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Study of Processing of Municipal Solid Waste Landfill Leachate

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Abstract - The release of leachate poses a serious risk to both surface water and groundwater from MSW dumps. Leachate is any liquid that percolates through a landfill and collects the solids and liquids that have been stored there. When garbage has moisture, it attracts rainwater, which then seeps into the landfill and forms leachate. In this paper, we present the findings of an analysis of an aerobic treatment process applied to leachate from Ghazipur (Delhi) landfill, by way of coagulation flocculation theory, with the aid of coagulant and accelerator substances to speed up and improve coagulation and flocculation performance.

The primary objective of this research was to utilise a naturally occurring, low-cost material "as an accelerator addition to improve the chemical treatment process using Alum coagulant," with the accelerator ingredients being Perlite and Bentonite. The accelerator chemicals, including Alum at a constant concentration of 90 mg/l, significantly improved the efficacy of the chemical therapy. We found that the performance of perlite effluent was superior than that of bentonite. At a concentration of 40 mg/l, the removal ratios for Perlite were 86.7% for conductivity, 87.4% for turbidity, 89.9% for biological oxygen demand (BOD), and 92.8% for chemical oxygen demand (COD). For Bentonite, these values were 83.5% for conductivity, 85.0% for turbidity, 86.5% for BOD, and 85.0% for BOD.

Keywords - Leachate Landfill, Municipal Solid Waste, Coagulation Flocculation Theory, Biological oxygen demand (BOD), Chemical Oxygen Demand

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INTRODUCTION

Substances that have been dissolved or suspended in liquid and removed from solid trash in a landfill. When water drains downward through a landfill, it picks up dissolved components from the decomposing waste, creating leachate. It is possible for leachate to escape garbage and enter groundwater in older landfills and in those without a membrane. When this occurs, neighbouring water sources like springs and flushes often contain elevated levels of leachate. The distinctive odour of a rotting egg is immediately discernible. The human nose has an extremely low detection threshold for it, but even brief exposure can desensitise it. Hydrogen sulphide gas is heavier than air, hence it tends to gather in enclosed areas. When precipitation, such as rain or snow, penetrates a landfill's waste pile, the resulting polluted liquid is called leachate. Toxic compounds, including some that are known to cause cancer and other major health problems, are present in the leachate. Municipal solid waste (MSW) and hazardous garbage can be disposed of in a landfill, which is a designed disposal option. Open dumping is the primary step of landfilling utilised to dispose of solid waste in most developing nations [1]. It has been found that landfill leachate, gas emissions, slope stability, and odour control are all issues that need to be addressed during landfill design and operation [2••].

Municipal solid waste (MSW) in landfills degrades through a series of chemical, physical, and biological processes. Decomposed material is leached from landfills as rainwater percolates through garbage [7•]. The decomposition of MSW primarily produces leachate from landfills [8]. Consequently, "landfill leachate is defined as the liquid effluent created from rainwater percolation through solid waste disposed of in a landfill, along with the moisture present in the trash and the degradation products of residues" [9••]. Factors such as precipitation, evapotranspiration, surface runoff, groundwater infiltration, and landfill compactness [10••] have a significant impact on leachate volume.

Sanitary landfilling typically has lower operating costs than alternative technologies like cremation (Gotvajn & Pavko 2015). Toxic wastewater, known as leachate, can be produced when garbage undergoes a sequence of biological and physicochemical changes in a landfill. The discharge of such wastewater could contaminate the soil and groundwater in the area (Zamri et al. 2017). Safeguarding the environment and human health is a top priority in both open dumping and sanitary landfills (Xaypanya et al. 2018). Key technologies that are appropriate for treating landfill leachate include biological procedures, chemical and physical processes. However, there has not been a thorough evaluation of landfill leachate that takes into account its unique properties, environmental factors, and available treatment options. This paper is meant to serve as that kind of critical analysis.

