



## DETERMINATION OF FILTRATION VELOCITY AND DIRECTION OF GROUNDWATER FLOW USING TRACER TECHNIQUE, PORT DICKSON, NEGERI SEMBILAN

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### ABSTRACT

*The filtration velocity of the groundwater was determine by introducing  $^{1m}Ci$  Br-82 into a borehole. Br-82 was in the form of potassium bromide. The result showed that the filtration velocity varies from 2.3 to 4.5 cm/day depending on the soil matrix with the clayey layer posting more resistance to flow. Au-198 in the form of aurium chloride was introduce into two other boreholes to determine the direction of flow. The general trend of flow was in the direction between N140E and N160E.*

**Key Words:** filtration velocity, radioactive tracers

### INTRODUCTION

The linkage between man and the environment has always been closely associated with human activities physically and culturally through the demand of water supply. The development of such activities on land has created, in some cases serious environmental impact to groundwater such as ground subsidence, salt water intrusion and groundwater pollution. In handling such scenario, Lankhorst Environmental Services has engaged Malaysian Institute For Nuclear Technology Research to carry out part of it's EIA study on groundwater flow pattern within a sludge farm in Port Dickson, Negeri Sembilan.

The experimental site is mainly reclaimed by laterite, which is, in a way may limit the migration of contaminants to the groundwater system. There are three boreholes (Nos. 1, 2 and 3) situated around the sludge farm currently used to monitor the fluctuation of groundwater table. The area is diagrammatically presented in Fig.1. The profile of boreholes No1 and No.3 is indicated in Fig.2.

## PRINCIPLE OF STUDY

The velocity of groundwater flow can be estimated by the use of hydraulic principle. According to Darcy [1], the flow in water-bearing soil varies directly to the slope of the hydraulic gradient. By applying this law, with an appropriate test inside the boreholes, one can established point dilution method using a tracer.

The horizontal Darcy or filtration of the groundwater flow can be measured with the above method. The dilution of tracer inside this volume ( $V_o$ ) takes place to the following differential equation,

$$\frac{dC}{dt} = -\frac{C}{V_o} \frac{dV}{dt} \quad (3.1)$$

where;

$C$  = concentration  
 $t$  = time  
 $V$  = filtration velocity

$$C_t = C_o \exp\left[-\frac{4\alpha V}{\pi d}\right] \quad (3.2)$$

where

$d$  = borehole diameter  
 $\alpha$  = coefficient accounting for the hydrodynamic disturbance

If  $t_{1/10}$  is the time needed for a concentration decrease to 10 times, i.e.  $C_o/C_t = 10$ , the following equation can be derived:

$$V = \frac{1.81d}{\alpha_{1/10}} \quad (3.3)$$

With the assumption that there is no vertical flow, a method based on the labelling of the water column in the borehole with tracer can be used to obtain the filtration velocity.

The direction of groundwater flow can be determined by rotating a collimated probe 360 degrees. The orientation of the probe can be ascertained by magnetic compass. The tracer concentration is recorded as a polar diagram. The flow direction is indicated by higher tracer concentration.

## EXPERIMENTAL APPROACH

### Measurement of filtration velocity

Borehole No. 2 with 7.6 cm internal diameter was chosen to determine the filtration velocity of groundwater. Radioactive Bromine-82 was used as tracer to label the total water column. The profiles of tracer concentration were measured using a watertight scintillation probe.

The water column in borehole No. 2 was labelled with Bromine-82 (1mCi). Time series tracer concentrations of the water column were monitored to determine the rate of dilution. The variation of dilution were plotted against elapsed time to obtain the value of  $t_{1/10}$  (Eq. 3). The filtration velocities were then calculated with respect to the soil profile.

### Measurement of Groundwater Flow Direction

Boreholes Nos. 1 and 3 were chosen to investigate the groundwater direction. The profiles of tracer concentration were measured by using a collimated watertight scintillation probe.

Gold-198 solution (20  $\mu$ Ci/ml) was dripped into the boreholes and left overnight to allow the tracer to flow freely and adsorped onto the borehole screen. The probe was inserted into the borehole at every 0.5 meter depth interval. It was rotated at every 20 degree in clockwise direction with respect to 0 degree North. The tracer concentrations at each interval were recorded and plotted in a radial graph mode and from the curves, the direction of groundwater can be deduced.

## RESULTS AND DISCUSSIONS

During the experiment the weather condition was predominantly dry. The ambient temperature was almost consistent within 30 - 35°C. The water level of Borehole Nos. 1, 2 and 3 are 1.65 m, 0.70 m and 2.80 m below the surface respectively. The area is generally sloping towards South-East. Borehole No. 3 is located in the reclaimed area.

