A Study on the Impact of Leachate on Soil Water System

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Abstract:- The solid waste management has emerged as one of the most widely debated environmental agendas of the 21st century and one of the prominent challenges in the contemporary times. The subject requires urgent and immediate attention before the situations turns from bad to worse and aggravates beyond control. The focus and need for appropriate solid waste management largely stems from the concern over the environmental challenges posed by the rising waste generation and need to have an efficient waste management solution for a clean sustainable environment.Per capita generation of wastes in Local Self Governments in Kerala is higher than those in other States due to the peculiar consumption pattern in the State. Plastic wastes and e-wastes are on the increase. High water table areas particularly in the coastal region and in low lying areas pose a technological challenge. Though all the five city corporations and 27 out of 60 Municipalities have already been completed the construction of Solid Waste Processing Plants and made the Plants operational, they are facing difficulties such as lack of adequate land for disposal of rejects from the compost plants, inadequacies of processing facilities and odour nuisance excessive leachate generation, water pollution and other environmental issues from operation of the compost plants.In this study an attempt is made to investigate the effect of leachate leached out from the solid waste collected from the treatment plant at Chudukadu in Attingal on the soil water system.

Keywords*:- *Municipal solid waste; leachate; percolation; effluent.

I. INTRODUCTION

The solid waste management has emerged as one of the most widely debated environmental agendas of the 21st century and one of the prominent challenges in the contemporary times. The subject requires urgent and immediate attention before the situations turns from bad to worse and aggravates beyond control. Looking at the global waste generation statistics, solid waste generation was on pace to increase 70 % by 2025, rising from more than 3.5 million tons per day in 2010 to more than 6 million tons per day by 2025. The growing rate of waste generation and the threats posed by its inept management has prompted international organizations and countries to bring it to the forefront of environmental debates, more so in the last four decades. The focus and need for appropriate solid waste management largely stems from the concern over the environmental challenges posed by the rising waste generation and need to have an efficient waste management solution for a clean sustainable environment. The sound of the Waste Management Hierarchy with its three R principle of reduce, reuse, recycle is clearly heard in the articulation pertaining to the Millennium Development Goals and the Rio+20 Summit. This brings in further focus to prioritize Solid Waste Management and frame appropriate measures to deal with the same at country levels.

The increasing pace of urbanization coupled with an increasing per capita waste generation driven by changing urban consumption patterns is exerting significant additional pressure on existing Municipal solid waste management systems across urban centres in India. It is estimated that per capita waste generation has been increasing at a rate of 1.3 % per year. The present rate of urban population, the increase in overall solid waste as can be assessed complicates the situation combined with the institutional as well as financial inadequacies with the urban local bodies. The study on MSW management done in Kerala has that the total solid waste generation in the State is about 8300 tonnes per day. Studies have also indicated that 70-80 % of the total waste generated is biodegradable in nature and these putrescible waste needs to be managed within 24 hours. Of the total, 13 % of the waste is generated by the five City Corporations, 23percent by the 53 Municipalities and the rest by the 978 Gram Panchayats.

In this project an attempt has been made to study the impact of leachate from solid waste on soil and water by selecting an area in Chudukadu within Attingal Municipal area. At present the waste collected is about 18 tonnes per day. Presently the Municipal authorities have entrusted the task of treating the daily created wastes comprising of Municipal, kitchen and town based discharges in a plant installed, operated and maintained by an NGO namely Kasargod Social Service Society thereby extracting the leachates out of the waste mass. The area available for free disposal is limited. The available areas are closely surrounded by habitated locations rendering the disposal a sensitive issue. The authorities are to take precautions to ensure that the leachates oozing out of the solid mass used to fill available low lying pockets should not contaminate the surrounding land areas. They should hence devise methods and means to see that the percolated leachates have traversed through enough depths of underlying soil layers before reach out to the peripheries adjoining the filled up area.

The objectives of the paper is to study the impact of leachate on various properties of soil and to help in devising a land basin lined with soil carpet of appropriate thickness so that effluent finding its way across it shall remain harmless for the adjoining soil water system, thereby giving a remedial measure alternative to treatment plants, where it is not practical to treat the Municipal waste in such plants.

II. MATERIALS USED

A. Soil

Soil samples were collected from site at Chudukadu in the premises of the treatment plant adjacent to Krishibhavan in Attingal. The original soil collected as sample was tested in the lab and various properties are recorded as shown in Table 1.

