Removal of Lead from Leachate of Waste water Using Clay as Liner Materials

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Summary:

Hazardous waste leachate effect can be reduced using clay as Liner materials in landfill.

Keywords: ground water contamination, Lead poisoning, heavy metal, clay.

Extended Summary

Lead is a heavy metal, which has adverse effect on our health & on the environment also. If lead comes in contact with ground water, the later gets contaminated. Lead builds up in the body over many years and can cause damage to the brain, red blood cells and kidneys. The greatest risk is to young children and pregnant women. Clay particle has porosity of 40 – 70% and permeability (K) value of clay is less than 10-7 cm/s and so the rate of advection transport through clay is very low. Clay has the property of swelling, plasticity, cohesion and adhesion. Low porosity, slow diffusive transport, high adsorption of cations, and plasticity / swelling is among the interesting property of clays. Some clay soils have the ability to act as membrane that restricts the passage of charged solutes. An experimental attempt has been taken in laboratory scale using clay as liner materials to protect groundwater from contamination of Lead.

Keywords: ground water contamination, Lead poisoning, heavy metal, clay.

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INTRODUCTION:-

Lead has adverse affect on our environment and our health. If lead is present in waste from an Industry, it will contaminant the environment & if the waste materials are dumped in a landfill, it will affect the ground water also. Landfill has been the most commonly practiced method for disposal of waste materials since this is normally the least expensive alternative available. So to dispose any hazardous waste to a landfill, liner is used which protects the landfill as it a barrier to fluid movement. The overall objective is to limit the discharge of toxic contaminants to groundwater. Liners provide the final line of defuse against groundwater contamination. In Industry Geo-membrane such as High Density Polyethylene, Flexible Polyethylene, Poly Vinylchloride, Polypropylene and Geo-synthetic clay liner are used as liner materials for Hazardous Waste landfill. But the problems to use these materials are: -

i) These are very costly, unsuitable for retention of some hydrocarbons and when exposed to sunlight is susceptible to UV attack.
ii) There is a possibility of structural cracking in liner material.
iii) These are non-biodegradable.
iv) Seepage problem from impoundment represents the greatest potential contamination from surface impoundment and can lead to groundwater contamination[1].

So, by using these materials as liner materials[2,3] there is every possibility of contamination of ground water, surface water by hazardous material.

So, for these problem Clay can be used as liner materials for the hazardous waste landfill as Porosity of clay particle is 40 – 70% and equivalent movement of liquid and associated contaminants through it is 0.03 m/year; Permeability (K) value of clay is less than 10^{-7} cm/s and so the rate of advection transport through clay is very low[4]. It can adsorb some contaminants also. The very low permeability of the clay barrier is expected to lengthen the lifetime of the landfill and slow down the consequent release of contaminants. Clay has the property of swelling, plasticity, cohesion and adhesion. Clay liners placed above groundwater table are generally unsaturated. Some clay soils have the ability to act as membrane that restricts the passage of charged solutes. Such membrane behaviour also results in Chemico-Osmosis, or movement of liquid in response to solute concentration gradient. Both these effects result in reduced solute transport through a soil barrier for waste contaminant.

There are certain standard for using clay as liner materials. These are[5]:

i) The permeability of the soil should be less than $1x10^{-9}$ m/sec for soil liners which are used for Hazardous waste, Municipal waste & Industrial waste landfill.

ii) The clay % in a given soil should be higher than 20% etc.

iii) Plasticity index should be >10 & Liquid limit should be >30.

iv) The thickness of the liners varies from few decimeters to more than 1 m depending on the waste composition.

But the problem associated with clay liners are they may be attacked by the chemical wastes or leachate they are meant to contain directly or indirectly. The interaction of soil with the chemical waste may attack the clay – double diffuse layer, as a result the permeation through the liner is increased & the possibility of groundwater contamination is also increased. To overcome this problem, some admixture like gypsum, cement, lime, bentonite, flyash etc is added with soil to stabilize the soil particles from chemical attack & to decrease the porosity of soil particles.

But the amount of groundwater recharge, storage, discharge, as well as the extent of groundwater contamination, all depend on the soil properties. So, for the work, Soil is collected from river Matla, Canning West Bengal as the properties of the soil fulfill the properties (Table 1) to be used as clay liner.

