Contaminant Transport in Seawater Intrusion Condition

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Introduction

Contaminant transport in coastal aquifers is inherently complex. The presence of the saltwater interface and the presence of tidal fluctuations affect groundwater flow in the area close to the shoreline and hence this also affects the pattern of contaminant migration in these areas (Koch & Zhang, 1992). This study assumed the Ghyben Hertzberg model (Henry, 1959) of sharp interface; and used experimental analysis plus the diffusion statistical model to monitor the contaminant movement in a real phenomena situation. The movement of the tracer (contaminant) was monitored in the laboratory using image analysis with the aid of a digital camera. Results from the image analysis model were then used in the diffusion statistical model to analyze the velocities of contaminant plumes in the three zones that exist in saltwater intrusion phenomena. The three zones are namely; saltwater zone, interface zone and the freshwater zone.

Materials and Methods

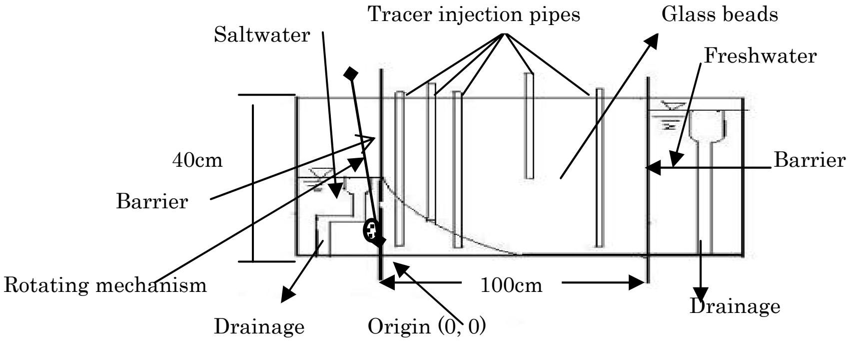

Figure 1. Laboratory view of the Seawater intrusion

An acrylic tank of length 100 cm, width 10 cm, height 40 cm was used. The upstream (freshwater) and downstream (saltwater) heads were maintained constant. Flow field of glass beads of diameters; 0.6 mm and 0.07 mm, with a mixing ratio of 20 % weight for 0.07 mm and 80 % for 0.6 mm were used. Hydraulic conductivity $k = 4.72\text{x } 10^{-5}$ m/s and porosity $n = 0.33$ were used. Red dye was used to monitor the shape of the saltwater interface. The blue dye used, was a conservative tracer and the concentration was substantially low. The suitability of the dye was proved by the consistent breakthrough curves of Sodium Chloride solution ($\text{Nacl}_{(aq)}$) and the dye obtained in one dimensional column tests. The tests ascertained that the dye traveled at the same rate as $\text{Nacl}_{(aq)}$ in glass beads and was not adsorbed on the glass beads. Barriers were used to regulate the flow conditions and to avoid turbulent conditions. After steady state conditions were obtained, dye tracers of 20 cm^3 were injected through the 5 acrylic pipes to each zone. Steady state conditions were maintained by the drainage facility at the bottom end of both sides of the acrylic tank. The hydraulic head (∂h) used was 4 cm. Temperature variation effects were neglected because constant temperature conditions were maintained during experimentation.

Results and Analysis; Diffusion Coefficient by Statistical model

The relation between the dispersion coefficients and the variance of plume is written by the following equation (Bear, 1972);

$$D_l = \frac{1}{2}\frac{d\sigma_\ell^2}{dt} \qquad (1)$$

Where σ_ℓ^2 the longitudinal variance of the plume, D_l is the dispersion coefficient and t is the time.