Properties	values
Specific gravity ,G	2.5
Liquid limit, W_L(%)	42.8
Percentage of sand (%)	75.7
Percentage of silt and clay (%)	2.6
Optimum moisture content (%)	24
Maximum dry density (g/cm^3)	1.42
Angle of internal friction,$Ø^0$	27
Cohesion, c	0.49
Shear strength (kg/cm^2)	1
pH	5.4
Electrical conductivity(dS/m)	0.34
Available OC (%)	1.77
Available P (Kg/ha)	12.99
Available K (Kg/ha)	111.10
Available Fe (ppm)	81.38
Available Mn (ppm)	12.39
Available Zn (ppm)	4.92
Available Cu (ppm)	2.21
Available S (ppm)	108.24
Available B (ppm)	1.16

Table 1. Properties of soil

B. Leachate

The ever increasing volume of waste and limitations in building and maintaining treatment plants, large scale dumping of this wastemay become a necessity. Under the above circumstances, there is need of precautionary measures in handling the waste and the leachate associated.

The leachate used for the study was collected from the treatment plant at Chudukadu. This sample was the liquid portion extracted from the solid waste brought to the plant consisting of Municipal waste, kitchen waste and town waste. This gave a real representation of the contaminant that was under study in the context of this project.

Parameter	Typical Range	Values for Attingal Landfill Leachate
pH	4.5 - 9	4.5
Electrical Conductivity (µmho/cm)	480-72500	1140
Total Dissolved Solids (mg/L)	725-55000	9000
Turbidity (NTU)	30 - 500	135
Organic matter		
Total Organic Carbon (TOC)(mg/L)	0 – 45,000	1700
Biological Oxygen Demand(mg/L)	20 -57,000	125
Inorganic Macro components		
Chloride (mg/L)	150- 4,500	160
Sulphate (mg/L)	8 – 7, 750	740
Potassium (mg/L)	50 – 2,200	1200
Ammonium- N (mg/L)	50 – 2,200	1200
Phosphorus (mg/L)	0.1-23	12
Manganese (mg/L)	0.03-1400	13
Iron (mg/L)	3 – 5,500	20
Heavy Metals		
Chromium (mg/L)	0.02 – 1.5	0.14
Copper (mg/L)	0.005-10	0.12
Lead (mg/L)	0.001 - 5	0.11
Zinc (mg/L)	0.03- 1000	1.235
Arsenic (mg/L)	0.01-1	0.03

Table 2. Properties of leachate

III. EXPERIMENTAL PROGRAMME

A. Effect of leachate on soil

A container of 10 cm x 10cm square section, 60cm height was used to fill soil sample. Non cylindrical shape was preferred to simulate the natural ground condition in a more representative way.10 liters of leachate was kept in another container at a higher level to provide sufficient head for self-flow through hose of 8mm diameter connected to the soil filled at top and pass through the soil column continuously. The rate of flow from the leachate container was so regulated that the flow through the soil mass was steady without overflow from the soil container. The effluent coming out from the bottom of this container was collected, bottled and kept safe for tests in the appropriate laboratories.

Fig 1:- Experimental setup

B. Effect of leachate on water

Four cylinders of 20cm diameter were used for stacking soil samples. In each container the soils were filled at same density and OMC at 15, 20, 30 and 40 cm depth.Leachates of same volume were arranged to pass through each one. The experimental setup was kept for 15 days. After 15 days the effluent coming out of each cylinder was collected separately. Various lab tests were also conducted on the resulting effluent and the soil mass from the bottom of each cylinder affected by percolation of leachate. Harmful constituents like Arsenic, Chromium, lead and other constituents in the leachate and effluent were determined from the test. Chemical analysis was carried out on the soil from each cylinder.

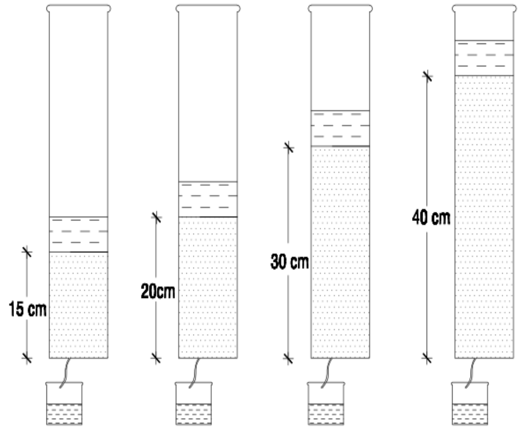

Fig 2:- Schematic diagram for experimental setup(Not drawn to scale)

C. Test on soil samples

The following tests were conducted to determine the properties of the soil. The soil properties determined are consistency limits, maximum dry density, water content, shear strength, pH, electrical conductivity and presence of metals and minerals.