Figure 3a shows the variation of tracer concentration at different depth and elapsed time (time after injection of tracer) of Borehole No. 2. From the observation, it is clearly shown that there are three separate dilution segment which coincide with the three soil layer namely laterite, sandy clay and silty clay as shown in Fig. 2 in borehole profile.

Figure 3b shows the dilution of tracer at different elapsed time at Borehole No. 2, based on the three soil profiles, from which  $t_{1/10}$  are determined. The filtration velocities are calculated using Eq. 3.3. They are summarized in Table 1.

**TABLE 1:** The variation of filtration velocity at different soil profile.

Soil profile	Elapsed time for $C_0/C_t=10$ ( $t_{1/10}$ , hours)	Filtration velocity (cm/day)
Laterite	74	4.5
Sandy clay	76	4.3
Silty clay	145	2.3

The results of flow direction for Borehole Nos. 1 and 3 are shown in Figs. 4a and 4b respectively. The general direction of the flow is between N140E - N160E.

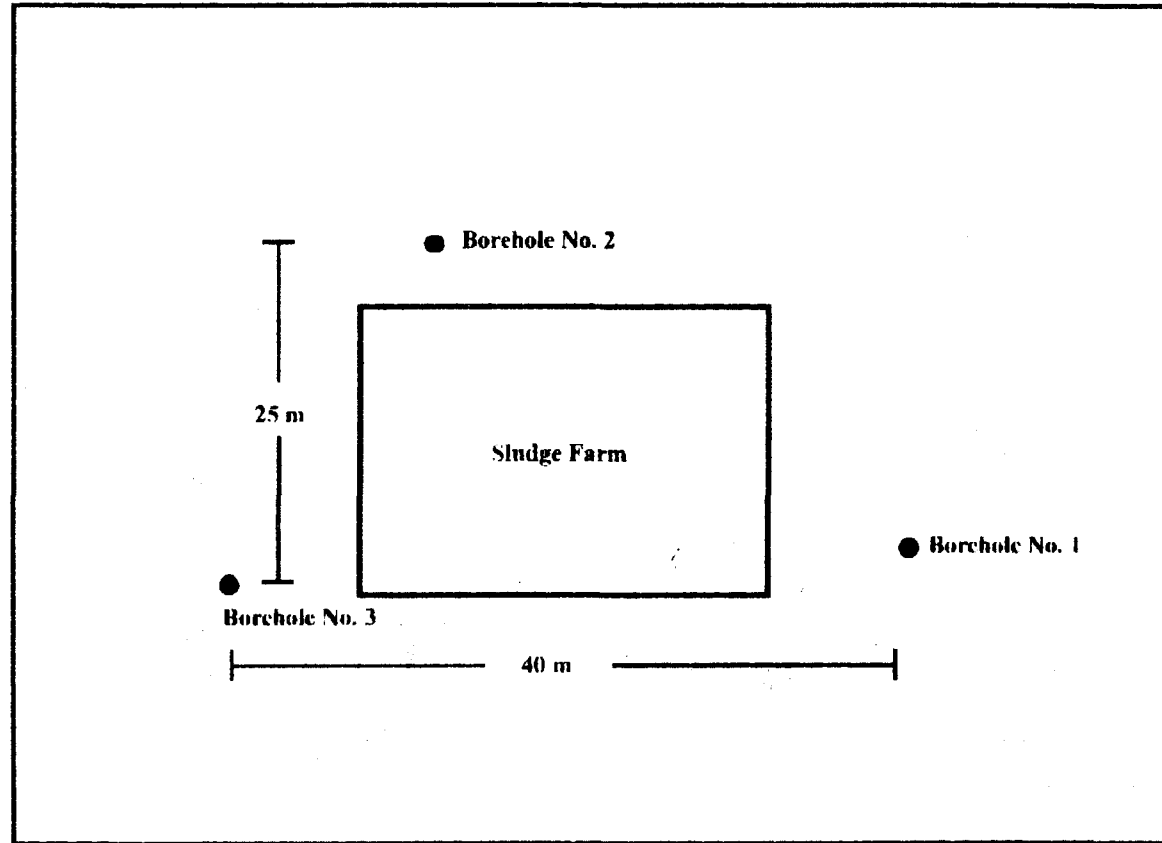
### CONCLUSIONS

Based on this study, the following conclusions can be derived:

1. The main pattern of the groundwater in sludge farm area is flowing toward N140E - N160E direction.
2. The filtration velocities in the area showed some variation depending upon the characteristics of the soil. The value ranged between 2.3 to 4.5cm/day.
3. The flow in silty clay is found to be slower than that of sand and laterite.

