SPECIAL ARTICLE

MATHEMATICAL APPROACH TOWARDS RECENT INNOVATION IN COMPUTATION AND ENGINEERING SYSTEM (MATRICS)

EVALUATION OF AQUIFER PARAMETER BY USING TRACER DYE

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ABSTRACT

Tracer dye can be used to transported through geologic media laterally with water. Three different dyes were selected for the laboratory study i.e. Rhodamine B, Sulphorhodamine, and Fluorescein. Initially column study was done to determine the adsorption of the dyes with the soil. In the batch study the fluorescein dye and sulphorhodamine shows good resistance to the adsorption of soil, but the concentration of fluorescein dye was varying with the temperature. Thiruvanchery Village, Kanchipuram district, Tamilnadu was selected for the field study and in field study Sulphorhodamine B and NACl were used as tracer. Single and two well dilution techniques had been used for the field to find out the parameters of the aquifer.16 open wells and 7 bore holes were identified. The dispersion coefficient estimated was 0.4 to 0.6 m2/day and dispersivity estimated was 13.5 to 15.5 m by single and two well dilution techniques.

KEY WORDS
Tracer, Dyes, Adsorption, Spectrophotometer, dilution techniques, dispersion coefficient

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INTRODUCTION

A tracer is a material that could be carried by the subsurface water which will give the indication about the groundwater measure and their corresponding path, the velocity of the flow in groundwater and polluted contaminants which might be transported by the water. Similarly, tracers dye support to identify the movement paths of water through a system. If enough information is collected about the geological media, then the dyes also help to determine the porosity, hydraulic conductivity, dispersivity, hydrogeological parameters and chemical distribution coefficients, [1-3]. The usage of tracers could improve our understanding of groundwater flow [4, 5]. The dye should travel through the same velocity and path as the water and should not interact with soil material and should be nontoxic [6]. The tracer would be present in a concentration of well above the background concentration of the equal component in the natural system [7][8]. Adsorption coefficient (k) by batch technique helps to explain the results of leaching studies, and given the pore water velocity, the leaching experiments can also yield k [11, 12].

The elementary theory and experimental specifics for the well tracer dilution technique are firm [14]. The single well dilution technique includes the outline of a identified quantity of tracer in a exact well and monitoring of the tracer concentration over a time period [15]. The velocity of filtration (V_f) is given by,

$$V_t = \frac{\pi r}{2\alpha t} \ln \frac{C_o}{C} \quad (1)$$

The two well dilution techniques were injecting tracer in one well and monitoring in the well at downstream well by natural and forced gradient. The tracer travels in its usual gradient and not by means of pumping. The break through curve was obtained from this and analyses of the resulting tracer break through curve dispersion coefficient and dispersivity is estimated by equation [15].

$$C(r,t) = \frac{M}{4\pi BV\sqrt{\alpha_L}} e^{\left[-\frac{(r-vt)^2}{4D_{Lt}}\right]} \quad (2)$$

The one-dimensional Dispersion equation is given below,

$$C(r,t) = \frac{\Delta M}{2Q\sqrt{\pi\alpha_L}\,vt^3} e^{\left[-\frac{(r-vt)^2}{4D_{Lt}}\right]} \quad (3)$$

$$D_L = \alpha_L v \quad (4)$$

Where, DL - Longitudinal dispersion co efficient in m2/s, Q - Pumping rate of the well in m3/s, ΔM - Injected mass of tracer per unit section in kg, V - Velocity in m/s, αL- Longitudinal dispersivity in meter, r - Radial distance between two wells in meter.

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MATERIALS AND METHODS

Dye selection

For the investigational study the three types of tracer dye were used namely Rhodamine B, Sulphorhodamine B and Fluorescein to determine the suitable dye for water study. The graph was plotted by using the known concentration's intensity value of the above tracer dyes. Standard curve for the dyes was shown [Table 1, Fig. 1].