Proctor test were done on the soil samples before and after permeating with leachate. The test provides relationship between the water content and the dry density. This provides important information on soil quality in the context of construction of foundation structures, as it relates to the load bearing capacity of the particular soil. Here the amount of compaction and the water content required in the field are assessed. The test was carried out as per Indian Standards IS: 2720 (Part VII)-1980 and IS: 2720 (Part VIII)- 1980 for light compaction for determining the maximum dry density and optimum moisture content on the soil prior to permeation with leachate result of which is kept as reference. Then the test is done on leachate permeated soil and the values were tabulated. The Consistency limits i.e. liquid limit and plastic limit values were determined as per Indian Standards IS: 2720 (Part 5)-1985.As per this standard , sieved soil sample weighing 120 g was poured on metallic trays, adding water little by little and mixing thoroughly to obtain a paste that was not too thick nor too lean. It was then placed in the Casagrande's device, leveled and divided in to two with the grooving tool. The number of blows at which the divided parts became closed was recorded. Also moisture content of the sample was determined. Test was repeated with increasing the water added and recording the corresponding number of blows and moisture content. The moisture content corresponding to 25 blows was considered as the liquid limit of the soil.

Triaxial test were conducted as per Indian Standards IS: 2720 (Part 11) -1993 to determine the shear strength parameters cohesion (c) and angle of internal friction (Ø) in the unconsolidated, undrained type of test with specimen of 38mm diameter and 76cm height .Shear strength was determined from the failure envelope,which is obtained from the Mohr's circle.

Test for presence of minerals and metals

These tests were conducted in soil analytical laboratory Parottukonam. Here chemical analysis was carried out and details of contents of sulphur, phosphorus, potassium and organic carbon were recorded. Also contents of metals iron, manganese, zinc, copper, boron were found out and recorded.

D. Test on effluents

Tests were conducted on effluent and pH, BOD, turbidity and presence of heavy metals were found out. Mohr's method is used to determine the amount of chloride present in the given sample of water. Water containing chloride when titrated with silver nitrate solution, white silver chlorides is precipitated. Using potassium chromate as indicator, the chloride ions are converted in to silver chromate. The end point is indicated by formation of reddish brown precipitate of silver chromate.

Biochemical Oxygen Demand (BOD) is a test conducted in accordance with Indian Standards IS 3025 (Part 44) : 1993on a body of water to assess the speed at which biological organism in it use up oxygen. It is expressed in milligrams of oxygen consumed per litre of sample during 5 days of incubation at 20 °C . Alternatively, it may be during 3 days of incubation at 27 °C . This is only an indication of the quality of water.

pH meter was used to measure pH value. It gives a measure of the acidity or alkalinity of the liquid, assessed by measuring concentration of hydrogen ions.

IV. RESULTS AND DISCUSSIONS

This chapter includes the results of various test conducted in laboratories and analysis of the results leading to final conclusions.

➢ *Effect of leachate on soil*

A. Standard Proctor test result

Figure 3 shows the relation between maximum dry density and optimum moisture content . The result shows the decrease in MDD and increase in OMC with permeation with leachate. The presence of liquid portion in the leachate increases the saturation of the soil resulting in the decrease of MDD and increase of OMC . The decrease in MDD may be attributed to the chemical reaction (due to change in the nature of pore fluid) between leachate and the soil.

Sample	Standard compaction	
	Maximum Dry Density (g/cc)	Optimum Moisture Content (%)
Original soil	1.42	24
Leachate permeated soil	1.38	26

Table 3. Standard Compaction Test Results

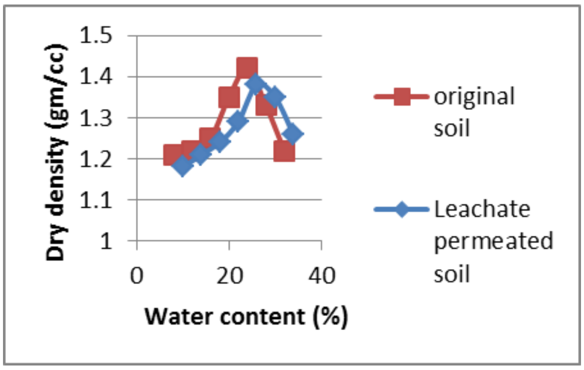

Fig 3:- Compaction curve of original and leachate permeated soil

B. Consistency Limit Test Results

Sample	Consistency limits	
	Liquid Limit (%)	Plastic Limit (%)
Original soil	42.8	25
Leachate permeated soil	36.0	24

Table 4. Consistency Limit Test Results

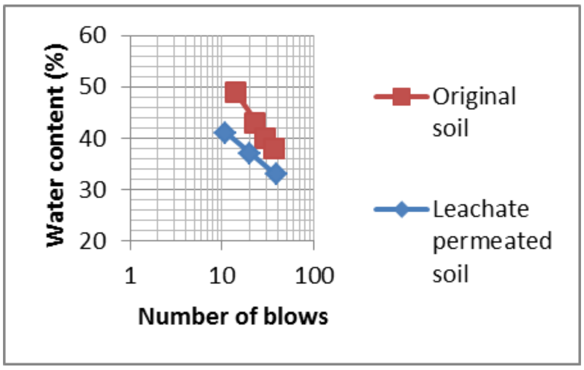

Fig 4:- Liquid limit of original and leachate permeated

Referring figure 4 the liquid limit and plastic limits are seen to decrease with permeation with leachate. These values correlate the amount of water with the state of the particular soil. The change in the behavior of a particular state may be attributed to the interaction between the soil particle and water molecules which is affected by the influence of presence of leachate.

