International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 6, June 2017)

Characterisation and Treatment of Municipal Landfill Leachate Using Natural Coagulants

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Abstract*— Leachate is a concentrated liquid that originates from the solid waste at the dumping sites. Release of leachate to the environment without any treatment may pollute the soil, and both surface and ground water. Coagulation is a most common method used for the removal of soluble metals. Natural coagulants are effective in the treatment of both wastewater and Leachate. In this study, leachate collected from the waste dumped site were treated with different natural coagulants such as chitosan and pine bark in order to remove the heavy metals present and also to reduce its turbidity. The nearby pond water also collected to check whether it is contaminated with leachate. The Municipal Landfill Leachate and nearby Pond water was analyzed for different Physico-Chemical parameters such as pH, Temperature, TDS, BOD, COD, Total Alkalinity, Chlorides. On the basis of turbidity, the result of coagulation showed that natural coagulants was most efficient under acidic and neutral conditions. At the coagulant dosage of chitosan 0.6g/mL removal of Turbidity is 85.2% and at the optimum pH 6 the maximum removal of turbidity was 91.3% and for the pine bark dosage of 4g/mL removal of turbidity is 83.3% and at optimum pH 7 the removal of turbidity was 85.2%. The present investigation also deals with analyzed of the heavy metals concentration before and after treatment in municipal solid waste leachate. The analytical analysis revealed that the leachate showed higher concentration of heavy metals viz.,As, Cu, Cr, Pb, Hg and Ni. Treatment with the natural coagulants have shown higher removal efficiency of metals and turbidity.

***Keywords*—coagulation, Heavy metals, Leachate, Natural Coagulants, Turbidity**

I. INTRODUCTION

Solid waste is all kind of garbage, refuse, trash and other discarded solid materials which were generated from human activities especially from Residential, Commercial establishments (e.g., Restaurants, Banks) and Institutions (e.g., Hospitals, Schools) Usually wastes are managed by Municipal authorities. Nowadays, solid Waste disposal practices became a huge problem in every country with increasing concern for the environment. People generated solid wastes in the form of bottles, boxes, clothing, plastic bags and much more results in million tones of solid waste generated per year. If all of the trashes are not managed properly, they will pose a major threat to human, animals and the Environment. (Rashid, 2009)

Leachates from MSW landfill sites are often defined as heavily polluted wastewater. Leachate is a liquid formed primarily by the percolation of precipitation water through the open landfill or through the cap of the completed site. Some infiltration will evapotranspire, some may be stored within the landfill, and the balance becomes percolate and eventually leachate. Leachates may contain large amounts of organic contaminants which can be measured as chemical oxygen demand (COD) and biological oxygen demand (BOD), ammonia, halogenated hydrocarbons suspended solid, significant concentration of heavy metals and inorganic salt (Zawawi Daud 2012). If not treated and safely disposed, landfill leachate could be a potential source of surface and ground water contamination, as it may percolate through soils and subsoils, causing pollution to receiving waters.

The generation rate of leachate is estimated based on few factors as the rainfall, the amount of the rainfall infiltrating to the waste through the cover, the absorptive capacity of the waste, the weight of absorptive waste and any removal of the leakage via seepage or discharge. Because of the uncertainties involved in the leachate generation process from real sites, the estimated leachate generation rate would include varied inputs to provide a worse-case scenario for sizing the leachate output and getting discharge consent to allow the leachate into the sewer.

The leachate generated from a landfill site will vary in volume and composition depending on the age of the site and stages biodegradation reached. Because of the changes in leachate composition with time, the leachate control systems should adapt to these changes. Leachate treatment is required to remove any contaminating components of the leachate and bring it to a standard whereby it can be released to a sewer, a water course, land or tidal water. Before release, a discharge consent or agreement is required from the local authorities or environmental agency. The consent or agreement may cover a range of potentially polluting components, for example, pH, concentration of organic material, ammonium and nitrate, suspended solids and metal content. Treatment processes for leachate are physico-chemical, attached growth processes, non- attached growth processes, anaerobic treatment, anaerobic/aerobic treatment, land treatment and leachate recirculation.

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Compared to other chemical coagulants the natural coagulants has various advantages such as cost-effective, Eco-friendly,it has multifunction in it, production of biodegradable sludge and lower sludge volume, and it is used as a bio-fertilizer, and also it has no affecton the pH of the water. Coagulation using natural coagulants is the destabilisation of colloids by neutralizing the forces that keep them apart. Natural Coagulants (cationic protein) neutralise the repulsive Electric charge (negative) of colloids allowing them to "stick together" creating "flocs". Flocculants facilitate the sticking of the coagulated particles to form larger floccules and their by fasten gravitational settling. Rapid mixing is required to disperse the coagulants thorough the liquid. Coagulation and flocculation processes are intended to form particles large enough to be separated and removed by subsequent sedimentation.

