (BFA) as immobilisation media to improve the digestion rate of landfill leachate in an anaerobic packed bed reactor. On the basis of the experiment data, the Contois and Haldane growth kinetic models were evaluated. For both acidogenic and methanogenic phases, Contois provided the greatest fit. According to a statistical examination of Contois kinetic parameters using the Pearson correlation coefficient, zeolite, as an immobilisation media, had a stronger beneficial effect on the performance of anaerobic digestion of a leachate than BFA.

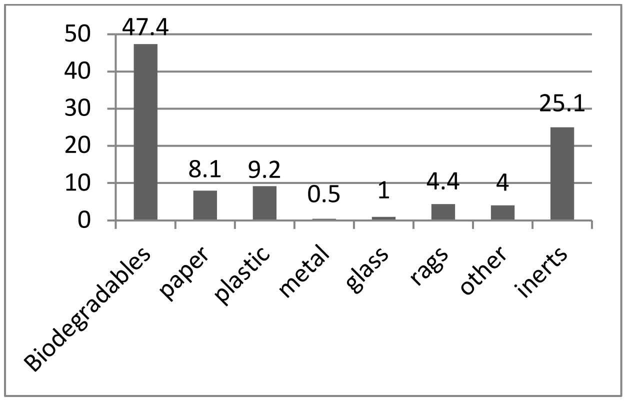
de Castro et al. (2020) used the modified Gompertz m model to assess the performance of anaerobic co-digestion of different concentrations of industrial landfill leachate associated with crude residual glycerin in terms of methanogenic potential, COD removal, accumulated methane production, and the effects of the factors (food/microorganism ratio and percentage of glycerin added to the leachate) and their interactions on kinetic parameters of methane The results showed a significant influence on the response variables: methanogenic potential, COD elimination, cumulative CH_4 production, and maximum predicted CH_4 production, with a 95% confidence interval.

For the treatment of landfill leachate and acid mine drainage, Zhou et al. (2021) conceived and built a laboratory-scale up-flow anaerobic sludge blanket (UASB) reactor (AMD). Chemical oxygen demand (COD), sulphate, and metal ions were all investigated. During the UASB's start-up phase, the highest COD and sulphate removal efficiency was 75 percent and 69 percent, respectively. At a 20-hour HRT, the greatest removal efficiency for COD and sulphate was 83 percent and 78 percent, respectively. In the UASB, the methane generation process was pitted against the sulphate reduction process.

LANDFILL SYSTEM

An engineering facility for disposing of MSW that is built and operated with public health and environmental issues in mind is referred to as a sanitary landfill (Sharma et al., 2020). Monofills are landfills that only accept one type of trash, such as ash, asbestos, and other similar pollutants (Sanjay et al., 2014). Landfills that are utilised to dispose of hazardous materials are known as secure landfills. Uncontrolled land disposal sites, sometimes known as waste dumps, are areas where trash is dumped in an unstructured manner on or into the ground (Luo et al., 2020). Due to financial restrictions, open dumps are the most common form of rubbish disposal in developing nations. Waste is thrown into wetlands for land development in Kolkata, Mumbai, Chennai, and Colombo . Ocean dumping is illegal by legislation in African nations. However, the practise continues to be outlawed in several African coastal cities (Luo et al., 2020). Other sophisticated waste disposal methods such as anaerobic digestion, composting, and incineration can be selected based on the kind of wastes in Northern European nations such as Germany, where the waste sorting system is quite efficient(Luo et al., 2020).

Table 1: Typical MSW Generation Fractions in India.



Source: Study conducted by CPCB & NEERI (2005)[16]

The framework provided by integrated solid waste management (ISWM) should be utilised to guide the selection of the most appropriate treatment technologies for MSW management. ISWM factories frequently use pre-processing facilities to separate organics from recyclables and other high-calorie waste. Organic waste is degraded aerobically to produce manure or anaerobically to generate power. Wholesalers receive separated recyclables for shipment to recycling facilities. High-calorie wastes are baled or processed so that they may be used as fuel or co-processed in cement plants. (SWACHH BHARAT MISSION MUNICIPAL SOLID WASTE MANAGEMENT MANUAL Part I: an OvervIew, 2016)

LANDFILL LEACHATE CHARACTERISTICS

The composition of landfill leachates varies greatly depending on the stage of waste development (i.e., aerobic, anaerobic acid, methanogenic, and stabilisation phases (CHAPTER-IV AUDIT FINDINGS ON URBAN LOCAL BODIES PERFORMANCE AUDIT Local Self Government Department 4.1 Waste Management, 2016). Around 200 toxic chemicals have previously been detected in landfill leachates in previous investigations (Naveen et al., 2017).

Although landfilling is a cost-effective, easy, and extensively utilised technique for solid waste disposal, it does have certain environmental consequences, such landfill leachate, methane emissions, and so on. Landfill leachate is one of the most complicated wastewaters, containing inorganic salts, heavy metals, a large number of biodegradable organics, and refractory components such as humic compounds, among other things (Salehiyoun et al., 2019). A municipal solid waste landfill's leachate includes high levels of contaminants such ammonical nitrogen, which is hazardous to a variety of creatures. The key drivers of leachate quality are the content and solubility of solid waste components. The quality of the leachate will alter as the content of the waste changes over time, such as due to weathering or biodegradation (Preston et al., 2020).

