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LANDFILL LEACHING: AN EXPERIMENTAL INVESTIGATION USING COLUMN APPARATUS

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Abstract *An attempt is made in this study to understand the leaching mechanisms in the landfills by detailed experimental investigation using column leach apparatus. Various combinations of soil profiles are incorporated in the column apparatus. Water at a predetermined flow rate is poured from the top and the leachate is collected from the bottom at regular time intervals. Then by use of Atomic absorption spectrometer the concentration of zinc is determined in the leachate. Parametric studies are carried out to study the effect of flow rate and liquid –solid ratio on the leaching behaviour of soil.It has been observed that with the increase of flow rate and liquid-solid ratio there is an increasing trend of leaching behaviour.However in some cases small deviation is also observed.*

Keywords*:* Numerical Modeling; Advection-Diffusion; Column leaching; Leachate

INTRODUCTION

For the past few years there is a growing concern over contamination of groundwater resources due to various anthropogenic sources. One of the major sources of groundwater contamination is due to leaching of hazardous chemicals from the landfill site to the underlying aquifer. The mechanism of leaching of contaminants through soil is a complex process as it involves various chemical and biological processes. During the past two decades various analytical and numerical models are made all over the world to study the mechanism of leaching. Javadi and Najjar (2007) had presented a finite element model for contaminant transport in soil which incorporates the effect of chemical reaction also. Souhail et al. (2007) had investigated the leaching behavior of mineral processing waste by column experiment and batch test.Wang et al (2008) conducted column leaching test on coal and its combustion residues in Shizuishan in China. J.Islam et al (2002) presented one dimensional reactive multicomponent landfill leachate transport model which takes into account kinetic biodegradation, kinetic precipitation –dissolution and geochemical equilibrium. Abriola and Pinder (1985) developed a model which incorporates multiphase transport and the transport of organic species. Celia and Boluloutas (1990) incorporated a new numerical solution to the solution of advection-diffusion type of problem. Li et al. (1999) developed a numerical method of contaminant transport taking into account the effect of miscible contaminant transport. Kakuri and Molenkamp (1997) developed a new model for the simulation of groundwater flow and contaminant transport through multilayered saturated soil in 1-D. Parkhurst et al (1980) presented a mathematical basis for incorporation of the

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equilibrium reaction in solute transport analysis. Darby and Naser (2006) had presented a comparative analysis between numerical and analytical results on nitrate leaching through unsaturated soil column. Brun et al (2002) presented a biogeochemical transport code to simulate leachate attenuation and biogeochemical processes for landfill plume. Zheng and Bennet (2002) presented their work on contaminant transport modeling consisting of elaborate discussion on geochemical modeling. However the exact mechanism of contaminant transport through soil is complex because of the fact that it is difficult to characterize the exact physical, chemical and biological processes which occur during the migration of contaminants through soil. Therefore, an attempt is made in this paper to understand the mechanism of landfill leaching by detailed experimental investigation by use of column leaching apparatus. The main focus of this research work is to investigate the correlation of leaching behavior of various types of soil with their compositional behavior.

THEORY

Mass transport of solute into the ground water is based on mass balance concept. The governing equation is known as advective-dispersive equation (Zheng and Bennet, 2002)

$$\theta R \frac{\partial C}{\partial t} = \frac{\partial}{\partial x_i}\left(\theta D_{ij} \frac{\partial C}{\partial x_j}\right) - \frac{\partial}{\partial x_i}\left(q_i C\right) + q_s C_s + \lambda_1 \theta C - \lambda_2 \rho_b C^k \tag{1}$$

where

R is the retardation factor which is defined as $R=1+\frac{\rho_b}{\theta}\frac{\partial C^k}{\partial C}$

C = Dissolved concentration (ML^{-3})

C^k =Sorbed concentration ($M M^{-1}$), a function of the dissolved concentration as defined by a sorption isotherm.

t = Time,

θ = Porosity of the subsurface medium.

D_{ij} = Hydrodynamic dispersion coefficient tensor, (L^2T^{-1}

q_i = Darcy velocity(LT^{-1})

λ_1 = Reaction rate constant for the dissolved phase

λ_2 = Reaction rate constant for the sorbed phase.