In Vellore, there are about 230 million tones of solid waste generated per day in year 2016. Municipal authorities has used many methods in managing the waste properly so that it does not pose any harm to human health. Composting, incineration, open dumping, reuse and recycling are some examples in managing wastes (Bhalla et al., 2012). However, landfill is the most common method employed to manage solid wastes in Vellore. The treatment can be carried out on or off site by physical, chemical or biological methods.

For this study, it will be focus on leachate treatment by a natural polymer named "chitosan"and "pine bark".

II. Materials And Methods

Sampling

The municipal leachate were collected from dumping site located in Vellore. To check contamination of leachate into the surface waters, water was collected from the pond just opposite to the dumping site. The collected municipal Leachate and water sample were taken in clean plastic containers and stored in refrigerator at -4^{0}C (Chrastny et al., 2012). The initial parameters were immediately analyzed Then, the water extracts of both municipal leachate and pond water were analyzed for the initial parameters such as pH, electrical conductivity, chlorides, total alkalinity, total hardness, and iron (Venkata Ramaiah and Krishnaiah, 2014). Soil samples were acidified in the field with concentrated HNO_3 (5 mL/L of water sample to reduce the pH of the sample, pH > 2.0) for the total metal estimation. Total metal content in soil was determined by digesting 0.5 g of soil/ sediment sample from each site with a mixture of Conc HNO_3 and $HClO_4$ (10 mL + 2 mL). The digested samples were filtered through Whatman filter No. 42 and finally volumes were made 10 mL with 0.1 N HNO_3 and analyzed for heavy metals using Atomic Absorption Spectrophotometer (Bharti et al., 2013)

Synthesis of natural coagulants:

The shells of crustaceans (crab and shrimps) were collected, and dried naturally by sunlight for 2 days (how many days/ time). Pine bark were also collected seperately and dried naturally by sunlight for 3 days and the shells over from hulls were removed manually. The dried shells and bark were ground to fine powder by domestic blender. This powder was sieved through 600µm. As pine bark and chitosan have the ability to retain metals, it is essential to understand the functional groups that mediate the phenomenon of adsorption. The process adsorption by dead biomass or some other molecules or their active groups is passive as it is based mainly on the affinity of the adsorbent with the sorbate. In such a case, the heavy metal is sequestered by chemical sites that are naturally present in the biomass. After the phase separation process, two components: a biomass loaded with metal ions and an aqueous phase free of contamination are to be obtained. This is followed by dealing with the "contaminated" biomass, and the concept of great interest is biosorbent regeneration and desorption for heavy metal recovery. This process is highly efficient because the biomass can be further used for the removal of more metal species from other contaminated effluents or degradation of the biomass, which offers no further use but does not cause secondary pollution like other chemical coagulants or chelators. Heavy Metal chelation occurs by complex mechanisms, such as ion-exchange and complexation of metal ions, and the possible of occurrence of these mechanisms may be simultaneous or by varying degrees depending on the concentration of the biomass and the metal ion and the solution composition (Cleide et al,2013).

Coagulation -flocculation process

Jar test is the most widely used experimental methods for coagulation-flocculation. A conventional jar test apparatus was used in the experiments to coagulate the turbid water samples using natural coagulants (Shweta .S. Angadi et al., 2015). It was carried out as a batch test, accommodating a series of six beakers together with six-spindle steel paddles. The doses of natural coagulants is varied for different beakers of 500 ml. After adding the natural coagulants it is rapidly mixed for about 1 to 2 minutes at 100 rpm then it is Slowly mixed for about 20 minutes at 30 to 40 rpm. After completing the mixing it allowed for settling of about 20 to 60 minutes.

The supernatant water after the treatment process was collected and the turbidity was measured using Turbidimeter. Optimum system pH was found by adding optimum coagulant dose with the pH of the sample varying from 5 to 9. the pH value producing maximum turbidity removal (optimum pH) was determined.

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III. Results And Discussion

A. Physico -chemical parameters

The physico -chemical parameters of sample are important for the treatment of leachate. The treatment depends on these parameters. The water from nearby pond and municipal landfill leachate are analysed for its physico chemical parameters and are compared with the Indian Standard. The results of the Physico-chemical characterization of Municipal Leachate and nearby pond water from Vellore have been competed. The parameters of Municipal Landfill Leachate were noted to be exceeding the limits. while comparing the results of nearby pond water with Indian Standards, it is also slightly modified. In this study, the Coagulation process are used for the treatment of municipal landfill Leachate. The coagulation process were carried out to degrade parameters by using natural coagulants from Municipal Landfill Leachate.

