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Dispersion of non Reactive Solute Through Perungudi Soil

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Abstract: An experimental study is conducted to investigate the dispersion of non reactive solute present in leachate through soil media at a municipal solid waste disposal site under saturated conditions. The dispersion coefficient is found using NaCl as a tracer. Breakthrough curves are obtained for the three types of soil present in the Perungudi dumping site. Dispersion coefficient values are obtained by fitting the convection dispersion equation to the observed breakthrough curves for the chloride test at various depths. The values can be used to predict the movement of non reactive pollutants through the soil media and its ultimate effect on ground water. It is found that dispersivity values for non reactive solutes are independent of the depth in the soil columns. These values help to model the movement of non reactive solutes present in solid waste leachate through the soil media.

Key words: Dispersion coefficient, non reactive solutes, leachate, municipal solid waste

INTRODUCTION

In most of the developing countries more than 90% of Urban Solid Wastes, Industrial Solid Wastes and Sludge's are being dumped on land without adopting sanitary land filling practices. Precipitation that infiltrates the solid wastes disposed on land mixes with the liquids already present in the waste and leach compounds from the solid waste. The result is a liquid known as leachate which contains dissolved non reactive solutes like chloride, bromide and reactive solutes like metals Iron, Copper, Lead, Chromium and Zinc etc. The fate and transport of these solutes from solid waste disposal sites through the soil media depends on the physical and chemical characteristics of the soil, the leachate characteristics and the mechanisms that affect the concentration of pollutants say advection, dispersion, diffusion as well as chemical, biological processes and radio active decay. These reactions shall hinder the dispersivity of leachates and thereby its flow. In order to estimate the environmental risk and develop strategies for groundwater protection against contamination by landfills, an understanding of solute transport and behavior of solutes in soil-groundwater system is required.

The present study is conducted to investigate the dispersion of non reactive solutes present in municipal solid waste leachate through the soil media at Perungudi waste disposal site at Chennai.

Dispersion theory: Dispersion coefficient is one of the important parameters used in the transport of the solutes through porous media. Estimations of the inherent flow and dispersion parameters of a porous media are crucial to the description of ground water flow and contamination movement. These 2 classes of parameters describe the physical process governing the movement of a non reactive solute through a saturated porous medium. The flow parameters are characterized by hydraulic conductivity and porosity whereas the dispersion parameters are characterized by the coefficient of hydrodynamic dispersion and dispersivity.

In situ estimates of advective and dispersive properties of ground water flow systems are essential for the adequate prediction of solute flow. Although, there appears to be considerable discrepancies between field and laboratory estimation of hydraulic and dispersive properties of the medium laboratory techniques provide a convenient mechanism for investigating the aquifer because of their inherent economical and logistical advantages.

Scale effects discussed in the dispersion literature refer to observations, calculations or calibrations that suggest the magnitude of the measured dispersion coefficients may depend upon the scale over which the measurements have been taken (Domenico *et al*., 1984). The drastically reduced scale of the laboratory test from that of field situation is believed to prohibit the sampling of a volume which is statistically representative of the porous medium. Field measurements of dispersivity have generally produced results which are 3-4 orders of magnitude greater than laboratory tests. Many examples this so called scale effect exist in determining dispersivity

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(Gelhar *et al.*, 1979; Pickens, 1978). The advection dispersion equation implies that dispersivity is a constant, distant independent property of the medium. The existence of scale effects results in an appropriate description of solute transport but conventional practice in the application of ground water models usually involves a simple scaling up of the dispersivity values obtained from column tests to the field situation. Various laboratory techniques have been developed to provide convenient estimates of hydraulic conductivity and dispersivity using column tests. In the present study laboratory column experiments is conducted to estimate the dispersion coefficient of non reactive solutes through the soil media at the site.

MATERIALS AND METHODS

Study area: Chennai is a major Indian city which consists of two designated landfills (or more specifically open dumps) currently being used for disposal of municipal solid waste from the Chennai city area, Perungudi in the South and Kodungaiyur in the North. The daily generation of waste is 4800t and is expected to reach 6000t by year 2010. The ground water samples collected from the wells in the nearby area surrounding the disposal site shows the presence of non reactive solutes like chloride, fluoride, dissolved solids etc.In this study soil samples are collected from the disposal site to understand the dispersion of non reactive solutes through the soil media.

