International Journal of Innovative Research in Engineering & Management (IJIREM)
ISSN: 2350-0557, Volume-3, Special Issue-1, April-2015
Fifth National Conference on Innovative Practice in Construction Waste Management (IPCWM'15) On 8th & 9th April, 2015
Organized by Department of CIVIL Engineering, Sri Ramakrishna Institute of Technology, Coimbatore, India

Study on Two Dimensional Dispersion of Pollutants through Porous Media

M.Priya
Assistant Professor
Department of Civil Engineering/Sri Ramakrishna Institute of Technology,Coimbatore/ India
Priyam2689@gmail.com

S. Yamini Roja
Assistant Professor
Department of Civil Engineering/Sri Ramakrishna Institute of Technology,Coimbatore/ India
yaminiroja@gmail.com

S. Sidhardhan
Associate Professor
Department of Civil Engineering/Government College of Engineering, Tirunelveli,India
Priyam2689@gmail.com

B. Perumal
Site Engineer, Z-Tech (India) Pvt Ltd/Chennai.
Priyam2689@gmail.com
.

ABSTRACT
This paper on study of two dimensional dispersion of pollutants through porous media. The experimental setup consists of a transparent tank, made up of 6mm thick Acrylic Sheet with inner dimension of 100cm x 10cm cross-section and 75cm depth for soil compartment . An additional attachment of 40cm x 10cm cross-section and 100cm depth is divided into two compartment perforated (10mm dia holer at 5cm c/c) acrylic sheet of 6mm thick. The front and rear side of the sand compartment is graduated with 1 sq.cm. Drains are provided at 3 places at the bottom of the compartment to replace the media. Sand was used as a porous media. The properties of the sand were found out from various experiments. Chemical pollutant chloride is supplied in the form of Sodium Chloride injection. Various concentrations of pollutants were tried. At every 5 minutes interval, the outlet samples were collected and analyzed for Chloride concentration. From the observed readings the break through curves are drawn. The dispersion index and dispersion coefficient were also calculated using the empirical formulae. From the experimental results, it was understand that, the movement of the pollutant is depending upon the concentration and depth of the porous medium.

Keywords
Dispersion, NaCl, Sand, pollutant.

1.INTRODUCTION
Water is one of the most important resources of the earth, which is essential for survival of human beings. More than 98 % of the fresh water occurs as ground water. So ground water is one of the most valuable natural resources.

Recent studies have shown that ground water is highly susceptible to pollution from natural as well as anthropogenic activities such as disposal of municipal sewage, industrial waste water, runoff, land fills, septic tanks effluent, solid wastes, fertilizers and sea water intrusion, etc.

In the recent past, India has gone through rapid industrialization, resulting in the problems associated with the disposal of industrial wastes. In most of the cases, the industrial wastes are disposed on the surface without any treatment. These wastes infiltrate into the subsoil and join the ground water becomes a two – phase flow. The problem now is two fold, namely, the dispersion of pollutant injected at a source and the movement of ground water in the direction of its slope. Dispersion is the microscopic phenomenon caused by a combination of molecular diffusion and hydrodynamic mixing occurring with laminar flow through porous media. Most mathematical descriptions of dispersion are based on statistical concepts. The dispersion of the pollutant can be mathematically described by a partial differential equation, which has no known exact solution. Hence many investigators tried different analytical solutions by making the several assumptions, which rarely resemble the field situations.

In this paper, Study on two dimensional dispersion of pollutants through porous media has been discussed.

2.MATERIALS
The materials used for our study are known concentration of Chloride solution and Sand. Their preparations are given below :

2.1 Preparation of Sodium Chloride Solution
The known amount of Sodium Chloride powder is added with the known quantity of water to make the solution. For example, to prepare 200 ppm NaCl solution 1 gram of NaCl powder is mixed with 10 litre of water.

2.1.1 Determination of chloride content
Chloride is determined by Mohr's method, the titration with standard silver nitrate solution in which silver chloride is precipitated at first. The end of titration is indicated by the formation of red silver chromate from excess Silver Nitrate and Potassium Chromate used as an indicator in neutral to slightly alkaline solution.