Table 1
Physico chemical parameters of Municipal leachate and nearby pond sample

PARAMETERS	MUNICIPAL LEACHATE SAMPLE			NEARBY POND WATER SAMPLE
	BEFORE TREATMENT	AFTER TREATMENT		
		CHITOSAN	PINE BARK	
pH	9.61	8.9	9	7.80
Temperature	32°C	31°C	31°C	29°C
Electrical conductivity (µS/cm)	5.27	5	5.1	1.5
Colour	Brownish black colour	Light brown colour	Light brown colour	Light grey colour
Odour	Unpleasant	Objectionable	Objectionable	Objectionable
Total dissolved solids(mg/L)	4500	2580	2200	3000
Total suspended solids(mg/L)	7000	2300	3000	5000
Total Solids (mg/L)	11500	4880	5200	8000

B. Treatment using Natural Coagulants

Chitosan powder

Table 2
Turbidity of sample using Chitosan Powder

S.NO	VOLUME OF SAMPLE (mL)	DOSAGE (g/mL)	TURBIDITY READING (NTU)		TURBIDITY REMOVAL %
			INITIAL	FINAL	
1	500	0.2	590	105.5	82.1%
2	500	0.4	590	98	83.3%
3	**500**	**0.6**	**590**	**87**	**85.2%**
4	500	0.8	590	93	84.2%
5	500	1.0	590	99	83.2%

From the Table 2, the percentage of turbidity removal was found to be increased with increase in the dosage level. The maximum amount of removal percentage obtained was 85.2% at 0.6g/mL.

Determination of Optimum pH:

Table 3
Removal of Turbidity in % with optimum dosage (Chitosan Powder)

S.NO	DOSAGE (g/mL)	pH	TURBIDITY READING (NTU)		TURBIDITY REMOVAL %
			INITIAL	FINAL	
1	0.6	5	590	93	84.2%
2	**0.6**	**6**	**590**	**51**	**91.3%**
3	0.6	7	590	65	88.9%
4	0.6	8	590	78	86.7%
5	0.6	9	590	83	85.9%

The optimum pH was determined at a pH of 6 and the turbidity removal was 91.3% as shown in table 3. It was found that the percentage of turbidity removal was suddenly increased from pH 5 to 6 and the percentage of turbidity removal was gradually decrease with decrease respect to the pH .

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International Journal of Emerging Technology and Advanced Engineering
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Pine Bark

Table 4
Turbidity of sample using Pine Bark

S.NO	VOLUME OF SAMPLE (mL)	DOSAGE (g/mL)	TURBIDITY READING (NTU)		TURBIDITY REMOVAL %
			INITIAL	FINAL	
1	500	2	590	125	78.8%
2	**500**	**4**	**590**	**98**	**83.3%**
3	500	6	590	122	79.3%
4	500	8	590	130	77.9%
5	500	10	590	143	75.7%

From the Table 4 the maximum amount of removal percentage obtained was 83.3% at 4g/mL.

Determination of Optimum pH

Table 5
Removal of Turbidity in % with optimum dosage (pinebark)

S.NO	DOSAGE (g/mL)	pH	TURBIDITY READING (NTU)		TURBIDITY REMOVAL %
			INITIAL	FINAL	
1	4	5	590	112	81%
2	4	6	590	98	83.3%
3	**4**	**7**	**590**	**87**	**85.2%**
4	4	8	590	96	83.7%
5	4	9	590	108	81.6%

The optimum pH was determined at a pH of 7 and the turbidity removal was 85.2% as shown in Table 5. It was found that the percentage of turbidity removal was gradually increased from pH 5 to 7 and then the percentage of turbidity removal was gradually declined.

C. Heavy metals

Table 6
Analysis after treatment using Chitosan

S.NO	DOSAGE (g/mL)	Ar (mg/L)	Cu (mg/L)	Cr(mg/L)	Pb (mg/L)	Hg (mg/L)
1	0	0.009	0.0025	0.07	0.09	0.005
2	0.2	0.007	0.0017	0.019	0.08	0.0011
3	0.4	0.008	0.0006	0.008	0.08	0.0008
4	0.6	0.007	0.0006	0.008	0.07	0.0008
5	0.8	0.006	0.0007	0.009	0.07	0.0009
6	1.0	0.006	0.0008	0.009	0.06	0.0009

Table 7
Analysis after treatment using Pinebark

S.NO	DOSAGE (g/mL)	Ar (mg/L)	Cu (mg/L)	Cr(mg/L)	Pb (mg/L)	Hg (mg/L)
1	0	0.009	0.0025	0.07	0.09	0.005
2	2	0.0017	0.0017	0.019	0.0016	0.0014
3	4	0.0008	0.0008	0.0008	0.0010	0.0012
4	6	0.0006	0.0006	0.0006	0.0009	0.0011
5	8	0.0005	0.0005	0.0006	0.0008	0.0010
6	10	0.0005	0.0005	0.0005	0.0007	0.0009
7	Nearby pond water	0.0006	0.0006	0.0007	0.0009	0.0008

Arsenic:

The permissible limit for arsenic is 0.05 mg/L. The present water sample contains arsenic ranging from 0.006 mg/L to 0.0017mg/L in different dosages. Hence after treatment, the water sample were below the detection level upto 60% heavy metals were removed.

