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An Experimental Study on Purification of Leachate and Analysis of Its Application in Plant Growth

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Abstract: *Landfill leachate is a significant polluting factor of the environment. The leachate generation is a major problem of municipal landfill sites or dump yards. The leachate is a toxic black liquid leached from the landfill containing dissolved and suspended matter in it. Leachate is a product formed when precipitation or atmospheric moisture enters the landfill that is undergoing degradation. The leachate contains organic and inorganic compounds, heavy metals and pathogens, if not collected they can pollute both surface and ground water. Due to their low biodegradability, high nitrogen content and presence of other possible toxic components, the co-treatment of leachate along with the municipal waste water in the conventional municipal waste water treatment plants is undesirable. Thus we are proposing a 3 stage treatment process which includes a filtration process that makes use of marine sand and fly ash filter beds followed by heavy metal removal using activated charcoal of palm flowers (koonka) and the final stage is a membrane filtration through Reverse Osmosis (RO) membrane. As the filtrate from the leachate treatment process contains nutrients useful for plant growth mainly the nitrogen (N) content which plays an important role in the crop yield. So along with the treatment process the suitability of leachate for irrigating plants is also studied. Thus the use of fertilizers can be reduced and the soil fertility is enhanced.*

Keywords: *Fly ash, Filtration process, Irrigating, Leachate, Marine sand, Palm flower (konka), Plants, RO membrane, Toxic.*

I. Introduction

Water is one of the five elements, its depletion and degradation in its quality is a major challenge. In India unscientific design of dump yards and indiscriminate disposal of waste is causing numerous threats to environment and mankind. Leachate is a dark-coloured liquid with strong smell that leaches or drains from landfill containing dissolved and suspended solids, percolating into the ground contaminating the ground water and the soil. Leachate composition is primarily a function of age of the landfill and the degree of water stabilization. The leachate consists of dissolved organic matter, inorganic macro components and heavy metals at higher concentration. Conventional methods of leachate purification include recycling and combined treatment with domestic sewage, chemical oxidation, adsorption, biological treatments, etc. Due to low biodegradability, high nitrogen content and presence of other possible toxic components, the co-treatment of leachate or conventional municipal waste water treatment plants is undesirable. Thus one should make sure that these components are removed or reduced according to the standards before discharge of the effluent. El Fadel H. in his paper has stated that the richness of silica in marine sand allows higher reduction of COD and BOD and the pozzolanic reaction between fly ash and lime of sand stabilizes heavy metal [1]. Amin Mojiri and et.al have said that the reductions of ammonia concentrations in permeate may be increased by means of a two or multiple step reverse osmosis [2]. Minu Singh and et.al have shown in their study that the application of nitrogen enhances crop productivity and nutrient content of leaf [3]. CY Cheng, et.al says that leachate is saline and has elevated concentration of various toxic pollutants resulting in the retardation of plant growth and this is avoided by dilution of leachate [4]. Shubrah Singh, et al have mentioned in their paper that the groundwater at Varanasi, India the nearby wells were significantly contaminated due to leachate and 9% of the samples near to the disposal site were unsuitable for drinking purposes [5]. Safoura Daneshfozouna et.al have shown in their study that the pH dependent heavy metal adsorption efficiency were more than 92% adsorption efficiency achieved independent of pH [6]. Thus this paper focuses on the treatment of leachate with locally available materials. The filtration process makes use of marine sand and fly ash filter as filter beds forming the first stage of treatment followed by heavy metal removal using activated charcoal of palm flowers (koonka) and the final stage of membrane filtration through Reverse Osmosis (RO) membrane. The filtrate from the leachate treatment process is analysed for its physiochemical properties and its suitability for irrigation purpose is also studied. Thus reducing the use of fertilisers and enhancing the soil fertility.

II. Objective

To treat the leachate collected from Kurumbapet, Pondicherry, India using a filtration process that makes use of Marine Sand and Fly ash, a heavy metal removal using activated charcoal from koonka (palm flower) and finally treatment through Reverse Osmosis (RO) membrane.