Table1: Properties of soil of Matla River

Properties	Value	Method/Instrument of measurement
Soil pH	7.49	pH meter
Moisture Content	26.1142 %	Tray Drier
Conductivity, μ s/cm	227	Conductivity meter
Liquid Limit	48	Liquid limit devices, AASHTO T-89-00 (2004)

Plastic limit	24	Plastic limit apparatus AASHTO T-90-00 (2004)
Plasticity Index	24	-
Permeability , m/sec	1.08 x 10^{-9}	Permeability apparatus
Clay %	27	Sedimentation process
Silt %	68	Sedimentation process
Sand %	5	Sedimentation process
Quartz	45%	X-ray Diffraction
Illite	25%	X-ray Diffraction
Feldspar	5%	X-ray Diffraction
Kaolinite	5%	X-ray Diffraction
Montmorillonite	5%	X-ray Diffraction
Chlorite	10%	X-ray Diffraction

Due to these properties of soil of Matla River (as fulfill the criteria of clay liner properties), it is used as liner materials & with it different concentration of known amount of lead metal is passed through the clay liner using different thickness & different ad-mixture of clay materials using special type of apparatus. The concentration of lead metals at different thickness of clay liner is experimentally extracted from soil using Atomic absorption spectrophotometer.

MATERIALS & METHODS

Soil used : Soil of Matla River.

Chemical Used : Lead nitrate, Hydrochloric acid, nitric acid etc.

Instrument used: Variable Head Soil Permeability Apparatus, Atomic Absorption Spectrophotometer etc.

Methods:

For the experimental work, known amount of Matla river soil samples (25 gm) are taken and the lead content in the samples are determined with the help of Atomic Absorption Spectrophotometer using standard method[6].

After that a fixed amount (2 kgm) of soil samples are taken in the special type variable Head Permeability apparatus (depth 12.6 cm and diameter 10 cm, diameter of stand pipe = 2 cm) which operates on the basis of Darcy's law:

$$K = 2.3 \frac{aL}{At} (\log H_0 - \log h_1) ,$$

where K = Coefficient of Permeability of the given soil sample, cm/sec

a = area of cross – sectional of stand pipe.

L = Length of soil sample

A = area of cross section of soil sample

H_0 = initial head of solution

h_1 = head of water after a fixed time.

Known amount of Lead solution is passed through the stand pipe to the sample chamber (depth 12.6 cm long & 10 cm diameter sample port). At the bottom of the soil chamber, a extra chamber arrangement is made (depth 10 cm & made from Perplex) where water (diffuse through the soil) from soil chamber can be collected and be taken out at the time of experiment. After different time intervals, water sample from the Perplex chamber can be taken out & lead concentrations are determined using Atomic Absorption Spectrophotometer. After a certain period of time, soil samples are taken out from the sample chamber & after 7 days exposure, soil samples from different depth of the sample chamber are taken & Lead concentration are measured using Standard method & with the help of Atomic Absorption Spectrophotometer for measuring the Lead solution variation (diffusion through the soil samples) among the different depth of the soil chamber[7,8].

For the second type of experiment soil is air dried, crushed & to it admixture is added (10% each) separately. Distilled water is added to the mixture to the ultimate optimum water content. All the specimens are permeated in 5 cm long & 10 cm diameter sample port & permeated first with de-ionized water. After that sample chemical mixture is passed through the different soil – admixture liner[9]. Chemical mixture solutions are passed through the different soil mixture. The concentration of different metals passing through the soil bed & solution at the lower portion of the membrane (as aqueous solution) is extracted using standard procedure & is determined using Atomic Absorption Spectrophotometer. The Total solid, pH etc characteristics of the aqueous solution are also determined using standard methods.

The different soil beds used are:

a) soil bed , b) soil – 10% bentonite mixture bed, c) soil – 10% gypsum mixture bed, d) soil – 10% cement mixture bed, e) soil – 10% lime mixture bed.