1. Triaxial Test Results

Sample	Triaxial test	
	Cohesion	Angle of internal friction
Original soil	0.49	27
Leachate permeated soil	0.51	16

Table 5. Triaxial Test Results

Unconsolidated, undrained triaxial test were carried out on original as well as leachate permeated samples of soil, to study the effect of leachate on shear strength. In this test confining stress and effective stress were kept constant and the samples kept in fully saturated state. From the table 5 it is observed that shear strength dropped from 1kg/cm^2 to 0.796 kg/cm^2 on contamination with leachate. This clearly shows the negative influence of contamination on the strength properties of the soil.

C. Effect of leachate on soil for different depths of percolation

After allowing the original sample of leachate through columns of compacted soil at varying depths, samples of affected soil from various depths were tested for various parameters and tabulated.

Depth	0	15cm	20cm	30cm	40cm
pH	9.1	5.1	5.1	5.1	5.0

Table 6. pH of affected soil at different depth

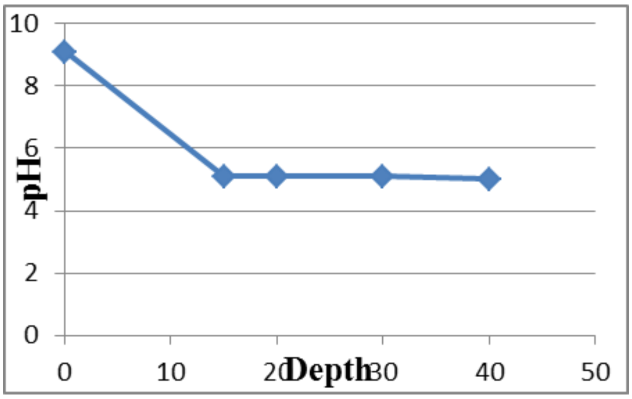

Fig 5:- Variation of pH in different depth of soil layer.

Referring figure 5, ,it is observed that the pH value of the sample soil shows a value of which is much above the neutral range i.e. in the alkaline range, on the top layer. However it comes down abruptly within the acidic range on passing just 15 cm thickness of soil. However it remained more or less constant across the remaining depth. Decrease in the soil pH can cause changes in the soil-water structure, the soil water adsorption, and movement of the pore fluid. Low pH conditions favor the soil particles to aggregate and reduce the soil inter-particle repulsion.[2]

Depth	0	15cm	20cm	30cm	40cm
Electrical conductivity (dS/m)	3.72	1.14	0.99	0.65	0.55

Table 7. Electrical conductivity of affected soil at different depth

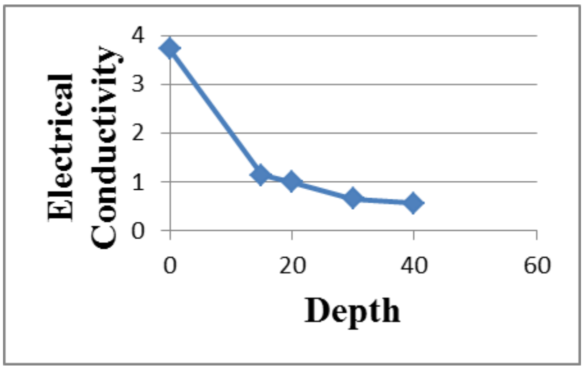

Fig 6:- Variation of electrical conductivity in different depth of soil layer.

Figure 6 shows sudden drop in the conductivity from a higher value at the point of start of percolation of leachate. From depth at 15cm onwards it shows gradual drops up to40 cm depth where the salinity of the soil is reasonably low showing improved quality level.

Depth	0	15cm	20cm	30cm	40cm
Available OC(%)	1.57	1.69	1.71	1.77	1.79

Table 8. Variation of Organic Carbon in different depth of soil

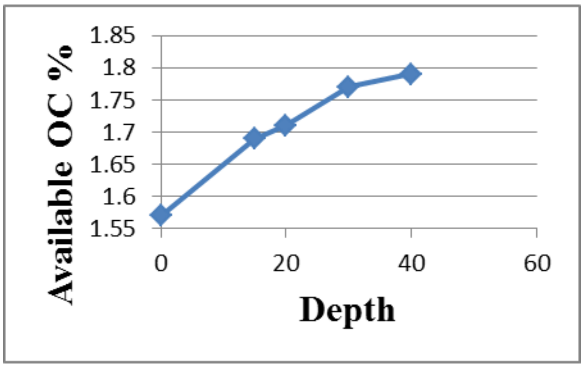

Fig 7:- Variation of Organic Carbon in different depth of soil layer.

