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Treatment of leachate from municipal solid waste landfill

Safaa M. Raghab *, Ahmed M. Abd El Meguid, Hala A. Hegazi

Housing and Building National Research Center, Cairo, Egypt

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KEYWORDS

Solid waste landfill;
Leachate;
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Abstract Leachate generation is a major problem for municipal solid waste (MSW) landfills and causes significant threat to surface water and groundwater. Leachate can be defined as a liquid that passes through alandfill and has extracted dissolved and suspended matter from it. Leachate results from precipitation entering the landfill from moisture that exists in the waste when it is composed. This paper presents the results of the analyses of leachate treatment from the solid waste landfill located in Borg El Arab landfill in Alexandria using an aerobic treatment process which was applied using the mean of coagulation flocculation theory by using coagulant and accelerator substances for accelerating and improving coagulation and flocculation performance.

The main goal of this study is to utilize a natural low cost material "as an accelerator additive to enhance the chemical treatment process using Alum coagulant and the accelerator substances were Perlite and Bentonite. The performance of the chemical treatment was enhanced using the accelerator substances with 90 mg/l Alum as a constant dose. Perlite gave better performance than the Bentonite effluent. The removal ratio for conductivity, turbidity, BOD and COD for Perlite was 86.7%, 87.4%, 89.9% and 92.8% respectively, and for Bentonite was 83.5%, 85.0%, 86.5% and 85.0% respectively at the same concentration of 40 mg/l for each.

Introduction

Sanitary landfill is a process in the solid waste management system. It can be defined as "a method of disposing of refuse on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation or at such more frequent intervals as may be necessary."

Leachate treatment technologies fall into two basic types, biological and physical/chemical. In larger systems and depending on the treatment goals, integrated systems which combine the two are often used.

Relevant literature

Solid waste landfills may cause severe environmental impacts if leachate and gas emissions are not controlled. Leachate generated in municipal landfill contains large amounts of organic and inorganic contaminants [1].

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* Corresponding author.
E-mail addresses: safaaragheb@yahoo.com (S.M. Raghab), aabd_elmaguid@yahoo.com (A.M. Abd El Meguid), hegazi100@yahoo.com (H.A. Hegazi).

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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	–	–
PbO	0.5	–	–
Cr	0.1	–	–
Total	–	–	99.81

Fig. 1 Municipal solid waste.

Leachate may also have a high concentration of metals and contain some hazardous organic chemicals. The removal of organic material based on COD, BOD and ammonium from leachate is the usual prerequisite before discharging the leachates into natural waters [2].

The leachate composition from the transfer station can vary depending on several factors, including the degree of compaction, waste composition, climate and moisture content in waste.

Table 3 Composition of MSW.

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

As a general rule, leachate is characterized by high values of COD, pH, ammonia nitrogen and heavy metals, as well as strong color and bad odor. At the same time, the characteristics of the leachate also vary with regard to its composition and volume, and biodegradable matter present in the leachate against time [3,4]. All these factors make leachate treatment difficult and complicated.

Many different methods are currently in use to treat the landfill leachate. Most of these methods are adapted for wastewater treatment processing and can be divided into two main categories: biological treatments and physical/chemical treatments [3].

There are many methods of leachate treatment [5] such as:

- Aerobic Biological Treatment such as aerated lagoons and activated sludge.
- Anaerobic Biological Treatment such as anaerobic lagoons, reactors.
- Physiochemical treatement such as air stripping, pH adjustment, chemical precipitation, oxidation, and reduction.
- Coagulation using lime, alum, ferric chloride, and land treatment.
- Advanced techniques such as carbon adsorption, ion exchange.

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Landfill leachate has also been effectively treated by the rotating biological contactor (RBC) process. The RBC is a biological process consisting of a large disk with radial and concentric passages slowly rotating in a concrete tank. During the rotation, about 40 percent of the media surface area is in the wastewater. The rotation and subsequent exposure to oxygen allows organisms to multiply and form a thin layer of biomass. This large, active population causes the biological degradation of organic pollutants. Excess biomass shears off at

Table 4 Physical properties of MSW.