Landfill Leachate And Its Characteristics

Leachate is created when water seeps through garbage in a landfill, carrying with it a variety of harmful chemicals (Mojiri et al. 2017). Pollutants found in municipal landfill leachate can be broken down into four classes: organic contaminants and substrates, inorganic compounds, heavy metals, total dissolved solids (TDS), and colour (Mojiri et al. 2016a). Table 1 categorises landfill leachate into three main age categories: young, intermediate, and old (Aziz 2012; Tejera et al. 2019). Leachate in "new" landfills (i.e. the acid phase) contains a low pH, large amounts of volatile acids, and minimally decomposed organic matter, according to Aziz (2012) and Vaccari et al. (2019). Table 2 displays global features of landfill leachate. According to [3,4,5,6], leachate is the liquid that are likely to contain a large amount of organic contaminants, the COD(chemicaloxygen demand), BOD(biochemical oxygen demand), ammonia, hydrocarbons suspended solids, concentrations of heavy metals and inorganic salt.

Organic and inorganic pollutants, and heavy metals

Heavy metal and other inorganic pollutants such as **trace elements, mineral acids, metals, metals compounds, inorganic salts, metals with organic compounds as complexes, sulfates, and cyanides**, having higher concentration than permissible limits can pollute water.

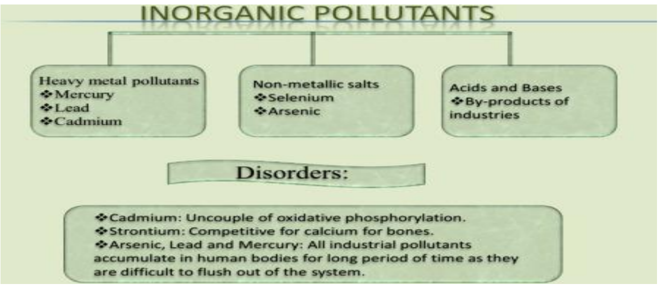

Figure 1: Inorganic Pollutants

Nitrate in wastewater has been degraded using several different advanced treatment technologies. The conventional advanced systems for the denitrification process of wastewater include biological methods (Kodera et al., 2017), catalytic methods (Murphy, 1991), reverse osmosis (Epsztein et al., 2015), ion-exchange systems (Samatya et al., 2006), adsorption (Adeleye et al., 2016), and electrochemical (EC) methods (Martinez et al. However, there are significant constraints on the use of these methods to the cleaning up of nitrate-contaminated wastewater. Treatment of water via a biological or catalytic approach can result in secondary pollution and even make the treated water poisonous. The process of reverse osmosis is sensitive to biofouling and needs a certain amount of particular pressure to function. The ion-exchange method is quite picky about the pollutants and ions it removes from wastewater. Major challenges for denitrification of wastewater include adsorbent selection and its reusability (Bhatnagar and Sillanpaa, 2011; Kapoor and Viraraghavan, 1997).

Anions and cations make up the inorganic macrocomponents that you're probably most familiar with: sulphates, chloride, iron, ammonium, aluminium, and zinc (Agbozu et al. 2015). According to Taaaj (2015), there are a wide variety of chemicals in landfill leachate, with inorganic compounds making up 80-95% and organic compounds making up about 52%. Chloride (Cl), nitrites and nitrates (NO3), cyanide (CN), sulphides (S), and sulphates (SO42) are all examples of inorganic ions. Ammonium and ferrous are two examples of inorganic cations (Taaaaj, 2015).

Heavier metals are among the most dangerous pollutants found in landfill leachate. Many heavy metals have been found in excessive amounts in landfill leachates because of the lack of practise in most developing countries to separate nonhazardous wastes from hazardous wastes before disposal (Edokpayi et al., 2018). (Chuangcham et al. 2008). Since removing heavy metals is a challenging task, this research focuses mostly on doing so in landfill leachate. According to Dan et al. (2017a), chromium (Cr), manganese (Mn), cadmium (Cd), lead (Pb), iron (Fe), nickel (Ni), and zinc are the most prevalent heavy metals found in landfill leachate (Z). Young (acetogenic) leachate typically has higher metal contents than older (sulfidic) leachate (Dan et al. 2017a).

REVIEW OF RELATED LITERATURE

If leachate and gas emissions from solid waste landfills are not managed, they could have devastating effects on the surrounding environment. Municipal landfills produce leachate that is high in both organic and inorganic pollutants [1].

Metals may be concentrated in leachate, and it may also contain certain harmful organic compounds. Before releasing leachate into natural waters, it is customary to filter it for organic matter using COD, BOD, and ammonium levels [2].