Table 1: Intensity value for Sulphorhodamine B, Rhodamine B and Fluorescein

Concentration	Fluorescent Dye		
ppb	SRB	Rhodamine	Fluorescein
1	0.02	0.088	0.63
2	0.034	0.156	0.711
4	0.053	0.294	1.006
6	0.075	0.456	1.116
8	0.094	0.619	1.261
10	0.116	0.736	1.902
20	0.325	1.283	2.723
40	0.557	2.049	5.518
60	0.915	2.844	6.938
80	1.119	3.639	9.456
100	1.426	4.26	11.35
200	2.123	6.845	20.56
400	3.345	7.452	32.91
600	4.523	8.125	46.38
800	5.359	9.025	54.95
1000	6.113	9.971	62.86

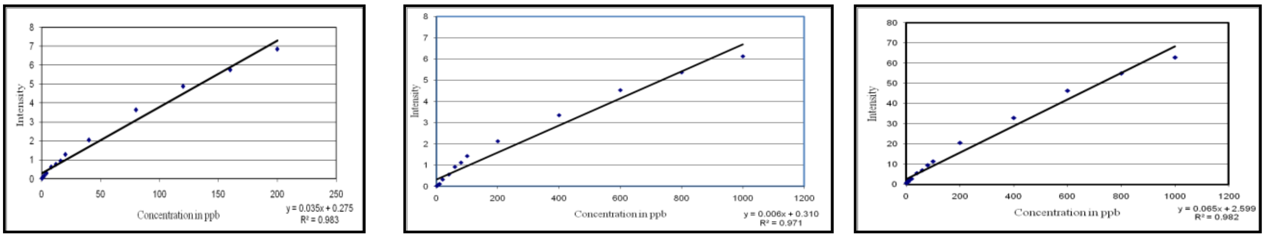

Fig. 1: Standard Graph for Rhodamine B, Sulphorhodamine and Fluorescein.

The dye was prepared at a known concentration level and transferred in to the column at different time break and the discharges of samples were collected. The tracer adsorption was measured from the discharge concentration and the proportion of adsorption was calculated from the standard graph. The column set up made for the laboratory experimental study [Fig. 2].

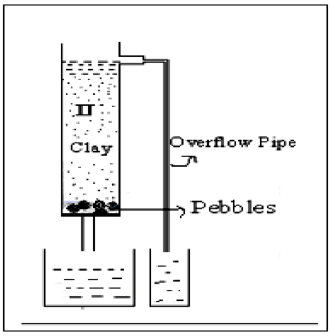

Fig. 2: Column study.

Study area

Thiruvanchery Village was selected for the field study. The field study was located in Kanchipuram District, Thambaram Taluk, Tamil Nadu, India. The study area was about 2 km2. The soil type in the study area was clayey soil and the cropping pattern followed by the farmer was paddy. Unconfined aquifer was identified

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in the field. Totally 16 open wells were present in the study area and the depth of the wells of about 10 m. The water level in the well were measured for every 8 months and also it was noted that the water level was increasing during the monsoon season and in non-monsoon season and in summer season the water level had been decreased. During pre-monsoon and post monsoon season the fluctuation of the water level was about 1 m. The zone of aeration in the study area ranges from 0.5 to 1m.

RESULTS

Experimental batch study

A small investigation study was for the dye, to identify the dye loss due to sunlight, and due to minerals present in the water and also due to the impurities present in the water and soil, the sediment been varied to determine adsorbent of the dye loss. The loss of dye due to above factors were determined and shown [Fig. 3] [Fig. 4].

It shows that the loss of dye was more in surface water because of the variation in water temperature due to sunlight. Fluorescein dye was affected by the temperature and show resistance to chemical decay and adsorption of soil. When the tracer dyes were used in marine location or in contaminated water, the performance of dye would be disturbed. Smart and Laidlaw (1977) found a noticeable drop in the sum of dye loss to the adsorbing materials with increase in the dye concentration. The loss of dye during these test was shown in the [Table 1]