In the case of organic carbon (OC) its presence gradually goes up to the value as in uncontaminated sample at 30cm depth then further rises to a higher level at 40 cm depth.

Depth	0	15cm	20cm	30cm	40cm
Available P(Kg/ha)	31.92	18.70	15.20	12.77	10.58

Table 9. Variation of Phosphorus in different depth of soil

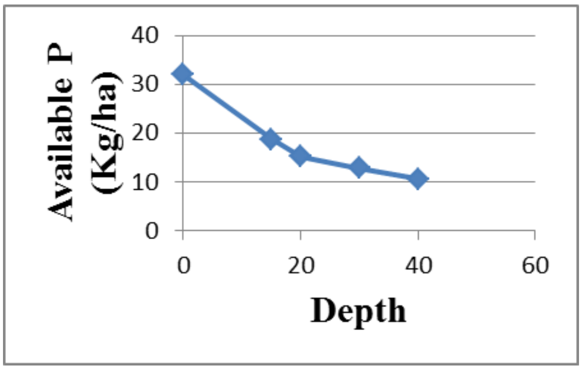

Fig 8:- Variation of Phosphorus in different depth of soil layer

Phosphorus after rising much above the value in uncontaminated soil sample, sharply drops till 20cm depth, then gradually drops to value little below the uncontaminated value. Conversion on to soluble compounds may be the reason.

Depth	0	15cm	20cm	30cm	40cm
Available K(Kg/ha)	7700	596.40	240.00	155.68	140.12

Table 10. Variation of Potassium with depth of soil

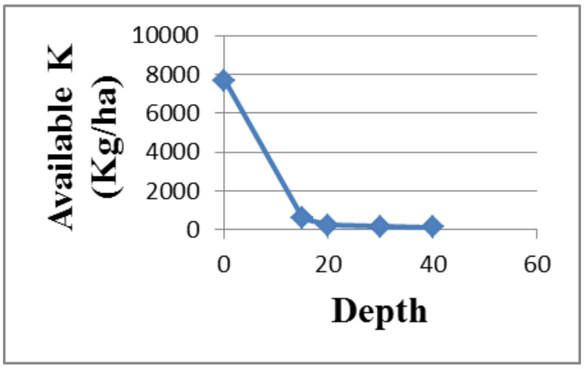

Fig 9:- Variation of Potassium in different depth of soil layer

Figure 9 shows the variation of potassium with depth. The presence of K showed a sudden drop from zero depth to 15cm depth and thereafter only slight variations towards 40cm depth where the value is little bit above the original sample.

Depth	0	15cm	30cm	40cm
Available Fe(ppm)	96.12	92.00	84.21	81.98

Table 11. Iron content at different depth of soil

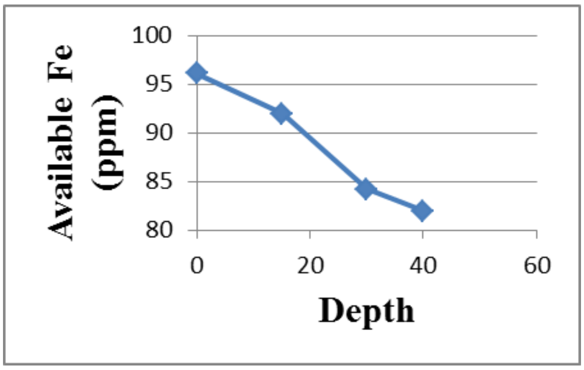

Fig 10:- Variation of Iron in different depth of soil layer

Figure 10 shows the variation of iron with different depth. Iron showed enhancement at initial level, then sharp drop towards 40 cm depth. This was still slightly above the uncontaminated value. However it showed decreased influence of the leachate towards this level.

Depth	0	15cm	30cm	40cm
Available Mn(ppm)	14.28	13.16	12.91	12.39

Table 12. Manganese content at different depth of soil.

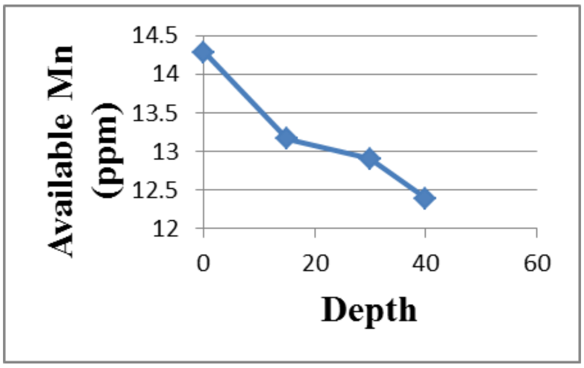

Fig 11:- Variation of manganese in different depth of soil layer

Figure 11 shows the variation of manganese with depth. Presence of manganese after initial enhancement dropped rapidly towards 15cm depth. Then showed gradual decrease till reached the uncontaminated level at 40cm depth.