Soil properties: From the borehole lithology it is understood that the site consists of three types of soil strata. Table 1 gives the description of the soil as obtained from the boreholes.

Experiments: Flow parameters hydraulic conductivity and porosity of the soil depends on the properties of the fluid as well as on the characteristics of the medium. The

Table 1: Soil details

Soil properties	Soil layer I	Soil layer II	Soil layer III
Depth, m	0-5	5-8.0	8-10.5
Soil type	Silty Clay	Clayey	Sandy
Specific gravity	1.43	1.56	1.76
Wet unit weight g cc^{-1}	1.66	1.62	1.64
Optimum moisture content,%	12	12	11
Voids ratio	0.67	0.43	0.67
Porosity	0.4	0.3	0.4
Pore water velocity cm sec^{-1}	2.72×10^{-6}	2.133×10^{-6}	3.47×10^{-4}
Hydraulic conductivity $cmsec^{-1}$	5.44×10^{-7}	3.2×10^{-7}	6.94×10^{-5}

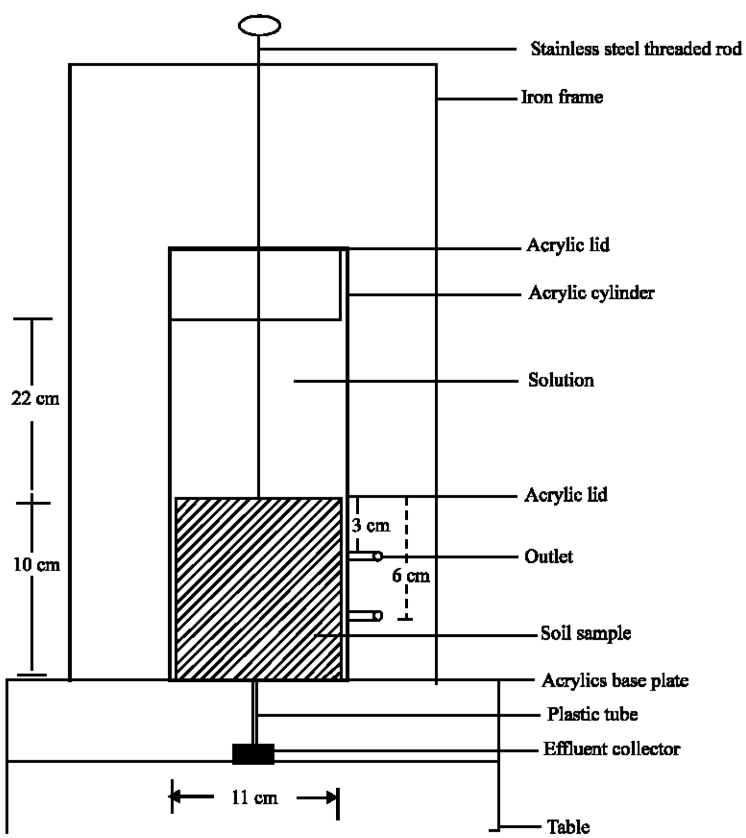

Fig. 1: Experimental set up

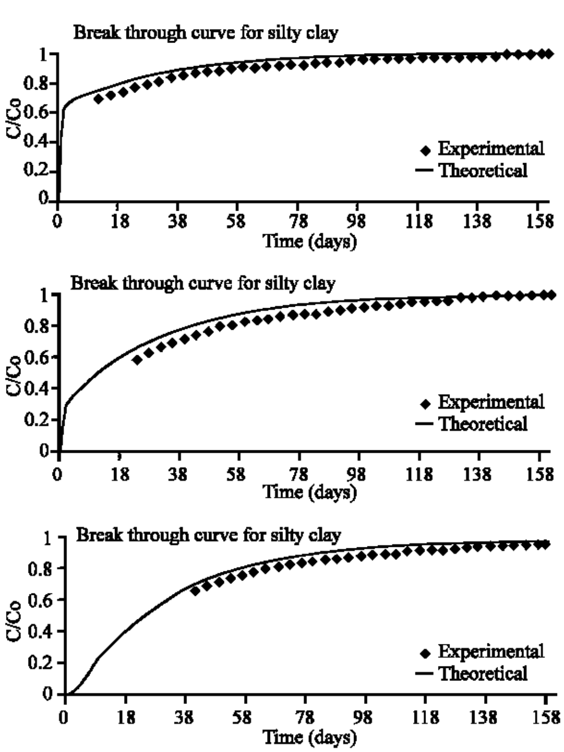

Fig. 2: Breakthrough curves for silty clay at depth 3, 6 and 10 cm

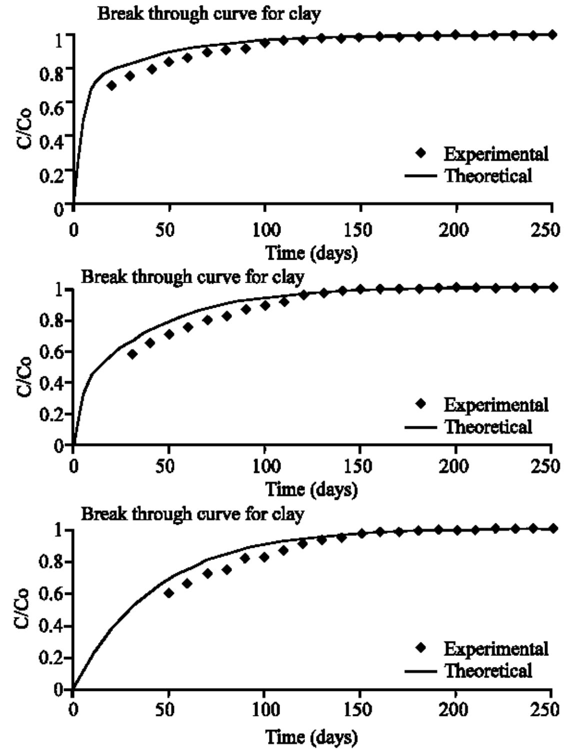

Fig. 3: Breakthrough curves for clay at depth 3, 6 and 10 cm

hydraulic conductivity of the soil samples were determined in the laboratory using variable head permeability test. Using Darcy's law for flow in soil and the experimental values of soil porosity, values of hydraulic conductivity and average pore water velocity were obtained for the three samples.

Dispersion was determined using laboratory soil column experiments on the three soil samples representing the soil strata in the study area. A Schematic diagram of the column apparatus made of acrylic and used in the experiment is given in Fig. 1. The experiments are based on single reservoir constant concentration technique (Gilham *et al*., 1984; Rowe *et al*., 1988; Zeki Camur *et al*., 2005). This method is used extensively in the measurement of dispersion coefficient in waste disposal applications. The soil samples were obtained by penetrating the aquifer by using 10 cm diameter thin waled aluminum tubing. The soil was compacted wet of Proctor optimum moisture to allow easier handling and to simulate possible field density.

Distilled water was allowed to flow from below initially to allow all the air in the voids to escape for a few days to assure complete saturation. A solution of Sodium Chloride of concentration equal to that present in leachate was used as a conservative tracer. The tracer was