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Before treatment the arsenic level is 0.009 mg/L. Arsenic is highly toxic in its organic form. Long-term exposure to arsenic from drinking water, irrigation of food crops and food can cause cancer, cardiovascular disease, neurotoxicity, diabetes and skin lesions.

*Copper***:**

The desirable limit for copper is 0.05 mg/L and the permissible limit in the absence of alternate source is 1.5 mg/L. The undesirable effect beyond the desirable limit is astringent taste, discoloration and corrosion of pipes, fittings and utensils will be caused. The present water samples are having copper ranging from 0.0025 mg/L to 0.0005 mg/L. Hence, all water samples are not contaminted due to copper and below the detection level. It is an essential element for living organisms, including humans, and in small amounts, necessary in our diet to ensure good health. However, too much copper can cause adverse health effects, including diarrhoea, vomiting, stomach cramps, liver damage, kidney diesease and nausea. (Venkata Ramaiah and Krishnaiah, 2014)

*Chromium***:**

The permissible limit for chromium is 0.05 mg/L. The water sample has no appreciable concentration of chromium and it is found to be below detection level. The detection level is 0.03 mg/L. Health effect related to hexavalent chromium exposure include diarrhoea, stomach and intestinal bleedings, cramps, liver and kidney damage.

*Lead***:**

The desirable limit for lead is 0.015 mg/L and the permissible limit is 0.05 mg/L . The water sample has no appreciable concentration of lead and it is found to be below the detection level. The detection level is 0.01 mg/L.Lead can enter drinking water,especially where the water has highly acidity or low mineral content that corrodes pipes and fixtures.EPA has set the maximum contaminant level goal for lead in drinking water at zero because lead is a toxic metal that can be harmful to human health even at low exposures levels. Especially young children, infants and fetuses are particularly vulnerable to lead. In adult it affects cardiovascular system, increased blood pressure, incidence of hypertension, decreased kidney function and reproductive problems. (Venkata Ramaiah and Krishnaiah, 2014)

*Mercury***:**

The permissible limit for mercury is 0.001 mg/L. The water sample has the concentration of 0.005 mg/L and after the treatment water samples have no mercury content that is below the detection level. Mercury is an inorganic, toxic metal that has disastrous effects on human bodies is too much is ingested.

It specifically damages central nervous system, endocrine system and kidneys. It also has a negative effect on the other organs, as well as the mouth, teeth and gums. (Venkata Ramaiah and Krishnaiah, 2014)

*Nickel***:**

The desirable limit for nickel is 0.07 mg/L as per the WHO guidelines for drinking water quality, 2006. The samples are in between 0.09 to 0.002 mg/L and is below the detection limit. It can become carcinogenic and toxic in high doses. Womens are most commonly allergic to nickel exposure than men. Exposure to skin can cause dermatitis upon contact. [M.A.Opasina, 2010]

It has urban migration problems and resource limitation. The development of residential areas near the dumpsite and indiscriminate dumping of Municipal wastes are still observed at this study site despite government closure of the site. Revealed that human activities is still taking place at the dumpsite, since there is a strong relationship between human activities and pollution of the environment. For instance, the dumping of animal droppings is still being practice, because most people living near the dumpsite have converted the site to vegetable garden because of the dumping of animal droppings which is a common practice at the site. Animal droppings are useful agricultural by-products as fertilizer supplements with very high potential for environmental pollution.

IV. CONCLUSION

The conclusions were drawn from the present studies on the removal of Turbidity of the natural coagulant. From the study, it clearly shows that the natural coagulant (Chitosan powder and pine bark) are effective in the removal of turbidity .Therefore, the need for economical, effective and safe method for disposal of pollutant in leachate has resulted in coagulation process. Thus, the environmental pollutions can be reduced by adapting Coagulation all over. The absence of proper management system and lack of adequate capacity for final deposition of solid waste has been a serious problem in urban areas. Developing countries like India have not been able to adequately address these problems due to high cost involved. This seems to be one of the reasons why contaminated dumpsites are often shut down for natural recovery of the site. Though there is a scarcity of data on physicochemical status of shut down dumpsites. The data recorded in this study support the assertion that most shut down dumpsites in heavily urbanized society may have been contaminated significantly due to on going human activities. This underlines the need for appropriate authority to further monitor shut down dumpsites alongside remediation process that may be initiated.

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