Depth	Zero	15cm	30cm	40cm
Available Zn(ppm)	12.72	8.35	5.63	4.98

Table 13. Zinc content at different depth of soil

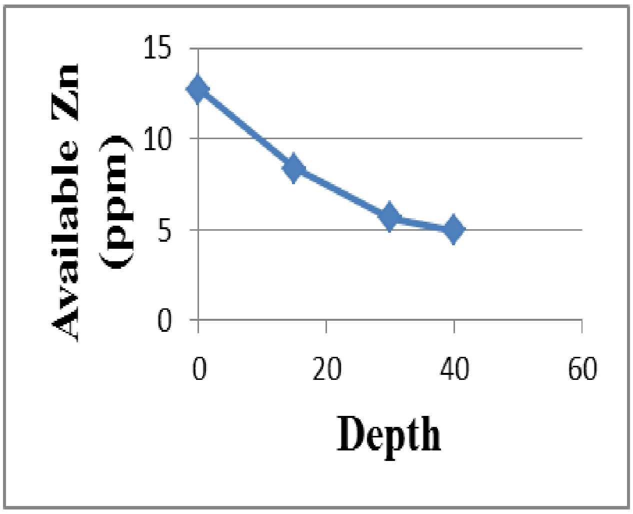

Fig 12:- Variation of zinc in different depth of soil layer

Figure 12 shows the variation of Zn with depth. Zn showed gradual drop after initial increase, towards the uncontaminated value at 40cm depth.

Depth	Zero	15cm	30cm	40cm
Available Cu(ppm)	2.13	2.11	2.11	2.10

Table 14. Copper content at different depth of soil

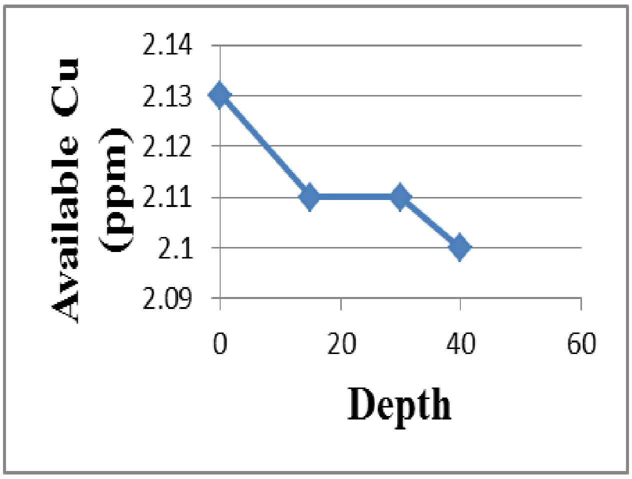

Fig 13:- Variation of copper in different depth of soil layer

Figure 13 shows the variation of copper with depth. The value of copper showed slight variation but reached the uncontaminated value at 40cm depth.

Depth	Zero	15cm	30cm	40cm
Available S(ppm)	83.35	91.50	101.00	103.20

Table 15. Sulphur content at different depth of soil

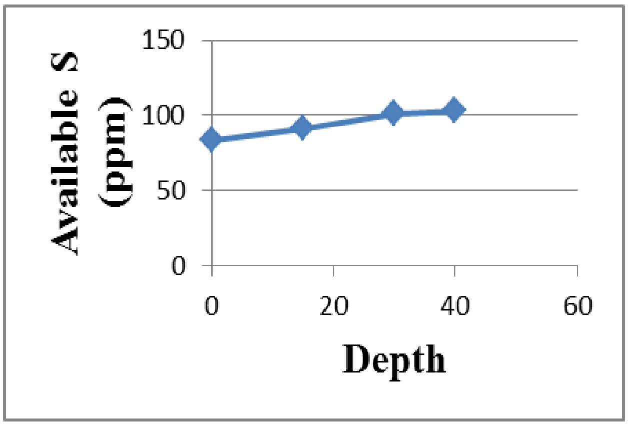

Fig 14:- Variation of sulphur in different depth of soil layer

Figure 14 shows the variation of sulphur with depth. Sulphur content dropped initially and then showed gradual enhancement towards 40cm depth, still below the uncontamination level.