Several factors, such as waste composition, climate, and moisture content, might affect the chemical make-up of leachate from a transfer station. Typically, leachate will have a high concentration of dissolved organic matter (COD), a low pH, a high ammonia nitrogen concentration, and a high concentration of heavy metals; it will also have a strong colour and a foul stench. In addition, leachate changes over time in terms of its composition, volume, and the amount of biodegradable matter present in it [3, 4]. Because of these obstacles, treating leachate is a complex and laborious process.

To remedy the landfill leachate, a wide variety of techniques are in use today. The majority of these techniques fall into two broad categories: biological treatments and physical/chemical treatments [3].

Aerobic Biological Treatment, which includes aerated lagoons and activated sludge, are two examples of the many options available for treating leachate [5].

This includes anaerobic lagoons and reactors.

- Air stripping, adjusting the pH, chemical precipitation, oxidation, and reduction are all examples of the physiochemical treatment.
- Lime, alum, ferric chloride, and land treatment are all methods of coagulation.
- Cutting-edge methods including carbon adsorption and ion exchange.

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This research was conducted to implement cutting-edge yet low-tech and easy-to-implement strategies for solid waste management [12], as the management of such waste has become an important issue and its leachate is viewed as very dangerous.

EXPERIMENTAL WORK

In order to speed up and enhance the coagulation and flocculation process, an aerobic treatment method was used, and coagulant and accelerator compounds were used.

Materials

Leachate

Leachate is collected from the solid waste landfill located in Ghazipur landfill in Delhi and the leachate composition will be as given in Table 1, Table 2.

Table 1: The chemical composition of leachate.

Parameter	Measured characteristic
BOD5	3400 PPM
COD	8250 PPM
pH	8.24
Turbidity	1400 NTU
TS	29942 PPM
TDS	26612 PPM
Conductivity	59400
SO_4	34712 PPM
Cl^-	6365 PPM
P_2O_5	1308 PPM
NO_3	3.95 PPM
NH_4	3745 PPM

Table 2: Physical properties.

Perlite		Bentonite	
Element	Percentage present %	Element	Percentage present %
SiO_2	75	SiO_2	53.62
Al_2O_3	18	Al_2O_3	14.47
Na_2O	4.0	Fe_2O_3	8.53
K_2O	5.0	CaO	1.63
CaO	2.0	MgO	3.96
Fe_2O_3	1.5	Na_2O	3.73
MgO	0.5	K_2O	0.96
TiO_2	0.2	SO_3	1.15
MnO_2	0.1	TiO_2	1.15
SO_3	0.1	P_2O_5	0.15
FeO	0.1	L.O.I	10.46
Ba	0.1	–	–

Municipal solid waste (MSW)

The MSW is delivered from a landfill located in 20th June City. Table 3, Table 4 show the Composition and the physical properties of MSW.

Table 3: Composition of MSW.

Component	Percentage (wt.%)
Organic materials	40
Unrecyclable Plastics	10
Unrecyclable materials	30
Agriculture waste	20
Total	100

Table 4: Physical properties of MSW.

Parameter	Characteristic	Parameter
Color	Dark brown	Color
Appearance	Very small granules	Appearance
Odor	Unfavorable	Odor

Timelines of the Experiments

- Alum was utilised as a coagulant, and Perlite and Bentonite were used as accelerators.
- The flocculation basin was left to sit for 30 minutes after a quick mixing period of 3 minutes at 350 rpm.
- The length of time being discussed.
- An average of 3.0 hours was needed for everything to settle down.
- Conductivity, turbidity, total dissolved solids (TDS), biological oxygen demand (BOD), and chemical oxygen demand (COD) were the parameters studied (COD).

- For the first run, we tried out a range of Alum concentrations, from 5 to 120 mg/l, by adding 5, 20, 45, 90, or 120 mg to the sample volumes.
- The optimum alum concentration was determined to be 90 mg/l; this value will be used in future iterations.
- The best alum concentration found in the first run (90 mg/l) was used in the subsequent experiment, which also included varying concentrations of Perlite.
- 5, 10, 20, 40, and 100 mg/l of Perlite are typically utilised.
- The optimum Perlite dosage is calculated.
- The third experiment combined various amounts of Bentonite with the optimal quantity of alum (90 mg/l).
- Bentonite is often administered at 5, 10, 20, 40, or 100 mg/l.
- We determine the best quantity of Bentonite to use.
- Conductivity, turbidity, total dissolved solids, biochemical oxygen demand, and chemical oxygen demand were the parameters studied.