Parameter	Characteristic
Color	Dark brown
Appearance	Very small granules
Odor	Unfavorable

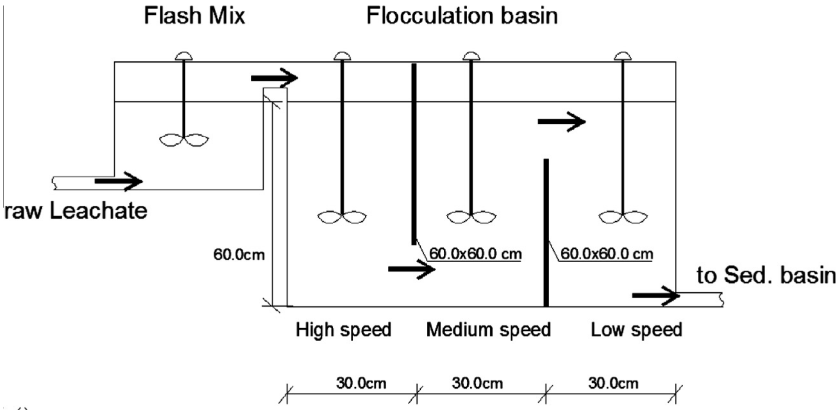

Fig. 2 The experimental pilot unit for chemical treatment.

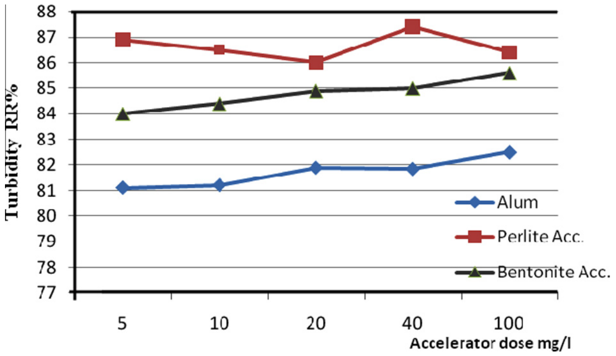

Fig. 3 Turbidity removal efficiency using different substances weights.

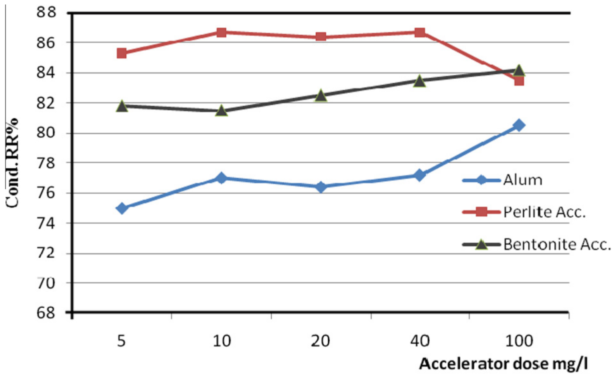

Fig. 4 Conductivity removal efficiency using different substances weights.

a steady rate and is then carried through the RBC system for removal in a clarifier [8].

Activated carbon adsorption systems have also been used in the treatment of landfill leachates for the removal of dissolved organics, however, they are generally considered as one of the more expensive treatment options and often, must be combined with other treatment technologies to achieve desired results [9].

The most common biological treatment is activated sludge, which is a suspended-growth process that uses aerobic microorganisms to biodegrade organic contaminants in the leachate. With conventional activated sludge treatment, the leachate is aerated in an open tank with diffusers or mechanical aerators [10,11].

Since solid waste management becomes an essential issue and the leachate is considered as very hazardous, this study is done to apply innovative methods that are low tech, simple in application [12].

Experimental work

Aerobic treatment process was applied using the mean of coagulation flocculation theory by using coagulant and accelerators substances for accelerating and improving the coagulation and flocculation process.