ρ_b = Bulk density of the porous medium (ML^{-3})

Experimental Investigation:

a) Experimental set-up:

The experimental set-up is shown below:

It comprises of a rectangular hollow chamber of size (0.2m x 1.75m) which is made up of Perspex sheet. The apparatus is placed on an iron stand.

b) Experimental procedure:

Contaminated soil samples are collected from various waste disposal sites near IIT Guwahati. In the beginning a small portion of contaminated soil filled in the top of the leaching column is taken. Following ASTM D3974-81 methods, digestion of the soil sample is done to determine the initial concentration of contaminant (zinc in this case) in the top soil. The procedure is as

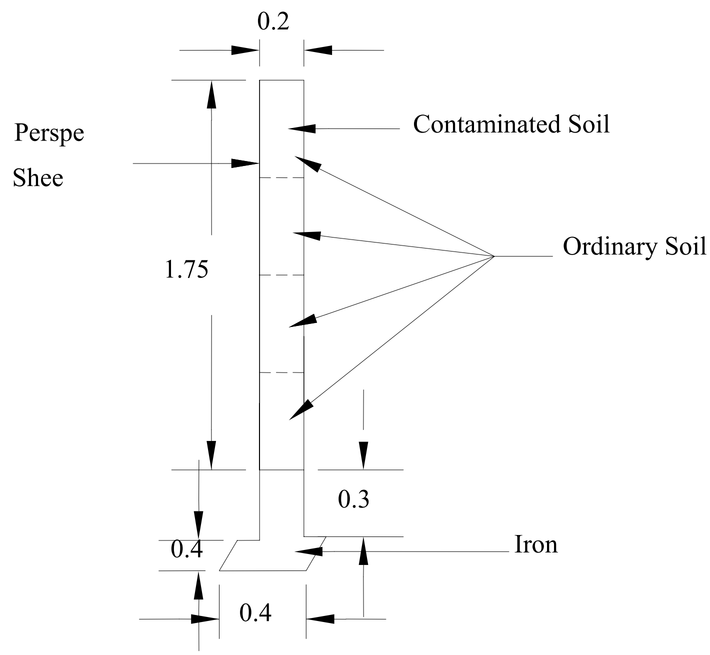
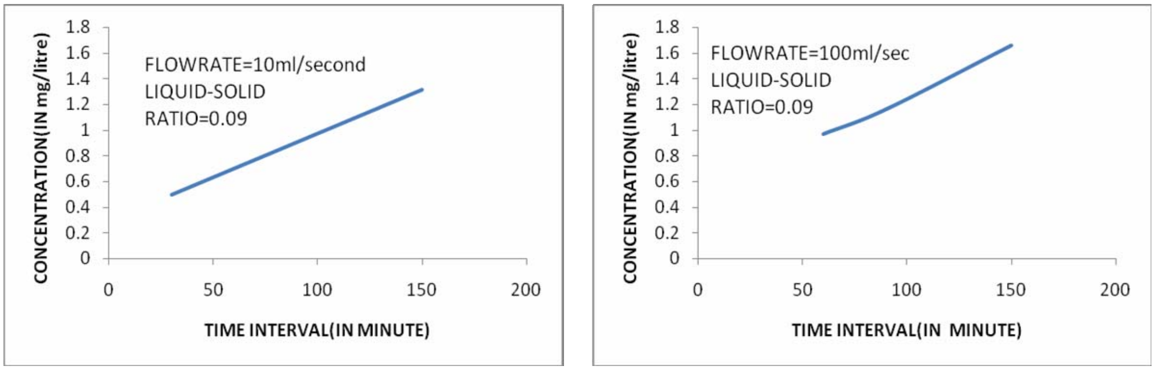


Fig1. Column leaching set-up

follows. The sample is crushed if any hard aggregate is formed during drying and weighed. Then 0.4 g each of the dried samples is taken into several 250 ml beakers. An empty beaker is also included in the analysis. Afterwards 100ml of water is added to each sample and the blank beaker. 1 ml concentrated nitric acid is added to observe the presence of carbonates. A foaming reaction indicates the presence of carbonates in the soil samples. In this case the nitric acid is added slowly to the sample. Afterwards 10 ml of concentrated HCl is added. The beakers are covered with ribbed watch glasses and then heated on a hot plate at about 95^{o}C. Each beaker is heated in the hot plate till the solution remaining in it is 10-15ml.The contents are allowed to cool at room temperature. Afterwards this solution is filtered and diluted up to 100 ml. This diluted solution is further analysed using Atomic Absorption Spectrometry and Flame photometry to determine the concentration of the concerned contaminant that is equivalent to the initial concentration of the contaminant in the soil sample. Regular water from the water supply system is used in the column leaching apparatus. It is poured from the top and allowed to drain through the soil column. After few minutes, the leached liquid starts appearing from the bottom boundary and this is collected in the beaker. The concentration of contaminant in the leached liquid at the bottom is also determined using Atomic Absorption Spectrometry and Flame photometry.