RESULTS AND DISCUSSIONS

With a constant Alum dose of 90 mg/l, we collected samples of Perlite and Bentonite at 5, 10, 20, 40, and 100 mg/l to determine their efficacy as accelerator ingredients. Each ingredient's outcomes have been compared to those of a chemical treatment with no accelerator substance, in this case Alum.

Regarding turbidity effectiveness

Based on the used leachate's chemical composition, we know that its turbidity was 1400 NTU; after experimenting with different alum doses, we found that 90 mg/l produced the highest removal effectiveness (82.5%). In varying combinations with Perlite and Bentonite, this Alum concentration has been used (the accelerators).

It can be seen in Fig. 3 that the turbidity decreases as the doses of Perlite and Bentonite are increased, with the highest removal efficiency for turbidity being achieved at the 40 mg dose for Perlite and the 85 mg dose for Bentonite, respectively. Bentonite's performance is unaffected by increased material weight, but Perlite's efficiency is reduced. Reduced turbidity is the result of a decrease in suspended particulates, which settle to the bottom once the ions in the water have been balanced. By their own weight, the equalising ions sink to the bottom and accumulate there. In a similar vein, Gerardi obtained 82.0 percent removal efficiency in a pilot plant [13]. However, Iglesias found that the removal effectiveness of turbidity was improved by using a sequential anaerobic-aerobic treatment procedure [14], with the turbidity being removed at a rate of up to 90%.

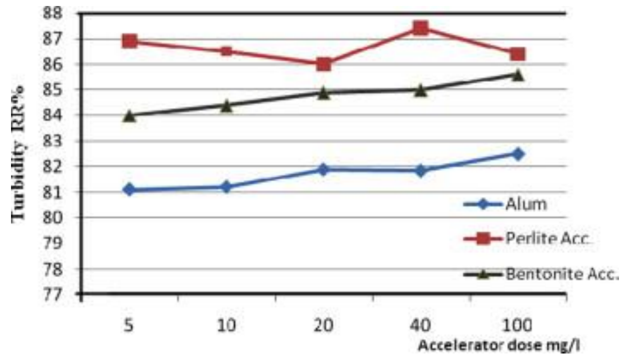

Figure 2: Turbidity removal efficiency using different substances weights.

For conductivity efficiency

Adding perlite and bentonite causes a change in conductivity, as shown in Fig. 3. For this correlation, 90 mg/l alum is used as the sweet spot for optimal values. At the optimal alum concentration, the particle sizes of perlite and bentonite shifted from 5 to 100 mg/l.

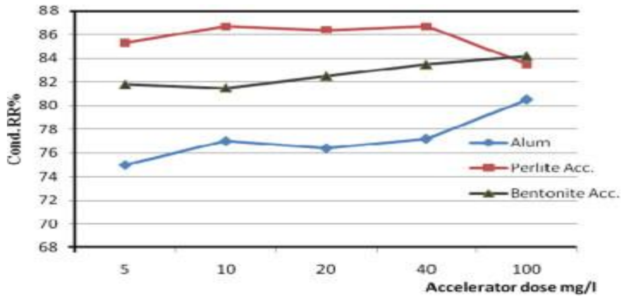

Figure 3: Conductivity removal efficiency using different substances weights.

For biological oxygen demand (BOD) efficiency

The relationship between the amount of Perlite and Bentonite and the rate of BOD removal is shown in Fig.4. For this correlation, 90 mg/l alum is used as the sweet spot for optimal values. After adding the optimal dose of alum, the concentration of perlite and bentonite jumped from 5 to 100 mg/l.