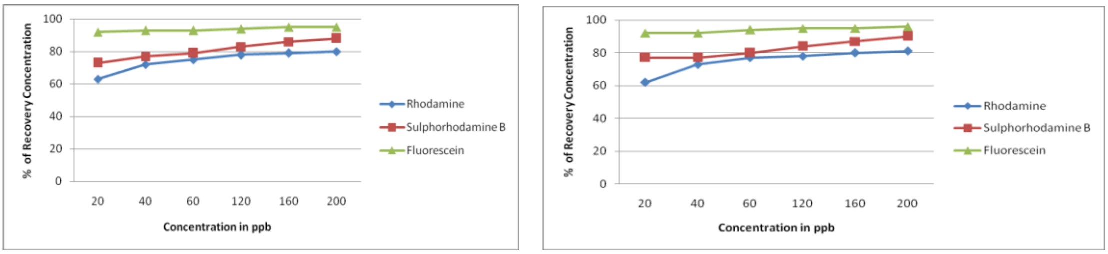

Fig. 3: Batch study for the different quality of water.

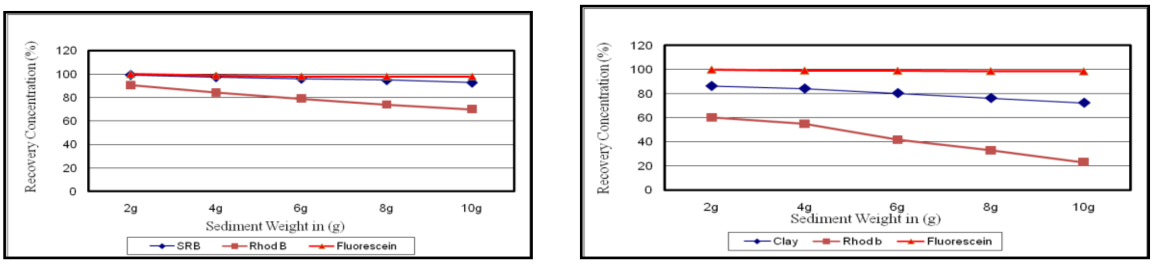

Fig. 4: Batch study for the different types of soil.

Finally, when the adsorption test was conducted by varying the sediment weight for all the three dyes, there is adsorption was very less for fluorescein dye. The result was plotted and tabulated [fig.5][Table 2]. it shows, when the sediment weight was increasing, the adsorption was more for other two dyes, fluorescein show resistance for soil adsorption.

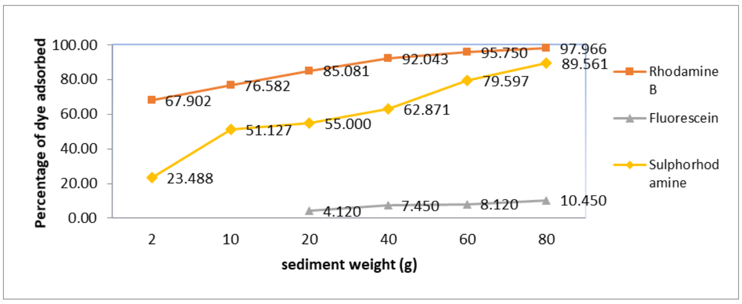

Fig. 5: Dye adsorption by varying sediment weight

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Table 2: Batch study result for the dyes

Dyes	Percentage of dye loss					
	Loss due to sunlight	Chemical Decay	Contaminated water	Marine water	clay soil	sandy soil
Rhodamine B	11%	8%	20%	20%	75%	30%
Sulphorhodamine B	15%	3%	10%	11%	20%	4%
Fluorescein	20%	2%	6%	4%	4%	2%

Soil column test

For the column study, the column was initially filled with pebbles and gravel to a depth and after that clay soil was filled. The column was saturated with normal water. After saturation of soil column, the dye concentration of 200 ppb was passed through the soil. the tracer sulphorhodamine dye was tested under column test, the result showed that the dye was adsorbed to the soil. The recovery of dye had been reduced with increase duration of time period [Fig. 6].