Materials

Leachate

Leachate is collected from the solid waste landfill located in Borg El Arab landfill in Alexandria and the leachate composition will be as given in Tables 1 and 2.

Municipal solid waste (MSW)

The MSW as shown in Fig. 1 is delivered from a landfill located in 15th May City. Tables 3 and 4 show the Composition and the physical properties of MSW.

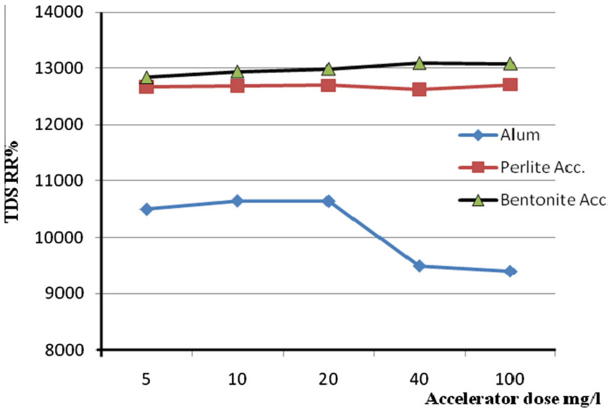

Fig. 5 TDS effluent concentration using different substances weights.

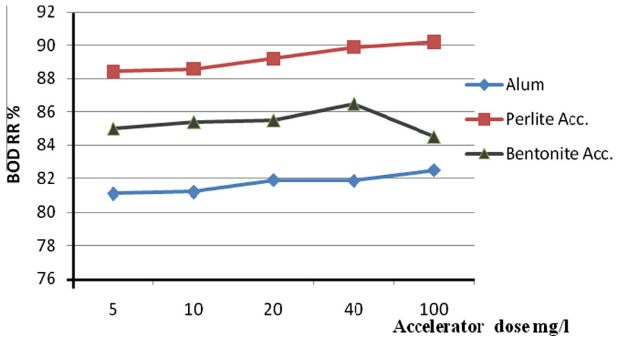

Fig. 6 BOD effluent removal ratio using different substances weights.

Experimental works sequences

- The coagulant used was Alum and the accelerator substances were Perlite and Bentonite.
- The rapid mixing rate was 350 rpm for 3 min. and followed by flocculation basin for 30 min.
- Duration time.
- Settling time was around 3.0 h.
- The measured parameters were conductivity, turbidity, total dissolved solids (TDS), biological oxygen demand (BOD), and chemical oxygen demand (COD).
- The first run was done by adding different doses of Alum as 5, 20, 45, 90, 120 mg/l to the samples.
- The optimum dose of alum is deduced, found to be 90 mg/l and is taken into consideration in the next runs.
- The second run was done by using the optimum dose of alum that resulted from the preliminary run (90 mg/l) with different doses of Perlite.
- The doses of Perlite used are 5, 10, 20, 40, 100 mg/l.
- The optimum dose of Perlite is deduced.
- The third run was done by using the optimum dose of alum (90 mg/l) with different doses of Bentonite.
- The doses of Bentonite used are 5, 10, 20, 40, 100 mg/l.
- The optimum dose of Bentonite is deduced.
- The measured parameters were conductivity, turbidity, TDS, BOD5, and COD.

The experimental work was done in the laboratory of Housing & Building National Research Center – Chemical Department Fig. 2.

Results and discussions

In order to evaluate the efficiency of Perlite and Bentonite, samples were taken at each dose of each i.e. with 5, 10, 20, 40, 100 mg/l as accelerator substances with a constant Alum dose of 90 mg/l. The achieved efficiencies for each substance have been compared with the Alum results as a chemical treatment without any accelerator substance.

For turbidity efficiency

As described herein above from the Chemical Composition of the used Leachate the Turbidity was 1400 NTU, by chemical treatment using Alum with different doses the best removal efficiency of 82.5% has been achieved at an alum dose of 90 mg/l. this Alum concentration has been used with the different doses of Perlite and Bentonite (the accelerators).