Calculation :

Chloride in mg / l = V X 1000 / (ml of sample taken)

Where V= Volume of silver nitrate added

2.2 Preparation of Sand medium

The river sand was brought to the laboratory and sieved by 0.60 mm sieve. The sand passing through o.60 mm sieve was taken for the experimental study. It was washed thoroughly several times to remove the dust, silt and other contaminant in the sand. The various soil properties were found out in the laboratory.

The properties of sand media determined are shown in Table 1

Table 1. Properties of sand media

Sl. No.	Properties	Value
1	Uniformity Coefficient	3.250
2	Curvature Coefficient	1.030
3	Specific Gravity	2.76
4	Void Ratio	1.085
5	Porosity	0.520
6	Permeability	0.0165 cm / s

3.METHODOLOGY

In the present work, it is planned to study the longitudinal dispersion of chemical pollutant in porous media using Chloride as a pollutant in the form of Sodium Chloride.

3.1 Dispersion

In groundwater hydrology dispersion may be encountered whenever two fluids with different characteristics come into contact. To fine out longitudinal dispersion, a column is packed with sand and the water containing a tracer of concentration C0 is supplied continuously after time t0, dispersion in the longitudinal direction of flow can be measured. From samples of water emerging from the column, a tracer concentration C is found. The solid line shows a typical S - shaped dispersion curve.

Dispersion is essentially a microscopic phenomenon caused by the combination of molecular diffusion and hydrodynamic mixing occurring with laminar flow through porous media. The net result produces a conic form downstream from a continuous point source tracer and an expanding ellipsoid for a single tracer injection. The equation for dispersion in homogeneous and isotropic medium for the two dimensional case has the form

$$dC / dt = D_L d^2C / dX^2 + D_T d^2C / dY^2 - v\, dC / dX$$

where,

C - Relative Tracer Concentration ($0 < C < 1$)

D_L , D_T - Longitudinal and Transverse Dispersion Co-efficient

V - Fluid Velocity

X - Co – ordinate in the direction of flow

Y - Co – ordinate normal to the flow

t - Time

The one – dimensional form of this equation can be expressed as

$$dC / dt = D_L d^2C / dX^2 - u\, dC / dX$$

where,

C - Concentration of pollutant in solution

DL - Longitudinal Dispersion Coefficient

u - Average pore water velocity

X - Longitudinal Direction

t - Time in sec

3.2 Ground Water Tracers :

A variety of tracers have been employed for studying dispersion and also for evaluating directions and rates of ground water flow under field conditions.

Dyes and chemicals that have been used successfully in tracer studies include Congo Red, Fluorescein, Fluorosilicic Acid, Hexafluoride Gas, Lithium Chloride, Pontacyl Brilliant Pink B, Potassium, Potassium Permanganate, Rhodamine WT & Sodium Chloride.

3.3 Determination of Dispersion Coefficient

For different time intervals the Chloride concentration of the collected samples is calculated. By using the formulae the mean, variance, dispersion index and dispersion coefficient are calculated.

4. EXPERIMENTAL SET UP

The experimental setup shown in Figure 1 consists of a transparent tank, made up of 6mm thick Acrylic Sheet with inner dimension of 100cm x 10cm cross-section and 75cm depth for soil compartment . An additional attachment of 40cm x 10cm cross-section and 100cm depth is divided into two compartment perforated (10mm dia holer at 5cm c/c) acrylic sheet of 6mm thick. Outlets are provided at 5 cm, 25 cm, 45 cm and 65 cm from top of the sand compartment. Outlets of tapings are screened with aluminums mesh of 0.1cm dia openings. Both compartments are perforated with 2 mm thick aluminium sheet with 8mm dia at 5cm c/c and also screened with aluminium mesh of 0.10 cm dia openings. The front and rear side of the sand compartment is graduated with 1 sq.cm. Drains are provided at 3 places at the bottom of the compartment to replace the media and clean the tank. Arrangement is made to supply the pollutant from an overhead tank placed above the apparatus.

Sodium Chloride powder of weighed quantity is added to the tap water and the overhead tank. By this arrangement concentration of Sodium Chloride in the overhead tank maintained constant throughout the run of an individual

International Journal of Innovative Research in Engineering & Management (IJIREM)
ISSN: 2350-0557, Volume-3, Special Issue-1, April-2015
Fifth National Conference on Innovative Practice in Construction Waste Management (IPCWM'15) On 8th & 9th April, 2015
Organized by Department of CIVIL Engineering, Sri Ramakrishna Institute of Technology, Coimbatore, India

experiment. Chemical pollutant chloride is supplied in the form of Sodium Chloride injection.