III. Materials Used

3.1 Leachate

The leachate sample was collected from the Kurumbapet dump yard, Pondicherry. The collected leachate's physical and chemical characteristics were found. The physical and chemical analysis involved temperature, pH, conductivity, turbidity, Total Kejaldal Nitrogen (TKN), chloride, COD, BOD and heavy metals.

Table 01: Physiochemical Characteristics Of Raw Leachate

Sl. No.	Parameter	Values	Indian Standard limits
1.	Temperature	8.37	6.5-8.5
2.	pH	30ºC	Shall not exceed 5ºC than the receiving water
3.	Conductivity	12 µS/cm	Below 1500µs/cm
4.	Turbidity	8 NTU	5 NTU
5.	TKN	17.8 mg/l	100 mg/l
6.	COD	1660 mg/l	250 mg/l
7.	BOD	152 mg/l	100 mg/l

3.2 Marine sand and fly ash

The marine sand was collected from 3 sites, from Aurovile (sample I), Kalapet (sample II) and Veeranpattanam (sample III). Sieve analysis was carried out for the sand samples and based on the uniform coefficient (U_c) obtained from the S-curve of each sample, the sample with U_c nearer to 1.5 was choose as the bed material.

Table 02: Sieve Analysis Of Marine Sand

Sieve size	Particle diameter (mm)	Cumulative weight of finer Sample-1 (%)	Cumulative weight of finer Sample-2 (%)	Cumulative weight of finer Sample-3 (%)
4.75mm	4.75	100	100	100
2.36mm	2.36	100	100	100
1.18mm	1.18	99	98.5	99.5
600 microns	0.6	78	54.5	95.5
425 microns	0.425	53	22.5	86.4
300 microns	0.3	42.5	10	60
150 microns	0.15	1	1	13
90 microns	0.09	0.5	0.5	2.5
Pan	-	0	0	0

The uniform coefficient of sample I, sample II and sample III are 3.066, 2.03 and 3.875 respectively.

The fly ash used is a class C fly ash because it mainly consists of silica, alumina and calcium, Class C fly ash has more carbon content than a class F fly ash. Based on a trial and error method the suitable proportion for marine sand and fly ash (class C) was derived using a miniature prototype filter. The optimum amount of fly ash to be added is 2% of marine sand.

3.3 Activated charcoal

The koonka (palm flower) was collected and was dried in the sun for a week's time. This sun dried koonka was burnt and the charcoal was obtained. This charcoal was crushed into powder. The powdered charcoal was activated by adding to it the calcium chloride solution prepared in the ratio 1:3 (100g Calcium chloride in 300ml water) in small increments and stirring it until the powder reached a paste consistency. This was allowed to sit undisturbed for 24hrs and this paste is kept in oven for 3hrs for the charcoal to get activated.

Fig 01.a. koonka (palm flowers), b. koonka being sundried and 3/4th burning of the sundried koonka, c. charcoal of koonka, d. grinding of charcoal and powdered charcoal (before sieving) and e. charcoal powder after sieving

3.4 RO membrane

The model of the RO membrane used is Hi-Tech ES-2012-100 RO. The membrane is a polyamide Ro membrane sheet. Its diameter is 1.8 inches and length is 12 inches. The testing Pressure for the membrane is 60psi, testing temperature is 25ºC and testing pH is 6-7.5. The membrane has a lifetime of 1 year. The permeate flow of membrane is 100 GDP and rejects impurities down to 0.0001 microns.

Fig 02.RO membrane

IV. Stages Of Treatment

Based on the theoretical studies the following three stage treatment process is proposed for the leachate treatment. This treatment ensures that the filtrate (effluent) has its physiochemical parameters within Indian Standard limits. The stages of treatment include a filtration process, a heavy metal removal process and a membrane treatment.