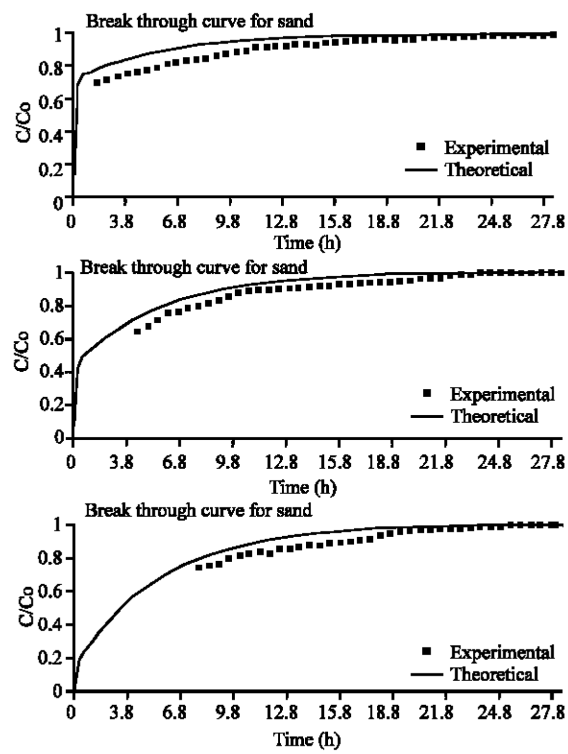

Fig. 4: Breakthrough curves for sand at depth 3, 6 and 10 cm

allowed to pass through the vertically positioned saturated column under a constant head. A continuous concentration time distribution of the effluent was obtained at depths z = 3, 6 and 10 cm ,by passing the discharge through a chloride electrode. Completion of the test occurred when the effluent concentration equaled that of the influent. Break through curve is developed by plotting the results on a normal graph with time along X-axis and C/C_0 along the Y-axis (C: Concentration at time 't' and Co: Initial Concentration). Figure 2-4 show the breakthrough curve obtained for the 3 soil types at depths 3, 6 and 10 cm.

RESULTS AND DISCUSSION

A dispersion theory based on solution of Fick's second law of diffusion is used as a mathematical model. A conventional macroscopic approach to the dispersion problem is to obtain a solution of the differential equation similar to Fick's second law of diffusion (Freeze and Cherry, 1979).

$$\partial C/\partial t = D\,(\partial^2 C/\partial x^2) - v\,(\partial C/\partial x) \qquad (1)$$

Where, C is the tracer or solute concentration at time t and distance x from its source, 'D' dispersion coefficient and 'v' average pore velocity which is defined as Q/pore area 'Q' being the volume of flow per unit time.

Assumptions:

- The flow and dispersion through the soil under consideration is one dimensional.
- The source is continuous with the same concentration of Co.
- The depth of the porous medium is finite.
- The porous medium is in saturated condition.

The initial and boundary conditions are

$C(x, 0) = 0;\ x \geq 0$
$C(0, t) = Co;\ t \geq 0$
$C(\infty, t) = 0;\ t \geq 0$

The solution to the above equation is given by Ogata and Banks (1961) as

$$\frac{C}{Co} = \frac{1}{2}\mathrm{erfc}\,\frac{(x\text{-}vt)}{2\,\tilde{a}D\,\tilde{a}t} + \frac{1}{2}\,\exp\frac{(v\ x)}{D}\ \mathrm{erfc}\,\frac{(x+vt)}{2\,\tilde{a}D\ \tilde{a}t}] \qquad (2)$$

Where, C/Co is the ratio of the concentration to the original and erfc is the complementary error function.

Table 2: Dispersion coefficient of chloride for the 3 soil types

Soil type	Depth 3cm, $cm^2\ sec^{-1}$	Depth 6 cm $cm^2\ sec^{-1}$	Depth 10 cm $cm^2\ sec^{-1}$
Silty clay	2.171×10^{-4}	2.412×10^{-4}	2.712×10^{-4}
Clay	2.80×10^{-4}	2.712×10^{-4}	2.36×10^{-4}
Sand	0.0412	0.0471	0.0432

One dimensional dispersion of non reactive solutes through the soil media is described by the Eq. 1. The solution to these equations has been given by Rowe and Booker (1985) and has been implemented in the computer program Pollute. The theoretical solution to the equation was then used to obtain a match to the experimental profile by varying the dispersion coefficient while keeping other geometrical and material parameters constant. The dispersion coefficient that was judged to provide the best fit to the experimental profile for each soil strata was selected as the experimental chloride dispersion coefficient (Table 2).

CONCLUSION

The migration of specific contaminants from field disposal sites may be successfully modeled in the laboratory using soil having similar mineralogical and geochemical composition. For the conditions examined in these tests the dispersion coefficient on samples of Silty Clay, Clay and Sand ranged from 0.0412 to 2.712×10^{-4} $cm^2\ sec^{-1}$. The values obtained are found to agree with the values reported in the literature. For clay soils it is clearly seen that diffusion will be predominant than dispersion because of very low velocity. The above values of dispersion may be used to predict contaminant migration in the field. The results show that transport of non reactive solutes is consistent with Fickian diffusion equation.

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