Figure 1 Experimental set - up

5. EXPERIMENTAL PROCEDURE

The properties of sand media were first determined. Then the sand was uniformly packed in the 100 x 65 x 10 cm compartment for the height of 60 cm. The sand medium was fully saturated by filling up water in the water compartment. The water was drained out completely after the sand was fully saturated.

Sodium Chloride solution is used as the pollutant. In this, we studied the dispersion of the Sodium Chloride and also found out the dispersion coefficient and dispersion index.

Pollutant (Sodium Chloride + Tap Water) was filled in the water compartment from the overhead tank upto the sand surface. The water level was kept upto the surface of sand medium by adjusting the valve in the overhead tank and allowing the pollutant supply continuously.

To effect a one-dimensional longitudinal flow, only one tapping along the X-direction was opened, all other tappings were closed during observation. The pollutant enters the media through perforated holes and travels through pores, which in turn was drained through the tappings.

The drained water was collected at the constant time interval of 5 minutes at various depths (20 cm, 30 cm from bottom). Chloride concentration of the collected water sample was found out by titration method. The observations were continued till the concentration of Chloride at the outlet was equal to the concentration of Chloride in the inlet. The observed time Vs concentration graph was drawn.

6. RESULTS AND DISCUSSIONS

The technical feasibility for longitudinal dispersion of pollutant transport in ground water was investigated in the study. The experimental study was carried out to understand the dispersion of various concentration of pollutant in porous media.

Standard methods performed chemical analysis for the pollutant.

The break through curves for Cl conc. Of 200 ppm, 600 ppm, 800 ppm and 1000 ppm @ 20 cm and 30 cm from bottom are shown in Figure 2, Figure 3, Figure 4 and Figure 5.

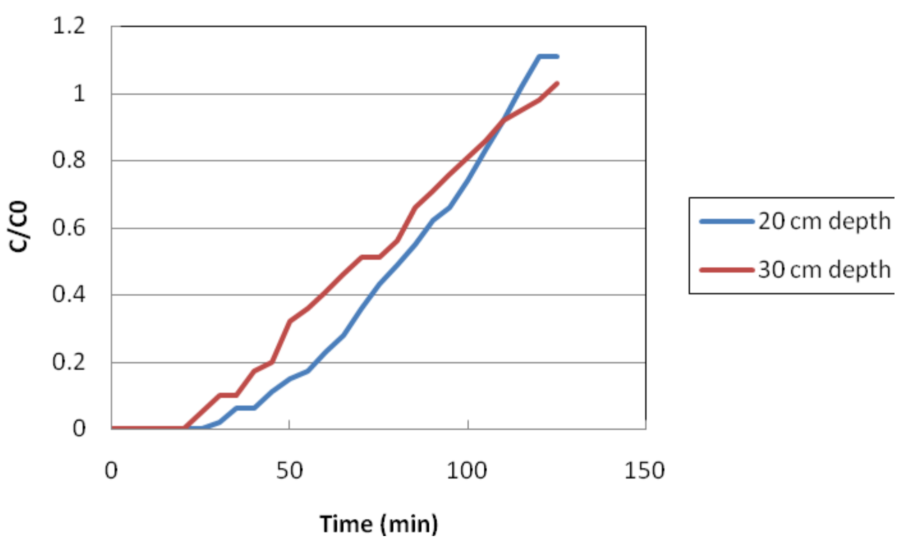

Figure 2. Break through curve for Cl conc. of 200 ppm @ 20 cm and 30 cm from bottom.