Depth	Zero	15cm	30cm	40cm
Available B(ppm)	1.67	1.50	1.21	1.19

Table 16. Boron content at different depth of soil

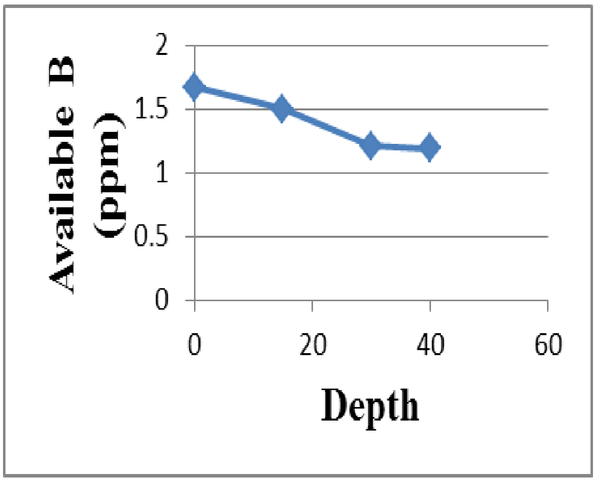

Fig 15:- Variation of boron in different depth of soil layer

Boron showed increase initially then dropped towards 40cm depth, still slightly above the uncontaminated level. Figure 15 shows the variation boron with depth.

D. Changes in characteristics of leachate on percolating through soil

Depth	0	15cm	20cm	30cm	40cm
pH	9.0	7.65	7.64	7.62	7.10

Table 17. pH of effluent

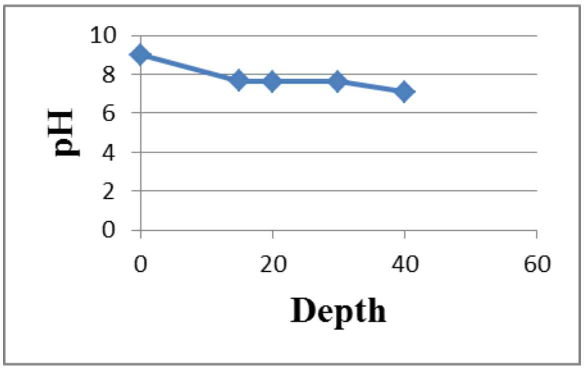

Fig 16:- Variation of pH of effluent in different depth of soil layer.

Figure 16 shows that the pH value of the leachate after showing an upward trend of 7.65 for 15 cm depth, then fall down to 7.1 at 40cm which in the neutral range shows a harmless state.

Depth	0	15cm	20cm	30cm	40cm
BOD (mg/l)	125	68.10	42.20	14.20	7.40

Table 18. BOD of effluent

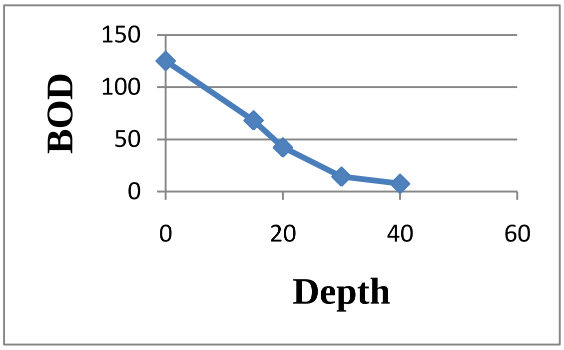

Fig 17:- Variation of BOD of effluent in different depth of soil layer

Depth	0	15cm	20cm	30cm	40cm
Chloride(mg/l)	260	199.1	213.5	245.8	274.4

Table 19. Chloride content in effluent

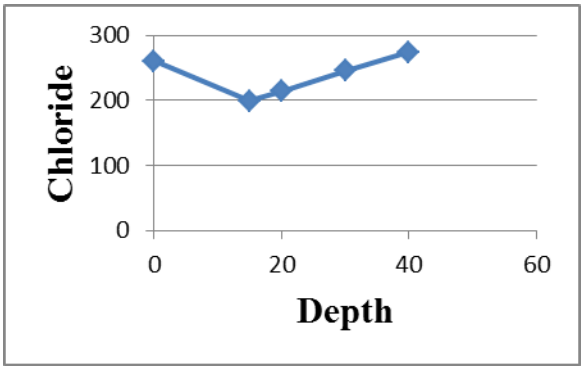

Fig 18:- Variation of chloride of effluent in different depth of soil layer

Depth	0	15cm	20cm	30cm	40cm
Turbidity(mg/l)	135	74	35	9	5

Table 20. Turbidity of effluent

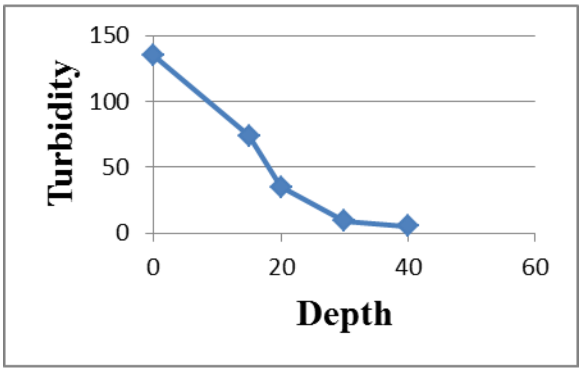

Fig 19:- Variation of turbidity of effluent in different depth of soil layer

Table 18 shows the BOD of the effluent. The BOD status also improved to safe limits. Table 19 shows the quantity of chloride content in the effluent. Chloride showed an upward trend. Table 20 shows the turbidity level of effluent. Turbidity level at 40cm depth has shown improvement to appreciable level of 5.