Anaerobic biological conditions are at the root of leachate production (Mandal et al., 2017). The first phase in anaerobic degradation is acid fermentation, which is followed by hydrolysis, acidogenesis, and acetogenesis (Sanjay et al., 2014). Dump age, waste type and content, site hydrogeology, seasonal weather variation, dilution by rainfall, precipitation, and the degree of decomposition within the landfill are all variables that impact the parameters of municipal landfill leachate (Luo et al., 2020).

Leachate contaminants are divided into four categories: (2) macro inorganic components such as ammonia (NH_4^+-N), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), manganese (Mn^{2+}), iron (Fe^{2+}), chloride (Cl^-), sulphate (SO_4^{2-}), and hydrogen carbonate (HCO_3^-); (3) heavy metals such as chromium (Cr^{3+}), nickel (Ni^{2+}), copper (Cu) (e.g., aromatic hydrocarbons, phenols, chlorinated aliphatics, pesticides, and plasticizers) (Sanjay et al. 2014.) (Mandal et al., 2017).

ANAEROBIC DIGESTION OF LEACHATE

Anaerobic digestion reduces the amount of organic waste discharged in landfills in industrialised nations, is ecologically friendly, and produces valuable byproducts (Zamri et al., 2021). Anaerobic digestion reduces the quantity of methane released into the atmosphere by landfills. Biogas and sludge can be utilised as by-products to replace fossil fuels and chemical fertilisers (Luo et al., 2020). According to a preliminary experiment on biogas generation from municipal solid waste (MSW) leachate conducted by (Azlina et al., 2009), anaerobic digestion not only resulted in renewable biogas production but also improved effluent quality.

Anaerobic digestion is a series of mechanisms that bacteria use to break down biodegradable materials in the absence of oxygen (AD). AD is a common renewable energy source that produces biogas, which comprises methane, carbon dioxide, and other gases in trace amounts. The effects of pH and initial organic loading rate on volatile fatty acid (VFA) and biogas generation must be evaluated during landfill leachate treatment by single and two-stage AD (Sanjay et al. 2014). Anaerobic biological processes provide a number of benefits over aerobic biological processes, including (1) much reduced sludge creation, (2) lower organics stabilisation, and (3) energy production owing to methane recovery (Lin et al., 2000). (1) anaerobic digestion (AD); (2) anaerobic filter (AF); (3) up-flow anaerobic sludge blanket (UASB); and (4) anaerobic ammonium oxidation are examples of anaerobic treatment of landfill leachate (Luo et al., 2020).

BIOGAS YIELD

The correct assessment of the volume of producible biogas and its methane content is one of the most important components of an anaerobic digester. Biogas generation and gas composition are influenced by the chemical makeup of feedstocks. The quantity of COD in the leachate has a significant influence on the amount of biogas produced and the amount of methane produced. Biogas production rates in the mesophilic temperature range of 25 to 35°C are intrinsically connected to the VSS content of the feed because methane is created by the breakdown of VSS (Azlina et al., 2009)

Several researchers investigated the effects of pH and initial organic loading rate on volatile fatty acid (VFA) and biogas generation during landfill leachate treatment by single and two-stage AD. The yields of methane and VFA are 0.21-0.34 L CH_4/(g COD removed) and 0.26-0.36 g VFA/(g COD removed), respectively (g COD removed). There has been a 21% increase in COD elimination overall.(Mandal et al., 2017)(Luo et al., 2020). Other studies revealed that for every tonne of COD added to leachate during AD treatment, more than 387 m^3 biogas was produced, with a methane concentration of around 65 percent and COD removal of 70 percent at an OLR of 17 kg m^{-3} day^{-1} (Mandal et al., 2017). In addition, AD is combined with other technologies to improve the efficacy of landfill leachate treatment in terms of pollutant removal and biogas production (Somani et al., 2019).

Co-digestion: Co-digestion is an anaerobic treatment that processes multiple substrates at the same time, resulting in increased system efficiency. Other substrates are usually added to an anaerobic digestion facility that has extra capacity. As a result, co-digestion might gain financially from sharing a mono-digestion reactor's extra capacity. In comparison to single substrate digestion, co-digestion results in higher energy generation and improved system stability. It's critical to have the right combination of substrates in order to maximise methane synthesis, as the right co-substrate reduces process inhibition (Jaroenpoj and Eng, 2014).

Co-digestion boosts biogas output by providing nutrients that are missing in the original substrate, resulting in favourable synergisms in the digestion medium. The modification of the C/N ratio is another cause for co-digestion. Microorganisms like a 25/1 ratio of carbon to nitrogen. The basic notion of co-digestion is to combine a low C/N ratio substrate with a high C/N ratio substrate (Jaroenpoj and Eng, 2014).Co-digestion is a desirable approach since it improves energy output while also benefiting the operating environment.

CONCLUSION

Because of its high organic content, anaerobic digestion is excellent for both landfill leachate treatment and biogas generation. To enhance the efficiency of pollutant removal and biogas production from landfill leachate, anaerobic digestion can be employed in combination with other methods. Anaerobic digestion of leachate produces biogas yields ranging from 22 to 700 L kg COD^{-1}. The constancy of biogas production is critical for the design of biogas to energy projects, as equipment selection is based on the amount of biogas generated. Co-digestion with different substrates is one way for increasing the poor biogas output stability of mono-leachate anaerobic digestion.

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