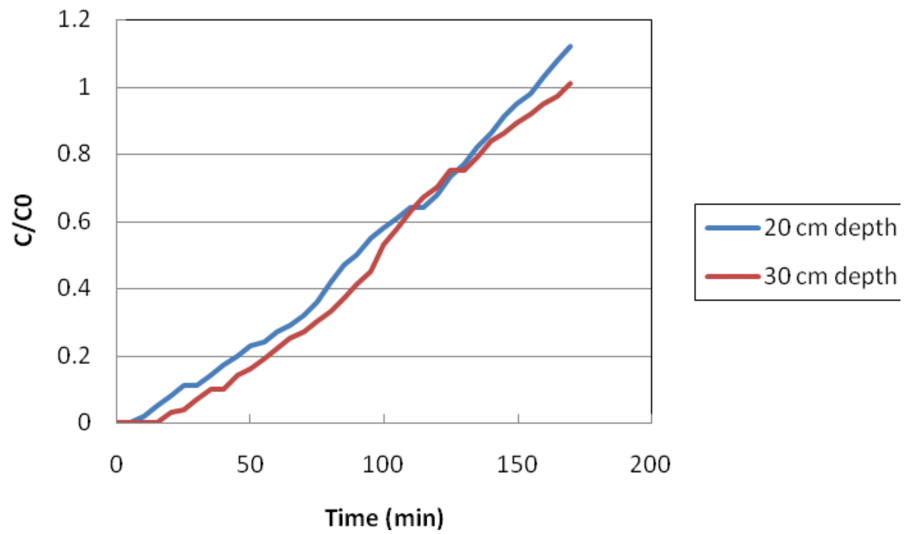

Figure 3. Break through curve for Cl conc. Of 400 ppm @ 20 cm and 30 cm from bottom.

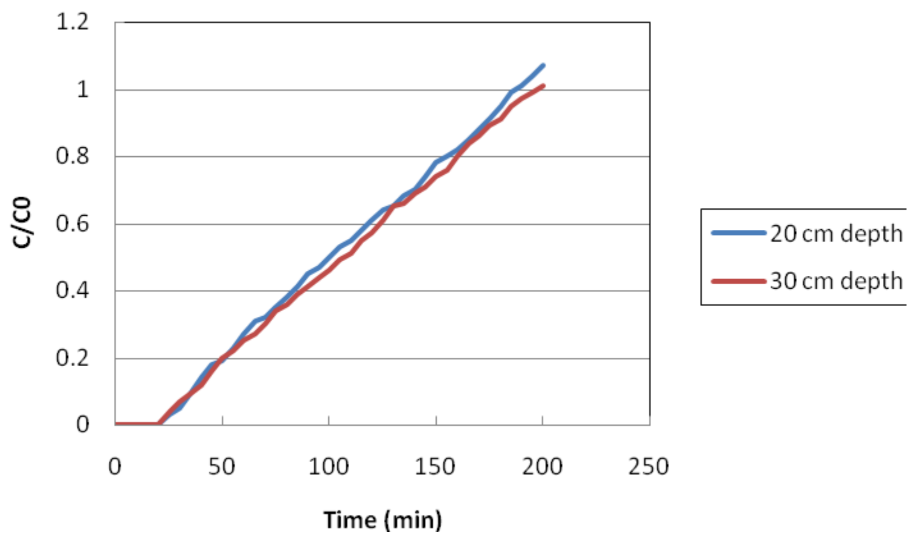

Figure 4. Break through curve for Cl conc. Of 600 ppm @ 20 cm and 30 cm from bottom.

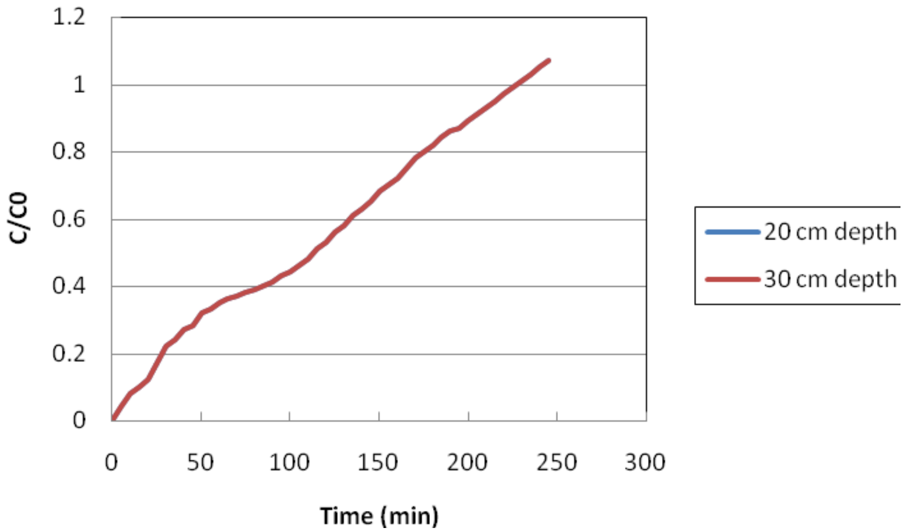

Figure 6. Break through curve for Cl conc. Of 800 ppm @ 20 cm and 30 cm from bottom.