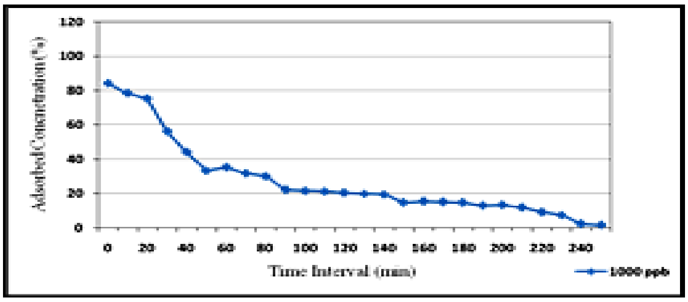

Fig. 6: Concentration Recovery of Sulphorhodamine B.

Fluorescein shows good resistance to adsorption when compare to Sulphorhodamine B [Fig. 7]. The main problem that occurred while using this dye was background fluorescence which present naturally in water. Therefore, it was mandatory to measure the background fluorescence before applying these dyes.

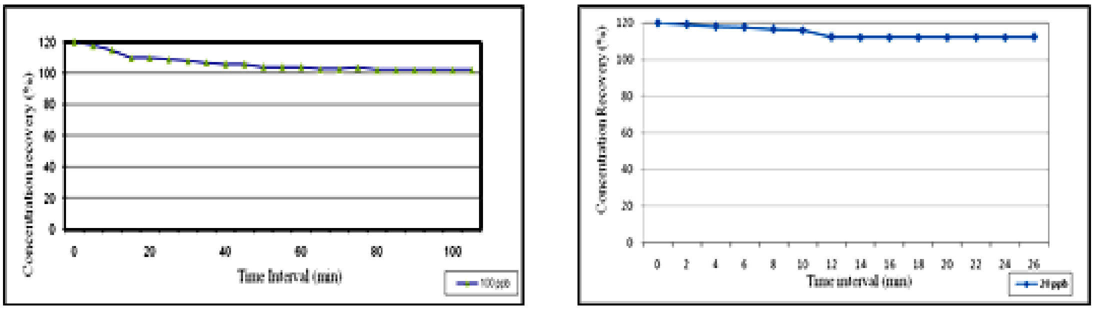

Fig. 7: Concentration Recovery of Fluorescein.

With this laboratory study the sulphorhodamine was selected for the field study, because of its easy availability and resistance to soil, where the Fluorescein was subjected to high background fluorescence[16]. Additionally, NACL was also used for a part of the field study.

Field study - well dilution technique

The well dilution technique was carried out with groundwater tracer such as organic tracer (Sulphorhodamine B) and chemical tracer (NaCl). The bore hole in the study area was plotted [Fig. 8]. The solution of 250 ppb concentration of one litre is poured instantaneously in the borehole L4. The water sample from the borehole L4 is collected from the time t=0 to the time t days until the background concentration attained. The concentration of the water samples collected from the borehole L4 is measured using the Fluorescent Spectrometer. The solution of 250 ppb concentration of 100 ml is poured instantaneously in the borehole B1. The water sample from the borehole B1 is collected from the time t=0 to the time t days until the background concentration in attained.

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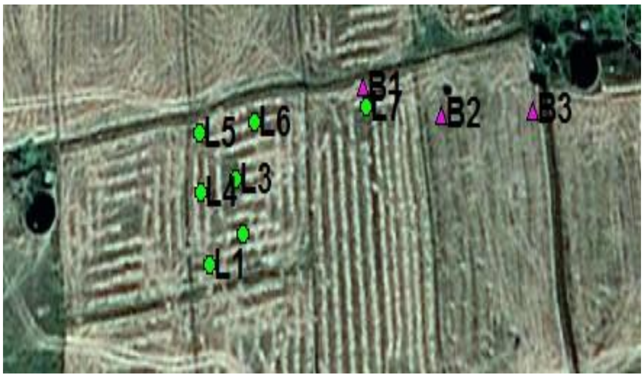

Fig. 8: Borehole Location in the Study Area.