Mathematical modelling Equation:

Using Buckingham Π Theorem, a mathematical expression has been derived. The equation is:

$$\frac{C_0 - C}{\rho} = f\left(\frac{k_l t}{x}\right) \qquad \text{--------------- (1)}$$

where ΔC = Concentration difference = $(C_0 - C)$,

C_0= Initial Concentration, C = Final Concentration., [M/L^3]

x = Length of the membrane = [L]

k_l = Coefficient of Permeability = [L/T]

ρ = Density of soil = [M/L^3]

t = time, in sec = [T]

RESULTS & DISCUSSIONS:

The experimental results are given below:

Table 2: Lead concentration variation along the distance during the experiment.

Sample taken from	Height from above, cm	Total Soil Sample gm	Solution concentration ppm	Metal after treatment (ppm)	Metal (mg/kg) after treatment
From soil Chamber	0	25	17.0018 x 10^3	91.453	365.812
	2	25		37.1	148.4
	3.5	25		22.15	88.6
	4.9	25		16.7	66.8
	5.8	25		12.264	49.056
	7.6	25		7.18	28.72
	9.3	25		4.533	18.132
	12.5	25		0.5906	2.3624
From Perplex chamber	Below Solution	-		0.321	-

Figure1: Lead concentration variation along the distance during the experiment.