(Note: Equal break through curve was obtained for for Cl conc. Of 800 ppm @ 20 cm and 30 cm from bottom.)

6.1 Determination of Dispersion Index

Dispersion Index is a measure of volumetric efficiency. The dispersion index as proportion is given as
Morill Dispersion Index = P90 / P10
Where,
P90 - 90 percentile value from log probability plot
P10 - 10 percentile value from log probability plot

The percentile values are obtained from a log - probability plot of the Time Vs Cumulative % of the total tracer, which has passed out the basin.
The dispersion index of the tracer can be calculated from the log graph drawn between the cumulative percentage Vs Time as obtained from the Tables below. The graphs are shown in Figure 6, Figure 7, Figure 8 and Figure 9.

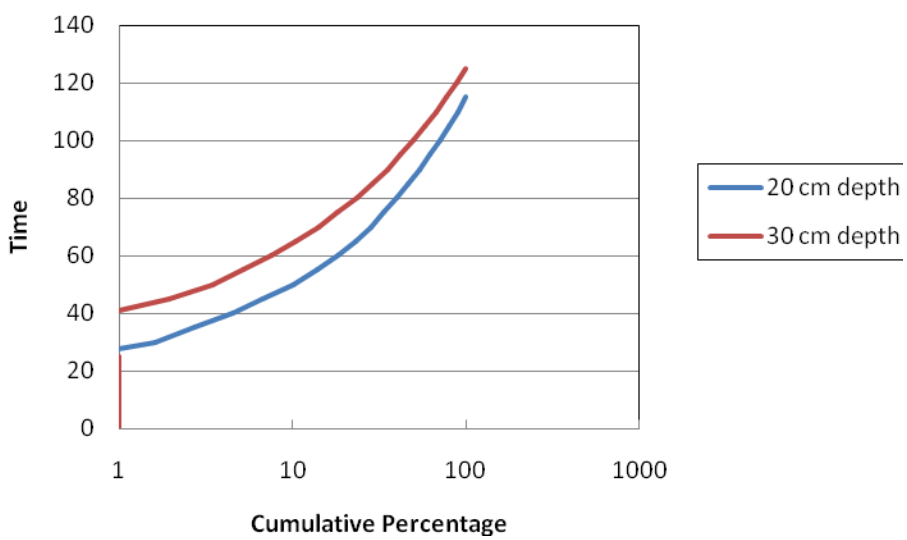

Figure 6. Dispersion Index for NaCl conc. of 200 ppm @ 20 cm & 30 cm from bottom

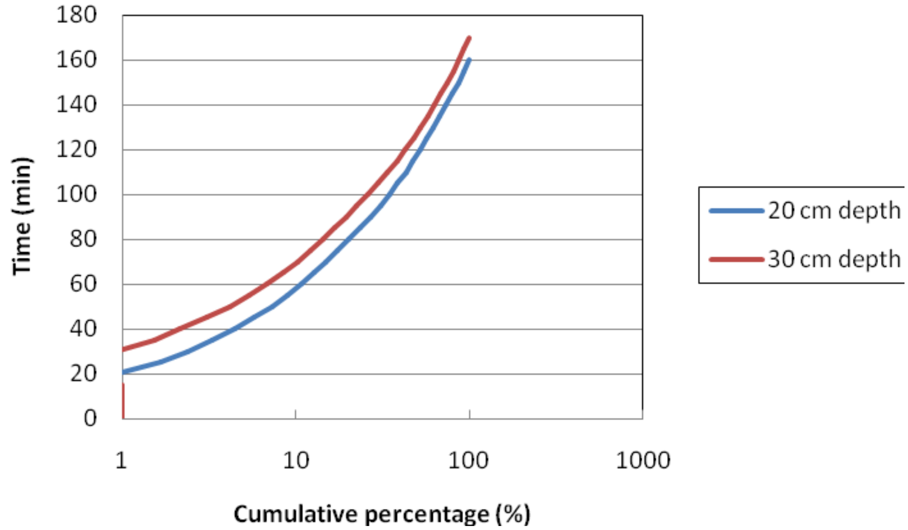