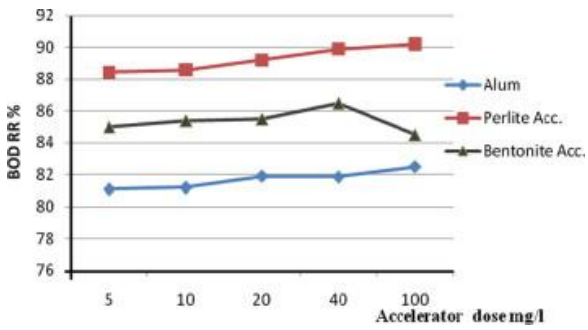

Figure 4: BOD effluent removal ratio using different substances weights.

The removal ratio of BOD was 82.5% when Alum was present at a level of 90 mg/l, meaning that 595 mg/l of effluent was produced from an influent concentration of 3400 mg/l.

Perlite's presence improves BOD behaviour compared to Alum's; this improvement was shown across the board as the BOD removal ratio increased with increasing Perlite concentration up to 40 mn, where it peaked at 89.9%; an increase in substance weight had a minor effect. This enhanced performance is mostly attributable to the adsorbent characteristics of Perlite, which result in a reduction in microbial populations and an acceleration of organic compound breakdown. In a similar vein, Kettunen showed that a HRT of 10 hours in the aerobic stage resulted in a maximum BOD elimination efficiency of 79%, with the concentration decreasing from 1400 to 294 mg/l [2].

In addition, Bentonite improved BOD removal efficiency up to 40 mn, where it reached 86.5%; however, as demonstrated in fig. 4, an even higher material weight had a negative impact.

For chemical oxygen demand (COD) efficiency

The correlation between COD removal effectiveness and Perlite and Bentonite additions is seen in Fig. 5. With alum present at a concentration of 90 mg/l, the removal ratio for COD was 84.0 percent, with the effluent concentration falling to 132.0 milligrammes per litre from an influent concentration of 8,250 milligrammes per litre.

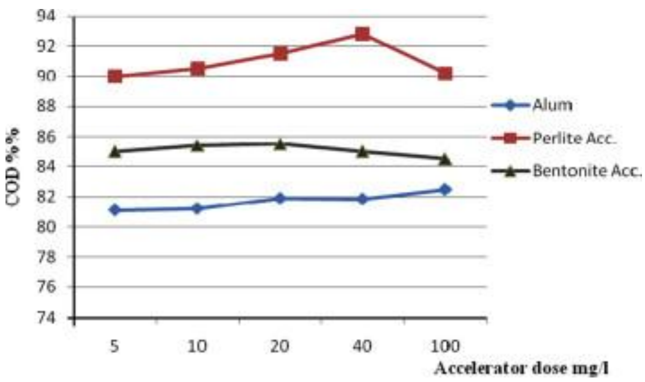

Figure 5: COD Effluent removal ratio using different substances weights.

CONCLUSIONS

- The results showed that the addition of Perlite and Bentonite improved the efficiency of the chemical precipitation process for treating leachate:
- Chemical treatment using Alum as a chemical coagulant with different doses achieved removal efficiencies of 82.5%, 80%, 82.5%, and 82.5% for Turbidity, conductivity, TDS, BOD, and COD respectively at a dose of 90 mg/l.
- The removal ratios for turbidity (86.4), conductivity (86.7), biochemical oxygen demand (BOD), and chemical oxygen demand (COD) were 89.9, 92.8%, and 92.9 percent, respectively, when 40 mg/l of a Perlite accelerator substance was used in conjunction with 90 mg/l of alum.
- The removal ratios for turbidity (85.0%), conductivity (83.5%), biochemical oxygen demand (BOD) (86.5%), and chemical oxygen demand (96.5%), respectively, at the 40 mg/l dose of Bentonite accelerator substance were higher than those at the 90 mg/l Alum dose.
- As the concentration of dissolved salts in the water increased, the TDS removal performance of perlite and bentonite was the worst.
- The turbidity, conductivity, BOD, and COD concentrations in the effluent were 176.4 NTU, 7900, 343.4 mg/l, and 594 mg/l after being treated with perlite adsorbent.
- Turbidity, conductivity, biochemical oxygen demand (BOD), and chemical oxygen demand (COD) concentrations in the effluent were reduced to 210 NTU, 9801, 510 mg/l, and 1237.5 mg/l, respectively, after being treated with bentonite adsorbent.

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