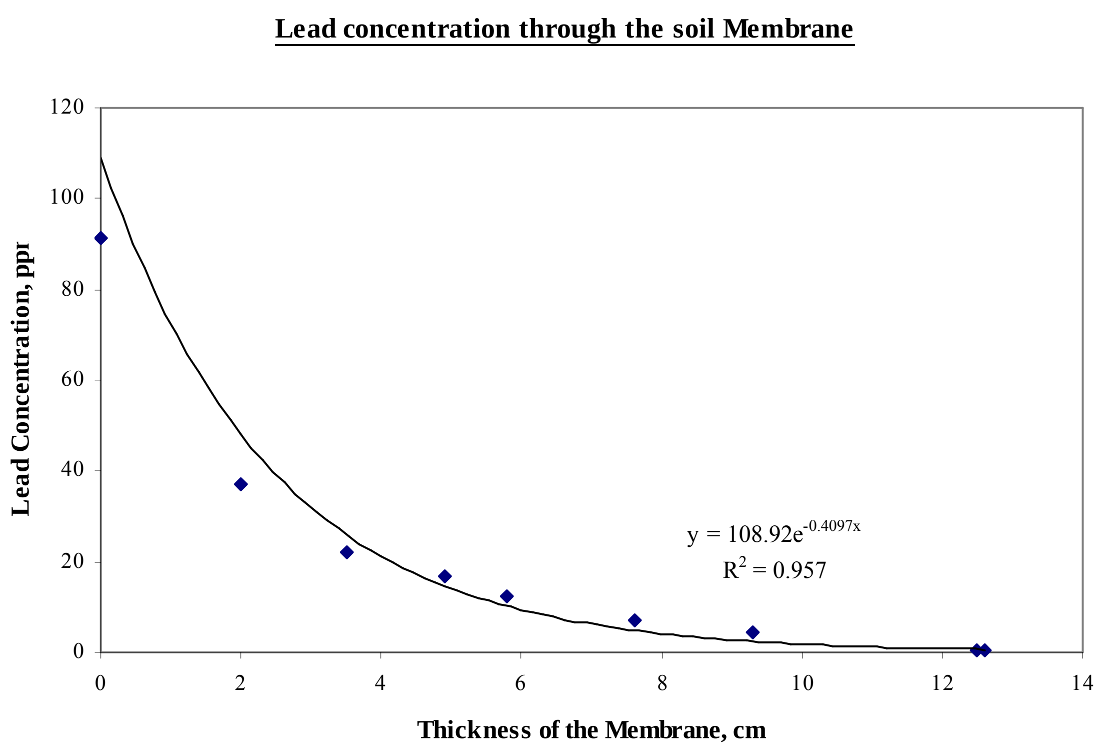


Figure 2: Lead concentration along the soil membrane

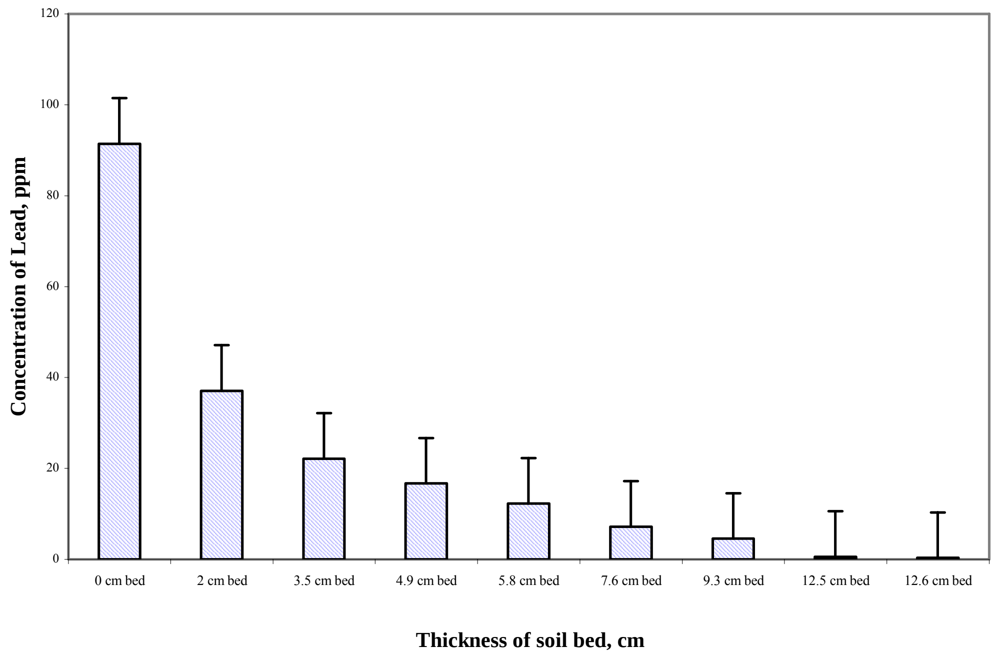


Figure 3: Modelling of samples of soil using equtaion 1

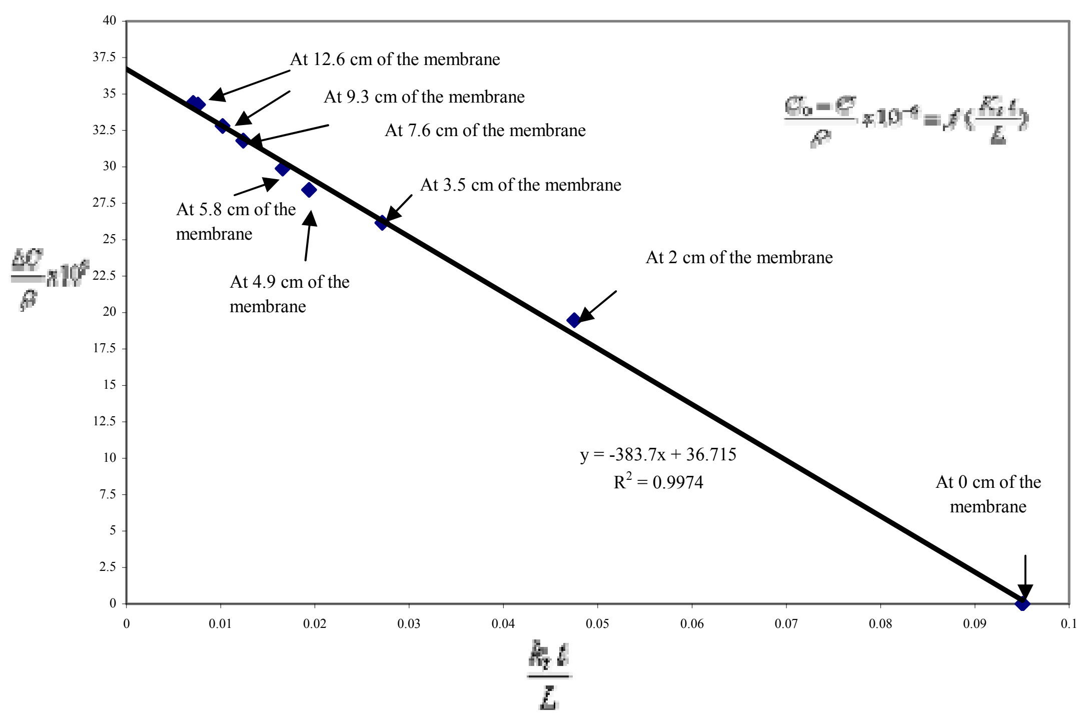
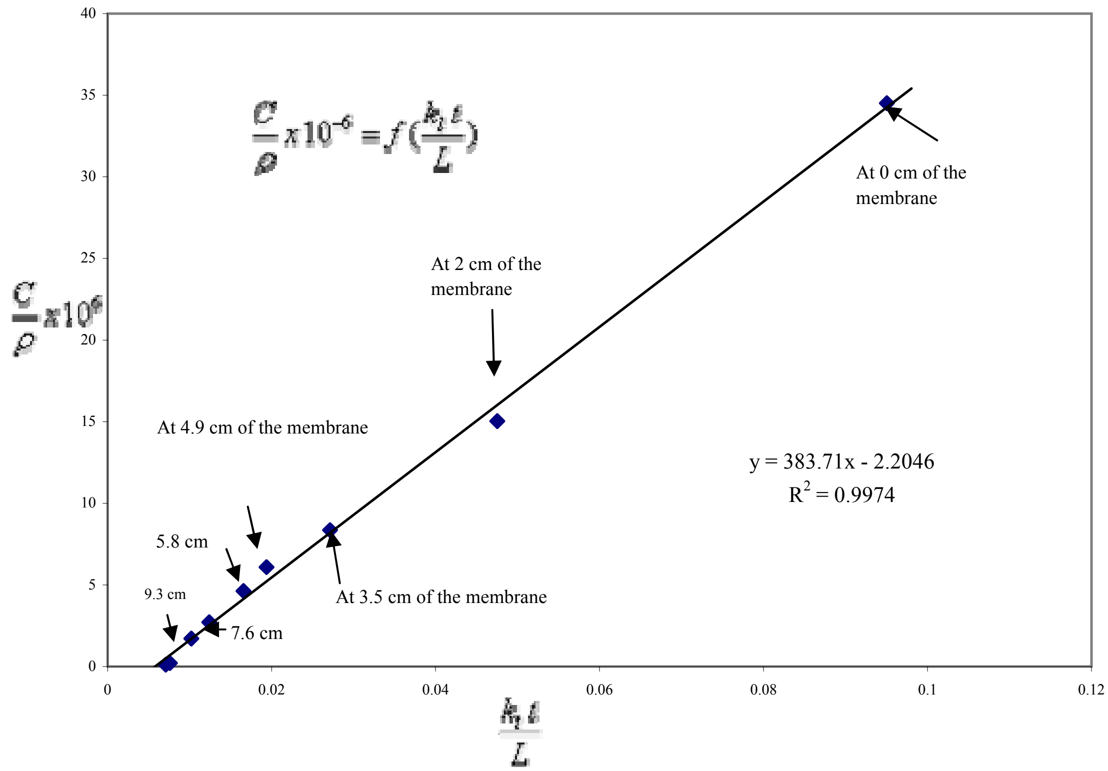


Figure 4: Modelling of equation of soil using Buckingham Theorem



From Table 2 & Figure1 & 2, it is observed that the lead ion concentration is decreasing as the soil layer thickness is increasing. The concentration is reduced from 85% to 99.28 % from upper to lower level through out the soil membrane. At the bottom of the soil layer, it is observed that the concentration of is 0.321 ppm, & it is below permissible limit. The reason of this phenomenon is that a large amount of lead ion is adsorbed by the soil samples of the above portion of the soil chamber as a result the solution transported from upper level to lower level through the membrane, the concentration is decreased gradually.

By using experimental data & using equation 2 it is observed in Figure 3 & in Figure 4, that the nature of the curve is straight-line & R^2 is .9974 (>80), so the predicted mathematical method is valid for this type of soil membrane.

Table 3:- Results of the concentration of Lead passing through the soil-admixture.