Figure 7. Dispersion Index for NaCl conc. of 400 ppm @ 20 cm & 30 cm from bottom

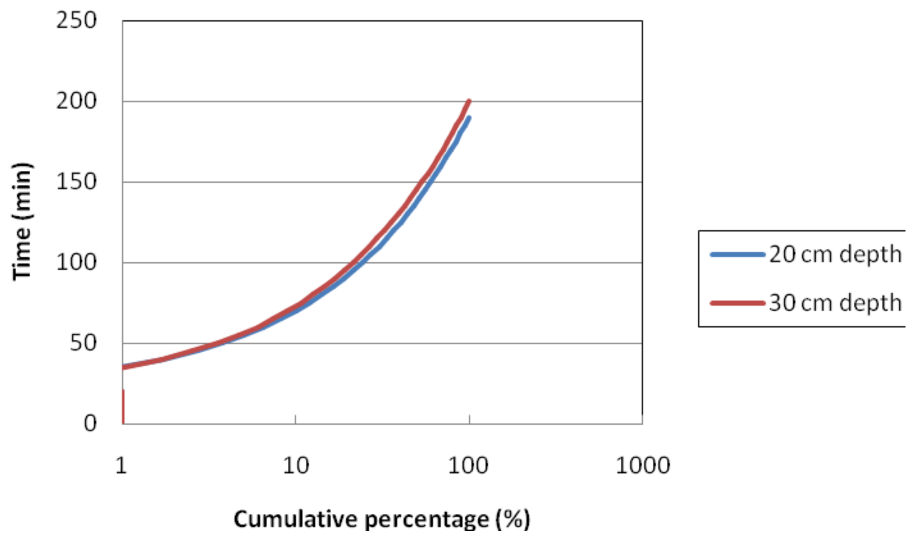

Figure 8. Dispersion Index for NaCl conc. of 600 ppm @ 20 cm & 30 cm from bottom

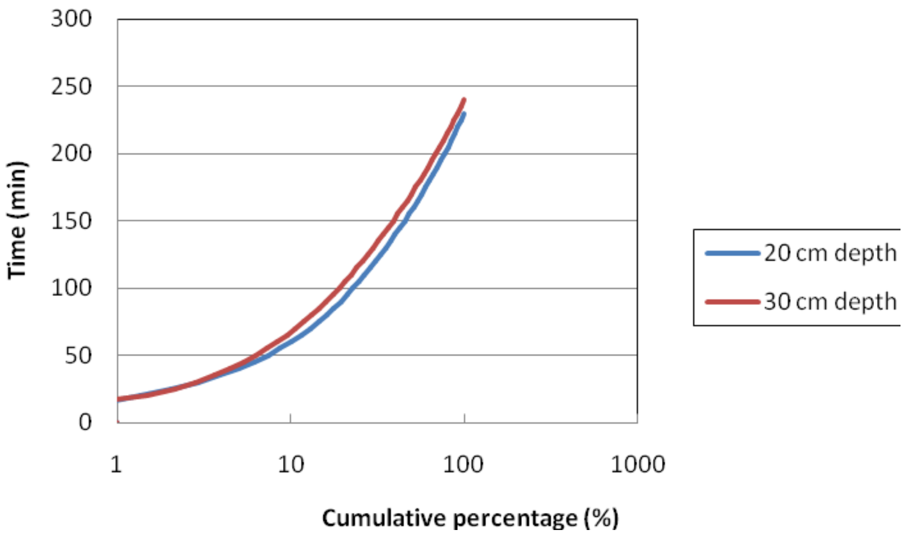

Figure 9. Dispersion Index for NaCl conc. of 800 ppm @ 20 cm & 30 cm from bottom

6.2 Determination of Dispersion Coefficient

The dispersion coefficient of the porous medium was determined by using the following empirical formulae

Mean Residence Time $t_{\Delta c} = \sum t_i C_i \Delta t_i \ / \ \sum C_i \Delta t_i$

Variance $\sigma^2_{\Delta c} = (\sum t_i2 \, C_i \Delta t_i \ / \ \sum C_i \Delta t_i) - (t_{\Delta c})^2$

Theoritical Detention Time T = Volume / Rate of Flow

Dispersion Number $d = \sigma^2_{\Delta c} \ / \ 2 T^2$

Dispersion Coefficient $D = d \times u \times L$

u = Rate of Flow / Cross sectional Area

The dispersion coefficient and dispersion index of the porous medium are given in Table 2.