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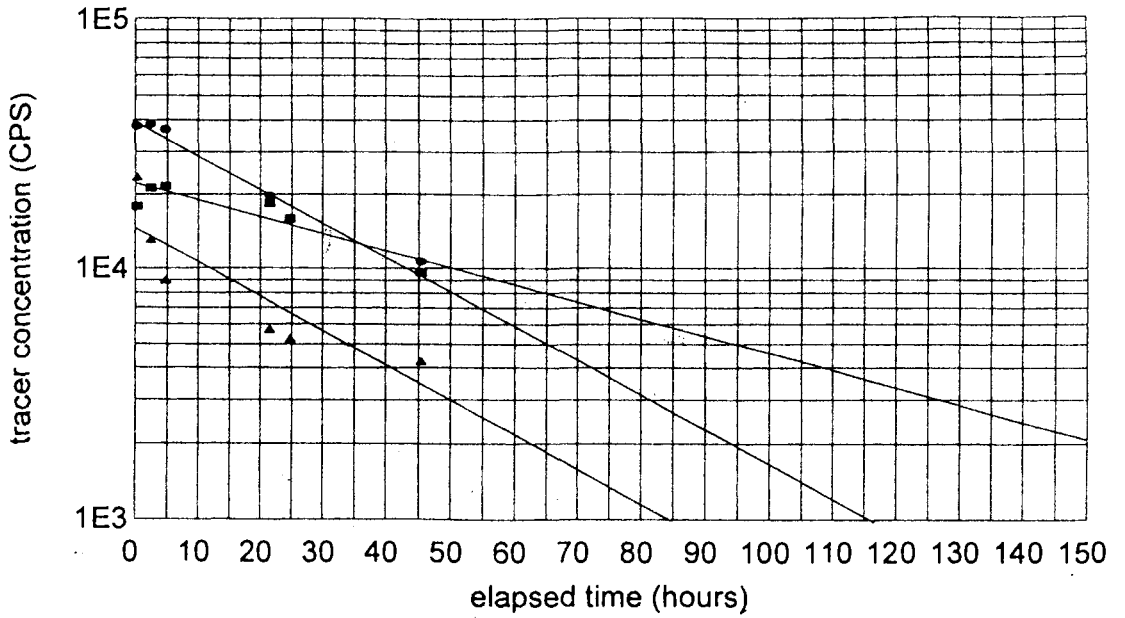
**Fig 1: General layout of Sludge farm area**

Date & (Time)	Depth of boring casing	ground water	samples and test			Strata				
			Depth	Remarks	Use	Depth	Remarks	Thickness	Description	
	M	b.g.l	M			M		M		
28.4.93 (08:00) (13:00)	6.00	Strike water table 2.40m				0.00		2.00	Very dense reddish-brown, clayey fine to coarse Gravels of LATERITE, with boulders.	
2.00						2.00				Soft gray peaty sandy CLAY with roots.
(16:00)		6.00m				4.00		2.80	Soft to firm yellowish-white, silty CLAY.	
29.4.93 (08:00)		W.L. - 4.56m				6.00			End of hole.	
		Drove to Nital Quarry purchased filter-gravels and transported back to Shell Refining. Washed the filter-gravels. Cut spots for the 3" dia. precipipes 4.50m length and covered with stainless steel mesh.				6.50				

Fig. 2.a : Soil profile of borehole No. 2

Date & (Time)	Depth of boring casing	ground water	samples and test			Strata				
			Depth	Remarks	Use	Depth	Remarks	Thickness	Description	
	M	b.g.l	M			M		M		
30.4.93 (10:00) (14:00)		2.90m				0.00		2.80	Very dense reddish-brown, clayey fine to coarse Gravels of LATERITE, with boulders and woods.	
(19:00)						2.80				2.80
1.5.93 (08:00)		2.00m				3.00		0.70	Very soft to soft gray peaty sandy CLAY with roots.	
1.5.93 (14:30)	(5.50)					3.70		2.30	Very dense reddish-brown, clayey fine to coarse gravels of LATERITE, with boulders.	
1.5.93 (14:30) (18:00)						6.00			LATERITE BOULDERS.	
2.5.93 (08:00)		W.L. - 2.02m							End of hole.	
3.5.93 (08:00)		W.L. - 1.90m								
4.5.93 (08:00)		W.L. - 0.83m								