Depth	0	15cm	20cm	30cm	40cm
Zn(mg/l)	1.235	0.663	0.564	0.514	0.343

Table 21. Presence of Zinc in the effluent

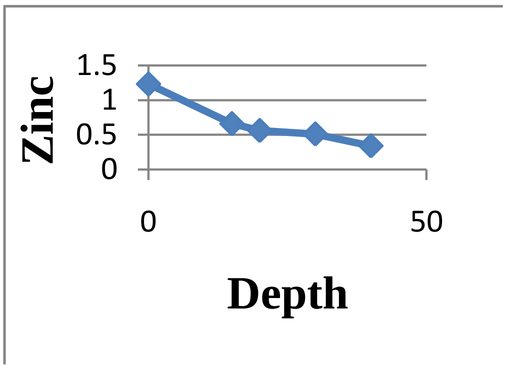

Fig 20:- Variation of zinc content in different depth of soil layer

Referring figure 20 zinc content of leachate sample before test was found to be at higher level. As the leachate passed through subsequent layers down, it gradually dropped reaching the lowest figure which was in the safe limits.

Depth	0	15cm	20cm	30cm	40cm
Pb(mg/l)	0.11	0.05	0.03	0.01	ND

Table 22- Presence of Lead in the effluent

ND- Not detected

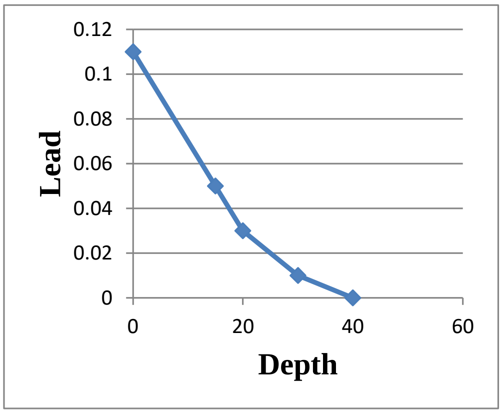

Fig 21:- Variation of lead content in different depth of soil layer

Referring figure 21, the presence of lead was found to be above 0.10 mg/l for leachate before testing. It sharply fell down to around 0.03at 20 cm depth. From there it gradually reduced to reach zero value at 40cm depth where the leachate emerged as effluent. This clearly gives an idea on how the harmful effect of the leachate is brought under control by letting it percolate through a depth of soil.

V. CONCLUSIONS

The highest rate of population growth, urbanization and economic expansion in India is not only accelerating consumption rate but also increasing the generation rate of all sorts of waste. The contemporary approach to solid waste management proves to be ineffective and inappropriate and there are complex and multifaceted problems in the management of solid waste.

The Solid waste management is a mandatory responsibility of LSGIs, as per provisions of the Kerala Municipality Act 1994, Kerala Panchayat Raj Act 1994 and the Municipal Solid Waste (Management & Handling) Rules, 2000. Therefore, the LSGIs have to provide basic infrastructure for collection, conveyance, treatment and disposal of Municipal Solid Waste. They are also responsible for operation and maintenance of such facilities. Though all the five city corporations and 27 out of 60 Municipalities have already been completed the construction of Solid Waste Processing Plants and made the Plants operational, they are facing difficulties such as lack of adequate land for disposal of rejects from the compost plants, inadequacies of processing facilities and odour nuisance excessive leachate generation, water pollution and other environmental issues from operation of the compost plants.

In this project an attempt has been made to study the impact of leachate from solid waste on soil and water by selecting an area in Chudukadu within Attingal Municipal area. The study revealed that leachate has multifold effects on both soil and water of the geographical area under consideration. It affects liquid limit, plastic limit compaction characteristics and strength properties of soil. This may lead to various geotechnical problems affecting the structural stability of construction projects.

The leachate also by percolating into the water table contaminates the ground water system, which in turn affect foundation of structure as well as public health. This affected the shear strength negatively. MDD decreased whereas OMC increased on permeation with leachate.

Study also indicated that leachate contains many objectionable elements which adversely affect the quality of the ground water. Excessive presence of parameters like acidity, minerals, chemicals, metals and heavy metals, S,P, Zn were detected including hazardous imparts on water quality.

The harmful impact of leachate can be reduced by percolating the leachate through liners of sufficient thickness. This study would help in designing waste dumping landfill basins using layers of selected soil materials of required thickness as liners allowing only harmless form of effluent to spread across the surrounding soil water system.

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