Kyoto University, seawater intrusion, dispersivity, velocity

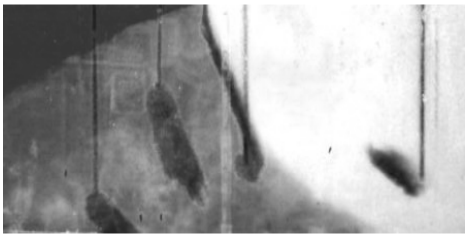

Figure 2a. Laboratory Experiments

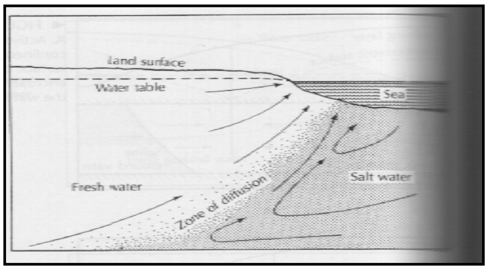

Figure 2b. Seawater intrusion, Cooper's Results

The movement of the contaminant plumes from the experimental results (Figure 2a) conformed to the findings of Cooper's (1964) as shown in Figure 2b. Furthermore, the same were also consistent with ; Bear (1972) and Koch & Zhang (1992). The results from the diffusion model (Equation 1) were as shown in the Figures below. Figures 3a, 3b and 3c show the longitudinal and transverse dispersivity and the relationship between velocity and mechanical dispersion respectively ($\partial h = 4$ cm).F is freshwater zone, SF is Interface Zone, S is saltwater Zone. Dispersivity is calculated by $D_l' = \alpha_L v$ and $D_T' = \alpha_T v$, where α_L is the longitudinal dispersivity and α_T is the transverse dispersivity. It could be observed from the Figures that, where the pore velocity was greater (at the interface zone) , longitudinal dispersivity was also dominant

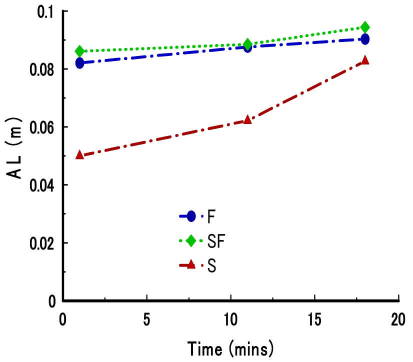

Figure 3a.Longitudinal Dispersivity in Three Zones

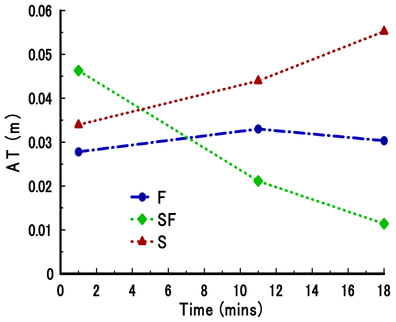

Figure 3b.Transverse Dispersivity in Three Dispersion zones

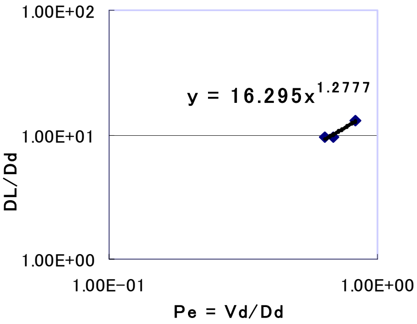

Figure 3c. Relationship of velocity and mechanical dispersion

The observed values from the statistical model for; the average flow velocities, longitudinal and transverse dispersivity in the flow field were as shown in Table 1 below.

Table 1. Figures of Velocity, Longitudinal Dispersivity and Transverse Dispersivity at three Zones

Zone	**V(m/sec)**	α_L **(m)**	α_T **(m)**	D_L **(m^2/s)**
Fresh	0.00110	0.090	0.03	9.61E-05
Salt	0.00103	0.083	0.05	9.43E-05
Interface	0.00140	0.094	0.01	1.31E-04

The Peclet number (P_e) which is defined by Vd_m/D_d, where v is the flux of the water, d_m is the mean grain size, and D_d is the molecular diffusion, was used to compare the effect of hydrodynamic diffusion on the experiment. From the Equation, $D^1{}_L / D_d = \alpha(P_e)^m$, It could be observed that; In all the zones, the value of m was 1.2, and $\alpha \approx 16$ (Figure 3c).In these zones the mechanical dispersion was dominant and effects of transversal molecular diffusion could be neglected(Bear,1972).The large α value was due to the effect of the small Peclet numbers implying that the mechanical dispersion was large.

Conclusion

The main spreading was caused by mechanical dispersion .Velocity was relatively large at the interface. Longitudinal dispersivity was dominant at the interface .Transverse dispersivity was relatively large in the saltwater zone. In the three different zones dispersion occurred based on the same non linearity as a function of velocity

References

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