Fig. 2.b : Soil profile of borehole No. 1



• laterite ▲ sandy ■ silty

Fig. 3.b : Dilution of tracer at different elapsed time for borehole No. 2

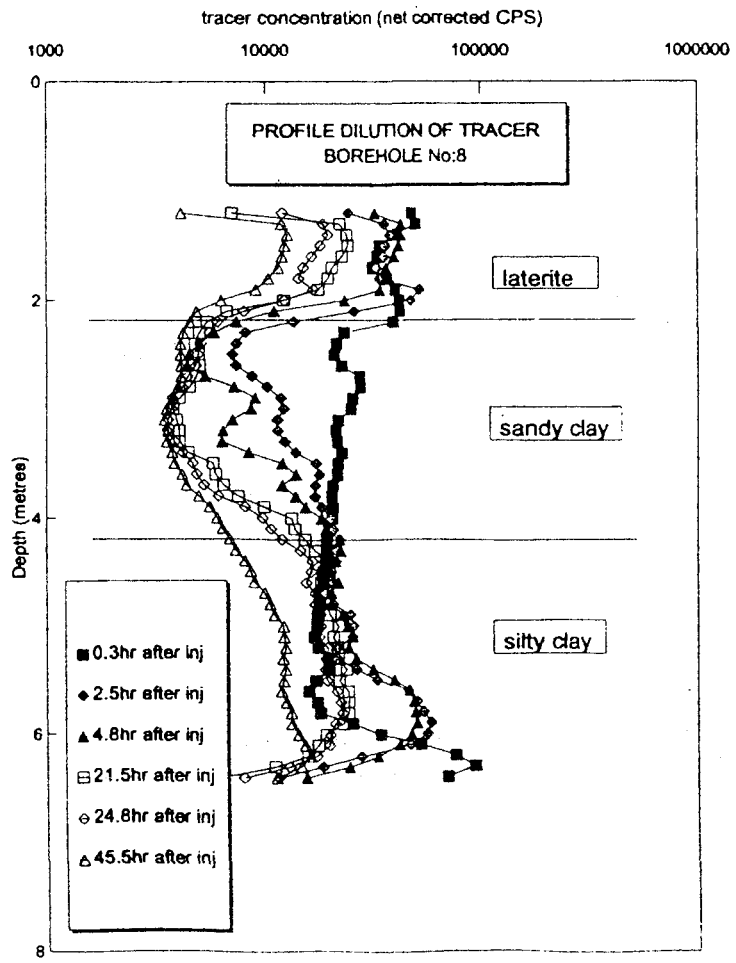
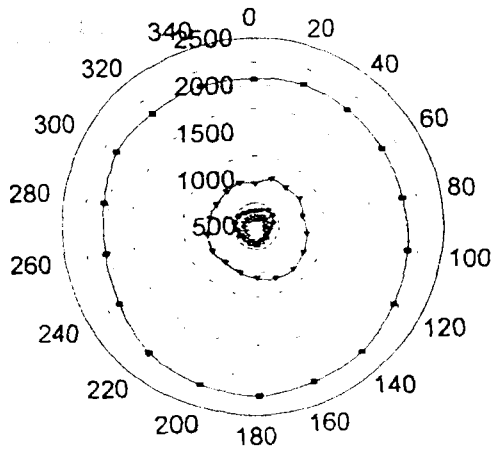
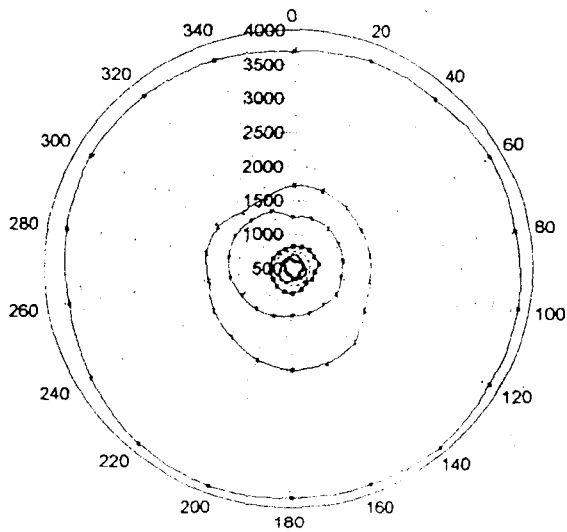


Fig. 3.a : Tracer concentration profiles at different elapsed time for borehole No. 2



— 2.5m — 3.0m — 3.5m — 4.0m

Fig. 4.a : Groundwater direction plot for borehole No. 1



— 3.5m — 4.0m — 4.5m — 4.8m — 5.4m — 5.8m

Fig. 4.b : Groundwater direction plot for borehole No. 3