TABLE 2. Dispersion Coefficient and Dispersion Index of the Porous Medium

Parameters	200 ppm conc.		400 ppm conc.		600 ppm conc.		800 ppm conc.	
	20 cm	30 cm	20 cm	30 cm	20 cm	30 cm	20 cm	30 cm
Dispersion Coefficient x 10^{-7}	1.56	1.47	3.9	3.73	5.19	5.83	10.3	10.8
Dispersion Index	1.821	2.231	2.429	1.833	2.562	2.688	4.00	3.33

6.3 Time Taken for the Pollutant Transfer

From the above study, it was observed that for the uniform one – dimensional flow through the homogeneous isotropic porous medium. The longitudinal dispersion of pollutant decreases as depth increases from bottom. The same trend was observed for different input concentrations.

The time taken for the pollutant transfer along the porous medium from inlet to outlet at the particular depth was given in Table 3.

TABLE 3. Time taken for the pollutant transfer along the porous media

Sl. No.	Concentration of pollutant (ppm)	Time taken in minutes	
		20 cm from bottom	30 cm from bottom
1	200	115	125
2	400	160	170
3	600	190	200
4	800	230	240

7. CONCLUSION

In this experimental study, a physical scale model was used to conduct the longitudinal dispersion of pollutants. Chloride was used as chemical pollutant and Sand was used as a porous media. Various concentrations of pollutant such as 200 ppm, 400 ppm, 600 ppm and 800 ppm were tried. From the observed readings the break through curves are drawn. In 200, 400 and 600 ppm concentration, the outlet chloride concentration and break through curves were varied at 20 and 30 cm depths from bottom. But in case of 800 ppm concentration, equal break through curve was obtained at 20 cm and 30 cm from bottom. And the dispersion index and dispersion coefficient were also calculated using the empirical formulae.

It indicates that depending upon the concentration of pollutant and its removal efficiency may vary. And also compare to 30 cm depth from bottom the pollutant removal is higher in 20 cm from bottom. From the experimental results, it was understand that the movement of the pollutant is depending upon the concentration and depth of the porous medium.

REFERENCES

(1) Bear.j. Hydraulics of ground water , McGraw-Hill book co., New York,1959.

(2) Chunmiaozheng & Gordon,D.Bennett,1995,*Applied contaminant transport modelling, Van No Strand Reinhold* .

(3) Das .s.k., s.k.Roy, l.k.Ghosh & r.s.Kankara.,2000 *Numerical Simulation of solute Transport in porous media with First Order Chemical Reaction. Indian journal of Environmental protection, Volume 20, Number 10.*

(4) David keith todd, 1959 Ground water hydrology, John Willey and Sons, NewYork .

(5) Karanth.k.r., *Ground Water Assessment and Management, Tata McGraw-Hill publishing company limited, New Delhi,* 1987.

(6) Subramanian .r.2000, *Tracer Movement along the Vertical Direction in Longitudinal Flow in Porous Material, Indian Journal of Environmental Protection, Volume 20,* November 11.

(7) Subramanian.r, &.chockalingam.m.p, 1996 *Effect Of Depth On Longitudinal Dispersion Coefficient in Porosity Media*, Indian *Journal of Hydrology, Vol 19.*

(8) Sushil k.singh *Estimating Dispersion Coefficient and Porosity from Soil- Column Tests, Indian Journal of Environmental Engineering*, November 2002.

(9) Sankara Narayanan et. al., (2004) *Project Report., Dispersion study of dye through porous media.*

(10) Ragunath H.M (1987) *Ground Water. – Volume 2 - Wily Eastern Ltd, New Delhi*

(11) Stenly N Davis, (1996) *Groundwater Tracers* - Scientific Publishers, Jodhpur

(12) Viswanadhan V (1983) *Axial Dispersion of Pollutants through Porous Medium. Ph.D Thesis* IIT Delhi.

(13) David Keith Todd (1980) *Ground Water Hydrology – Vol 2*- Berkeley , California