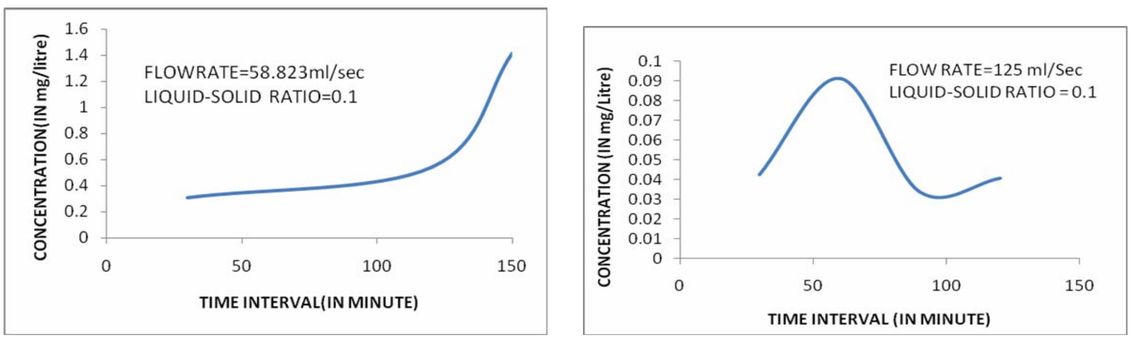
RESULTS AND DISCUSSION:

The experiment was carried out in a 60 cm soil column. It consists of 30cm sand, 25cm red soil, and 5cm contaminated soil. The variation of concentration of zinc in the leached liquid at the bottom for different cases are given in the figures below (Figures 2, 3, 4, and 5)



a) At flow rate 10 ml/s **b) At flow rate 100 ml/s**

Fig2. Concentration vs Time graph for Zinc in the leached liquid at the bottom for liquid-solid ratio 0.09



a) At flow rate 58.8 ml/s **b) At flow rate 125 ml/s**

Fig3. Concentration vs Time graph for Zinc in the leached liquid at the bottom for liquid-solid ratio 0.10

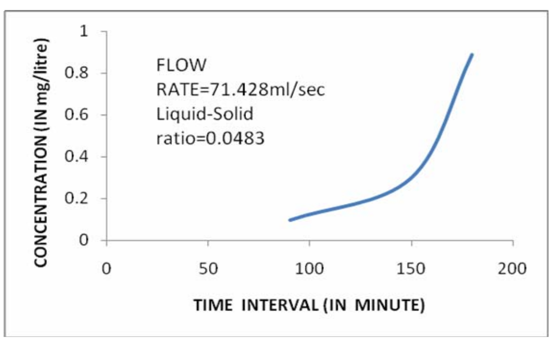


Fig 4. Concentration vs Time graph for Zinc at flow rate 71.428ml/s and liquid-solid ratio 0.048

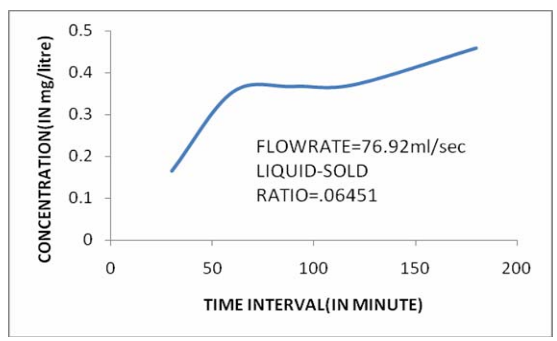


Fig 5. Concentration vs Time graph for Zinc at flow rate 76.92 ml/s and liquid-solid ratio 0.064

It is observed from Fig 2 that as the flow rate is increased from 10 ml/sec to100ml/sec the concentration of zinc at the start of appearance of leach liquid at the bottom increases. This suggests that the amount of leaching may be increasing partially with the flow rate. The leaching rate may also be function of flow rate in such cases. However from Fig 3 for a different solid-liquid ratio, this relation is not witnessed. In this case the concentration increases gradually then decreases between 60minute to 100minute time interval. Afterwards it again increases. Investigations are being carried out on this behavior of soil on this aspect. On increasing both the liquid-solid ratio as well as the flow rates, the concentration patterns are plotted in Figures 4 and

5. From these figures it is observed that as the liquid-solid ratio is increased for the same flow rate, the amount of leaching is also increased. It implies that leaching rate is directly proportional to the liquid-solid ratio in the column. This result may have significance in landfill leaching sites citing that if depth of water on the top of landfill is more, greater leaching of the contaminant takes place.

CONCLUSION:

(1) With the increase of flow rate the rate of leaching increases partially. Thus a heavy rainfall may induce more leaching in a landfill site compared to a light rainfall.

(2) The effect of liquid-solid ratio is vital in the leaching behavior of soil. Liquid-Solid ratio is found to be more prominent than the flow rate in the leaching behavior of soil. Thus stagnant water above a landfill site may enhance leaching.

(3) Further experimentation is also proposed by changing the pH. Also cylindrical column apparatus are proposed for future experiment.

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