From Fig. 3 we can deduce that the turbidity decreases by increasing the weights of Perlite and Bentonite, maximum removal efficiency for turbidity is 87.4% for Perlite and 85.0% for Bentonite at 40 mg dose for each. The increasing of substance weight has no effect on the performance for Bentonite and decreases the efficiency in case of Perlite. The decrease in turbidity referred to the decrease in suspended solids and this is due to the sedimentation of these particles after equalizing its ions. The equalizing ions come to the bottom by gravity under the force of their own weight. A similar result was found by Gerardi in a pilot-plant where the achieved removal efficiency was 82.0% [13]. Whereas in a study carried out by Iglesias, the turbidity removal was as high as 90% for the whole sequential anaerobic–aerobic treatment process, which gave a better removal efficiency [14].

For conductivity efficiency

Fig. 4 represents the relation between the change in conductivity and amount of perlite and bentonite. This relation is determined according to the optimum values of 90 mg/l alum. Perlite and bentonite changed from 5 to 100 mg/l at an optimum dose of alum.

Conductivity in the presence of Alum with dose of 90 mg/l achieved 80.5% removal ratio i.e. the effluent was 11583 from the influent of 59400.

Conductivity in the presence of perlite gets non linear behavior, generally this behavior changed to increase the conductivity with the increasing of the amount of perlite up to 20 mg/l. This mainly refers to the change of some amount of dissolved salts which increases the conductivity. The values of conductivity decreased at doses up to 40 mg/l, this refers to that perlite adsorbs salts on its surface and decreases the conductivity.

Conductivity in the presence of bentonite increased initially at 5 mg/l and was fixed up at 40 mg/l then this value sharply decreased at a dose of 100 mg/l. This mainly refers to the adsorption behavior of bentonite which can adsorb several types of ions on its surface and decreases the conductivity. The equalizing ions come to the bottom by gravity under the force of thier own weight [15].

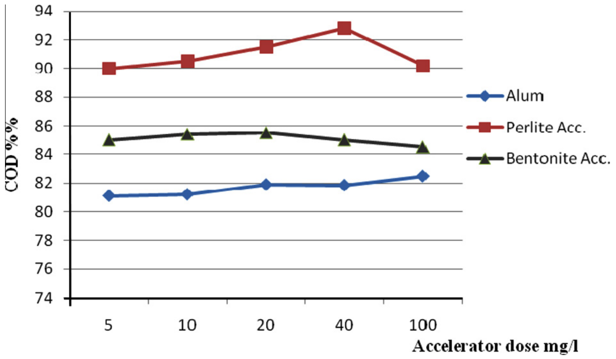

Fig. 7 COD effluent removal ratio using different substances weights.

Table 5 Main consistent, source and cost of perlite and bentonite.

Low cost adsorbents	Main consistent	Primary source	Cost LE / cubic meter
Perlite	Includes any volcanic glass that will expand when heated quickly, forming a light weight frothy material	Natural	180–300
Bentonite	Clay generated frequently from the alteration of volcanic ash	Natural	50–100

For total dissolved solid (TDS) efficiency

TDS in the presence of Alum with a dose of 90 mg/l achieved 23.47% removal ratio i.e. the effluent was 8800 PPM from an influent of 11500 PPM.

Fig. 5 represents the relation between the change in conductivity and amount of perlite and bentonite. This relation is determined according to the optimum values of 90 mg/l alum. Perlite and bentonite changed from 5 to 100 mg/l at an optimum dose of alum.

TDS in the presence of Perlite or bentonite shows worst behavior, generally this behavior changed to increase the TDS with the increasing of the substance weight. This mainly refers to the increase of dissolved salts which increase the TDS where the additive substance contains a high amount of salts.