Kind of Mixture	Soil	Soil - Bentonite	Soil – lime	Soil - Cement	Soil - Gypsum	Soil – Fly ash
Upper Level, ppm	19.994	23.631	19.418	10.0148	20.464	12.007
Lower Level, ppm	0.594	0.881	1.027	0.48	1.213	0.759
Lower aqueous solution, ppm	0.025	0.038	0.189	0.032	0.036	0.207

Figure 5: Concentration of Lead of lower portion passing through the different mixture of the sample port

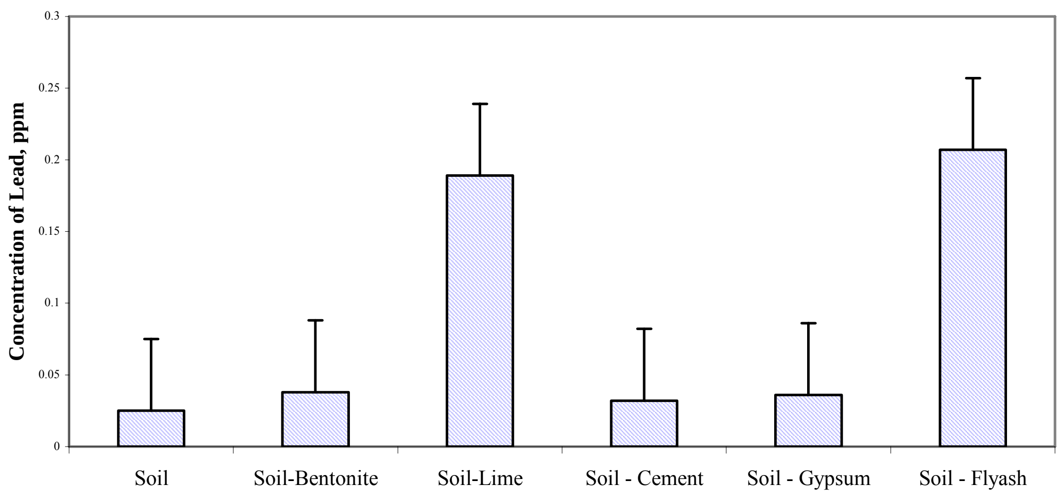


Figure 6:- Lead concentration at different level for different mixture

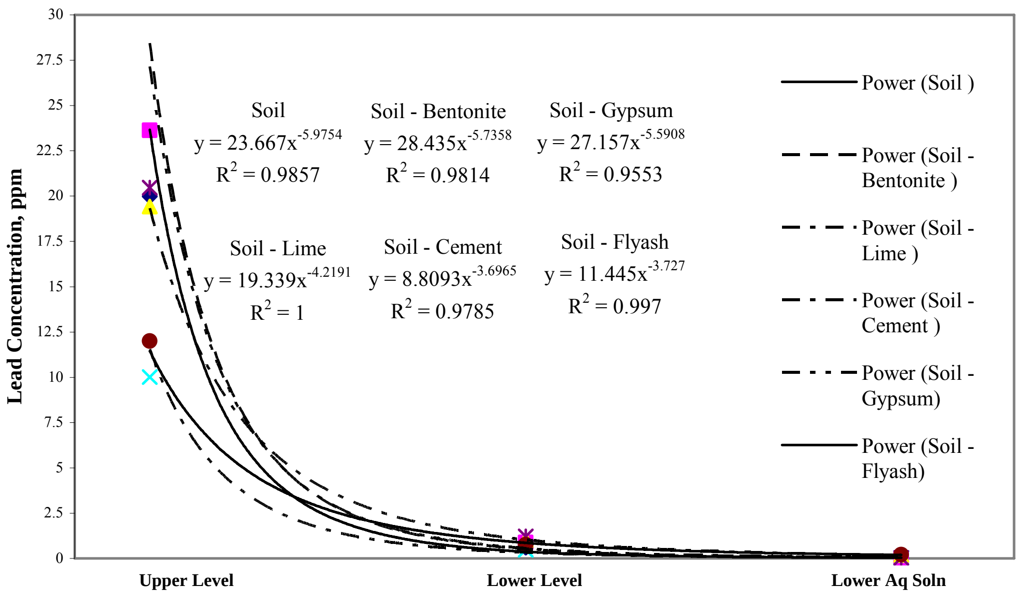
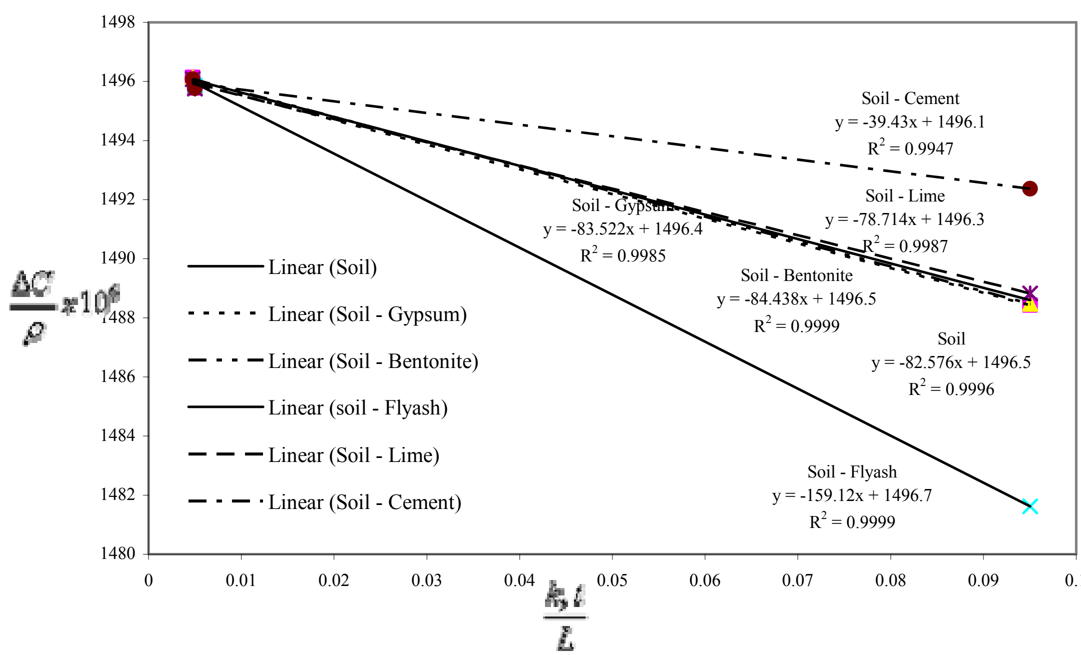