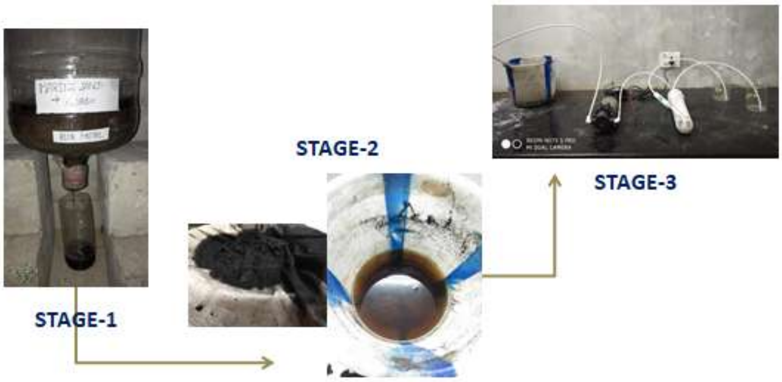

Fig 03.three stages of treatment process

Stage I:-Filtration Process: The filter model is a cylindrical unit of 25cm in diameter and 40cm in height. The height of filter bed is 36cm and 14cm for raw leachate. The filter bed consists of a coarse gravel layer at the bottom and over it a layer of marine sand and fly ash mixture. In order to protect the surface of filter bed diffuser plates are used.

Stage II:-Heavy Metal Removal: The filtrate (effluent) from the stage I filtration process is kept in contact with the activated charcoal of koonka for 24 hours. The optimum mix proportion for charcoal and effluent was found to be 1:10 ratio i.e. for 1 part of charcoal 10 parts of effluent. The activated charcoal absorbs the heavy metal. After 24hrs the solution is filtered and the charcoal is separated.

Stage III:-Membrane treatment: Once the heavy metal absorption is done the effluent is passed through the RO membrane at 60psi with the help of a pump. The final effluent is thus tested for its physical and chemical properties.

V. Results And Discussions

The filtrate from the final stage of treatment is analyzed for its physiochemical properties and heavy metal concentration. The fig . shows the leachate and the filtrate from different stages.

Table 03: Physiochemical Properties Of Final Filtrate

Sl. No.	Parameter	Values	Indian Standard limits
1.	Temperature	7.02	6.5-8.5
2.	pH	31ºC	Shall not exceed 5ºC than the receiving water
3.	Conductivity	4000 µS/cm	Below 1500µs/cm
4.	Turbidity	4 NTU	5 NTU
5.	TKN	3.7 mg/l	100 mg/l
6.	COD	383 mg/l	250 mg/l
7.	BOD	92 mg/l	100 mg/l
8.	TDS	11,600 mg/l	2000mg/l

Fig 04: leachate and filtrate from different stages of treatment

The three stage treatment process has reduced the COD of leachate from 1660 mg/l to 383 mg/l therefore the rate of reduction of COD using the treatment process is 76.93%. The TKN of leachate is reduced at the rate of 79.2%. The BOD reduction with the help of this treatment process is only 39.49%. The TDS of raw leachate was 1,11,700 mg/l whereas for the final filtrate it is found to be 11,600 mg/l. Therefore the treatment process has provided a reduction rate of 89.6% for TDS. The turbidity for raw leachate was 8 NTU and it is 4 NTU for the filtrate. The turbidity of the filtrate is within IS permissible limits (5 NTU). The pH of raw leachate was 8.37 and for the filtrate is found to be 7.02 this shows that the leachate collected was slightly alkaline in nature and after treatment it is under IS limits (6.5-8.5).

When electric conductivity of water is 3.0-6.0 dS/m the TDS should be 2000-4000mg/l and the irrigation water is classified as medium saline water. According to IS when EC of water is 3000-6000µS/cm (3.0-6.0dS/cm) the irrigation water is classified as high saline water, thus this indicates that the filtrate to be used for irrigation needs to be diluted.

VI. Conclusion

The leachate treatment process by 3 different treatment stages has provided 76.93%, 79.21%, 89.6% and 39.49% reduction rates for COD, TKN, TDS and BOD respectively. The turbidity and pH of the filtrate is under IS limits thus the treatment process is effective on this aspect. This treatment process makes use of locally available materials and thus its cost efficient. Since the filtrate is being classified as high saline to medium saline water and yield of the crops are depended on the EC of water the filtrate needs to be diluted before irrigation. Thus the filtrate can be used as a substitute for portable water in irrigation works.

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