A similar result was found by Jokela, where he reported that the TDS removal efficiency decreases to 25.0% by the increasing of adsorbent substance [16].

For biological oxygen demand (BOD) efficiency

Fig. 6 represents the relation between the change in BOD removal efficiency and the amount of Perlite and Bentonite. This relation is determined according to the optimum values of 90 mg/l alum. Perlite and Bentonite changed from 5 to 100 mg/l at an optimum dose of alum.

BOD in the presence of Alum with a dose of 90 mg/l achieved 82.5% removal ratio i.e. the effluent was 595 mg/l from an influent of 3400 mg/l.

BOD in the presence of Perlite gets better behavior than Alum, generally this behavior changed to increase the BOD removal ratio with the increasing of the amount of Perlite up to 40 mn which reached 89.9% the increase of the substance weight showed a slight effect. This better performance mainly refers to the change in numbers of microorganisms and the degradation of organic compounds due to the adsorbent behaviors of Perlite. Similar result was found by Kettunen study, the maximum BOD removal efficiency was 79% with the concentration decreased from 1400 to 294 mg/l at a HRT of 10 h in the aerobic stage of the same study [2].

Also the Bentonite increased the BOD removal ratio up to 40 mn which reached 86.5% the increasing of the substance weight showed a worse effect as shown in fig. 6.

For chemical oxygen demand (COD) efficiency

Fig. 7 represents the relation between the change in COD removal efficiency and the amount of Perlite and Bentonite. COD in the presence of Alum with a dose of 90 mg/l achieved 84.0% removal ratio i.e. the effluent was 1320 mg/l from an influent of 8250 mg/l.

COD in the presence of Perlite gets better behavior than Alum, generally this behavior changed to increase the COD removal ratio with the increasing of the amount of Perlite up to 40 mn which reached upto 92.8%. The increase of the substance weight decreases the removal efficiency. This better performance mainly refers to the change in numbers of microorganisms and the degradation of organic compounds due to the adsorbent behaviors of Perlite.

Also Bentonite increased the COD removal ratio up to 40 mn which reached 85.0% and the increasing of the substance weight showed worse effect as shown in Fig. 7.

In a study carried out by Pouliot et al., the COD removal was as high as 85–90% for the whole aerobic treatment process, which gave a better removal efficiency [17].

Accelerator Costing

Since the cost effectiveness of an adsorbent is one of the important issues that must be considered when selecting an adsorbent, the price of low cost adsorbents has to be compared as given by table 5.

Conclusions

Results showed that the performance of the Perlite and Bentonite enhanced the Leachate treatment by chemical precipitation as follows:

- Chemical treatment using Alum as a chemical coagulant with different doses achieved removal efficiencies of 82.5%, 80.5%, 82.5% and 82.5% for Turbidity, conductivity, TDS, BOD and COD respectively at an alum dose of 90 mg/l.
- Using Perlite accelerator substance with different doses with 90 mg/l Alum dose enhanced the treatment performance and achieved the best removal efficiency at 40 mg/l substance dose and the removal ratios were 87.4%, 86.7%, 89.9% and 92.8% for Turbidity, conductivity, BOD and COD respectively.
- Using Bentonite accelerator substance with different doses with 90 mg/l Alum dose enhanced the treatment performance and achieved better removal efficiency than Alum at 40 mg/l substance dose the removal ratios were 85.0%, 83.5%, 86.5%, and 96.5% for Turbidity, conductivity, BOD, and COD respectively.
- Perlite and Bentonite gave the worst removal performance for TDS due to the increase of dissolved salts, which increased the TDS concentration.
- Perlite adsorbent achieved effluent concentration of 176.4NTU, 7900, 343.4 mg/l, 594 mg/l for Turbidity, conductivity, BOD and COD respectively.

- Bentonite adsorbent achieved effluent concentration of 210 NTU, 9801, 510 mg/l, 1237.5 mg/l for Turbidity, conductivity, BOD and COD respectively.

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