Figure 7:- Effect of Lead on different Soil - Admixture using Equation 1



From Table 3 & Figure 5 – 6, it is observed that the concentration of Lead is reduced from upper level to lower level. The reason behind is that the admixture mixed with soil, decrease the porosity of the soil particles, strengthening the soil, cementing the soil porosity & so decrease the path of flow of the solution. Lead has the binding effect with soil. So the permeation rate through soil – admixture is low. In case of soil – cement mixture, the results are better than other mixture. The reason is behind is that cement particles decrease the soil porosity due to their cementing effect, strengthening the soil from flocculation & so decrease the permeability. In case of gypsum, due to this cementing effect, permeation rate is decreased, but due to the presence of calcium ion, which can diffuse the double diffuse layer of soil particles, so the permeation can increase. Due to the combined opposite effect, the permeation rate is somewhat higher than soil – cement mixture. In case of lime, due to the presence of calcium, the permeation rate is increase. Bentonite is also a good alternative, but due to the properties of cracking, in absence of solution, the permeation rate is increase. From Figure 7 it is observed that the nature of the curve is straight line for all the soil – admixture & $R^2>0.9$. So, the predicted model used here is satisfying the phenomenon.

Conclusion:

It is seen from the experimental results that the lead concentration can be reduced from 85% to 99.28 % at the bottom level of the soil chamber. At the bottom of the special perplex chamber where aqueous samples can be collected, it is seen that concentration of lead in solution is 0.321 ppm, The reason behind it is that a large amount of lead ion are adsorbed by the soil samples of the above portion of the soil chamber. So a little amount of lead ion is diffused through the pore space of the soil samples and lead ion concentration is reduced from above portion to lower portion of the soil chamber. So, if clay can be used as liner materials, then Hazardous chemicals affect like Lead can be reduced. From second type of experiment it is also observed that the reduction % from upper to lower level is higher (for Lead metal) in case of soil – cement mixture liner. It is also observed that soil – gypsum mixture is also a best alternative for using this material as liner material. So, it can be concluded that to protect the liner from chemical attack, soil – cement or soil – gypsum liner can be used as liner.

Clay is not costly & it is easily available and it is not create problem like Plastic materials. So, we can conclude that clay can be used as liner materials for the Hazardous Waste Landfill.

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