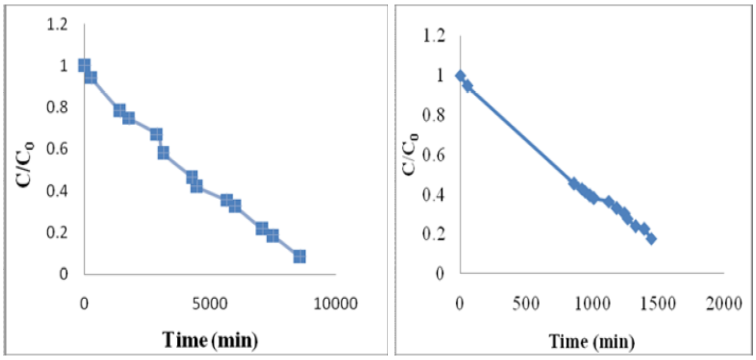

Fig. 9: Single Well Dilutions in Borehole L4 and B1 – Sulphorhodamine B.

400 gram of NaCl is diluted in the water sample from the study area and it is poured instantaneously in the borehole L1. The water samples are collected from the borehole L1 at different times. The concentration of NaCl in L1 was reduced in 10865 min. 200 gram of NaCl is diluted in the water sample from the study area and it is poured instantaneously in the borehole L6 [Fig. 9][Fig. 10].

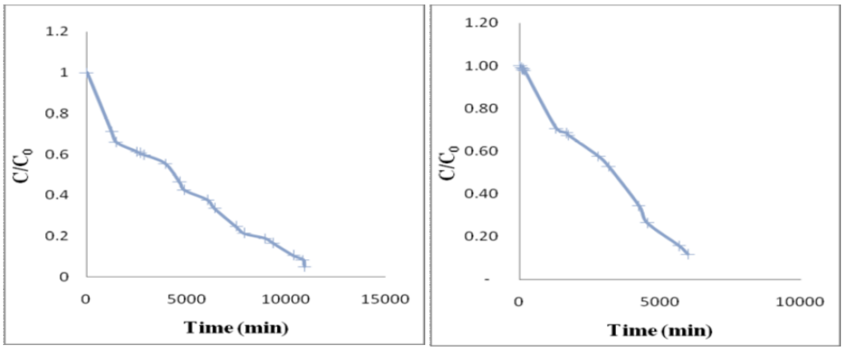

Fig. 10: Single Well Dilutions in Borehole L1 and L6 –NaCl.

From the above experiment the velocity and permeability was assessed by the given equation (1) and(2). The dispersion co efficient and dispersivity was estimated by equation (3) and (4) [Table 3] [Table 4].

Table 3: Estimated parameters by Single Well Dilution Technique

Groundwater Tracer	Sulphorhodamine B	NaCl
Filtration Velocity m/day	0.05	0.04
Permeability m/day	4.76	3.82
Dispersivity in m	11.5	10.6
Dispersion coefficient m^2/day	0.45	0.31

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Table 4: Estimated parameters by Two Well Dilution Technique

Groundwater Tracer Breakthrough	Natural Gradient	Forced Gradient
Velocity m/day	10.05	108
Dispersivity in m	13.55	15.31
Dispersion coefficient m^2/day	0.43	0.61

CONCLUSION

The above study exposes that the Rhodamine B dye was seriously adsorbed to soil when compare to the other two dyes Sulphorhodamine B and Fluorescein. The amount of dye absorbance increases, if the adsorbent quantity and time increases. The batch study result shows that the fluorescein dye was affected by sunlight, therefore the change in temperature would affect the recovery dye concentration. It shows Fluorescein was greatly affected by photochemical decay. Also, it shows the good resistance to adsorption of soil. The adsorption of dye was less in clay soil, and the recovery of dye concentration was more and that was shown by soil column test. In column test the fluorescein dye recovery concentration was more when compare to the other dye. For field study the organic tracer dye sulphorhodamine and NACL was taken and used for well dilution techniques. From the single well dilution field study the filtration velocity assessed was 0.04 to 0.05 m/day, permeability estimated was 3.8 to 4.8 m/day, dispersion coefficient estimated was 0.3 to 0.45 m2/day and dispersivity estimated was 10.5 to 11.5 m. By the two well dilution studies the dispersion coefficient estimated was 0.4 to 0.6 m2/day and dispersivity estimated was 13.5 to 25m.

CONFLICT OF INTEREST

There is no conflict of interest.

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FINANCIAL DISCLOSURE

None.

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