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Isotope Technique (^{14}C, ^{131}I) for Safety Analysis of Domestic Solid Waste Disposal Site in Jakarta, Indonesia- A Case Study

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Abstract

Bekasi is one of city around Jakarta which has been developed for the last 10 years. In the south of Bekasi placed sanitary landfill area for domestic solid waste of Jakarta Metropolitan as a Disposal Site. The objective of the present study is to evaluate the location of Bantar Gebang Bekasi solid waste disposal site for safety analysis. The geohydrologycal parameters are determined by using isotopes techniques (^{14}C, ^{131}I) to study the shallow groundwater characteristics of the site. From the results of ^{14}C the direction of groundwater movement is found to be from South to the North and turned to North West of Jakarta at Jakarta Center. From radiotracer method (^{131}I) the direction of shallow groundwater in the rainy is observed to be from the disposal site to the surrounding area and the Ciketing canal which flows to the North. For the dry season from the disposal site to the surrounding area. The results from environmental isotopes and hydrochemistry analysis indicate that the pollutants from the site have given an impact to the surrounding area of disposal site which was shown by migration of nitrate. It is recommended that the decision maker should give high priority to the geology, geohydrology and environmental pollution studies for consideration of disposal site for the safety of sanitary landfill.

Keywords: Isotope, Safety, Disposal

1. Introduction

There is worldwide a growing awareness and concern of governments, communities and industry about the risks to people and the environment from the location and operation of sanitary landfill and disposal sites for domestic solids waste. The identification, assessment and management of health and environmental risks are now recognized as essential elements for orderly economic and social development (Lederman, 2007). The development of the city will increase the demand to clean water according to demand of the town. At the same time that is also happened by improvement of contamination of surface and ground water, especially shallow ground water which is resulted by human activities.

Environmental safety analysis represent processes considering environmental condition and participate society in course of decision making from development of a project or an activity. Research by using isotopes technique for environmental safety analysis of a waste disposal site covers predicting the origin, direction, and rate of shallow groundwater movement with the aid of mathematical model. A few researches on investigation of groundwater pollution by using isotopes techniques are available in the literature. Fritz et al. (1976) has developed environmental isotope method of ^{18}O and deuterium as movement indicator of leachate water from sanitary landfill. Shivanna et. al. (1998) applied the isotopes technique to investigate groundwater pollution in India. In Frankfurt, Germany, Begey et al. (1995) using radioactive tracer ^{131}I to determine hydrodynamic parameter. And for Tandia et. al. (1998) research about origin, process and migration nitrate compounds in the aquifers of Dakar region, Sinegal.

The development carried out in Bekasi district at the last 20 years may followed by growing demand of water to the area. In general the water demand is usually met directly from underground using small and big capacities of pump. The location of disposal site for domestic solid waste Jakarta Metropolitan has been operation since 1987. One of the serious problems is movement of polluted water containing dangerous pollutants from the disposal site to shallow and groundwater system around the location. Therefore, the decontamination technique as a remedy and early protection of shallow ground water can be applied for the present disposal site. In the present research environmental safety analysis using isotopes technique carried out for the site by using isotopes approach (^{14}C, ^{131}I) and mathematical model for pollutant transport. The objective of the study is to evaluate the location of Bantar Gebang Bekasi solid waste disposal site for safety analysis in order to protect the shallow groundwater around the disposal site from leachate water pollutant.

2. Methodology

2.1 ^{14}C-Dating analysis

Analysis of C-14 is performed by converting $BaCO_3$ into C_6H_6 in a benzene synthesis unit. The Chemical reactions are:

$$BaCO_3 + 2\,HCl \longrightarrow BaCl_2 + H_2O + CO_2$$

$$2CO_2 + 8\,Li \xrightarrow{temp} 2C + 4Li_2O$$

$$2C + 2\,Li \xrightarrow{temp} Li_2C_2$$

$$Li_2C_2 + 2\,H_2O \longrightarrow C_2H_2 + 2\,LiOH$$

$$3C_2H_2 \xrightarrow{Catalyst} C_6H_6$$

The radioactivity of C-14 in benzene compound is measured by a normal procedure with liquid scintillation counter. Thus, the observed ^{14}C distribution in the BEKASI is expressed in percentage of modern carbon, i.e. the carbon content in 1 gram modern carbon of 1950 (13.56 ± 0,06 dpm) with oxalic acid standard RM49. The age of groundwater is evaluated by using formula (Clark et al., 1997):

$$t = 8267 \ln Co/C \qquad (1)$$

where, C = the value of % modern carbon of the sample and

Co= the initial carbon-14 content

The ^{14}C values calculated for adjusted age is obtained by correction of Co, i.e. :

$$Co = [\{100\,(\partial-\partial_c)\}/(\partial_G - \partial_c - \varepsilon)] \times (1 \times \quad 2\varepsilon/1000) \qquad (2)$$

where, ∂ is the C-13 content of carbonate species dissolved in sample, ∂_C is that of aquifer carbonate, ∂_G is that of the soil CO_2 at the time of recharge and ε is the fractionation factor between bicarbonate and soil CO_2. The value adopted for the calculation are $\partial_c = 0$, $\partial_G = -25 \pm 1‰$, $\varepsilon = 8 \pm 0,5$ ‰

2.2 Method of Single Well

Measurements of directions and velocity of groundwater flow are conducted by using single well technique in which the boreholes of 3 inchs diameter are made as injection and measurement points. Experiments are conducted by injection of ^{131}I tracer of quantity 1 mCi, in the form of KI, soon followed by counting of the location background. Then the measurement of tracer can be done after it is mixed in the well for about 1 day. Counting of tracer response is done by using gamma scintillation detector (NaITl). It consists of a collimator (Figure 1) with a scale and and a flow meter in order to measure the total count from the borehole. For every borehole, counting is conducted to the North, South, West, East, North-West, North-East, South-West, and the South-East directions. Measurement of Darcy velocity is done by measuring the change of concentration or activity of radiotracer ^{131}I at the same well at certain time by using the same instrument (Syafalni et al. 1997).

Measurement of Darcy velocity (filtration velocity) by dissolution method is based on the decreasing of concentration at certain time as mathematically:

$$v_f = \Pi r_1/2\alpha t \ln Co/C \qquad (3)$$

in which

$$\alpha = 4K_1/\{K_1[1+(r_1/r_2)^2] + K[1-(r_1/r_2)^2]\} \qquad (4)$$

where:

v_f = filtration velocity

r_1 = inside well radius

r_2 = outside well radius

Co = initial concentration $t=0$

C = tracer concentrasi at time t

t = time

K_1 = hydraulic conductivity screen

K = hydraulic conductivity aquifer layer

For calculation of K_1 (cm/detik) for plastic screen can be done empirically using 0,1f. And f concerning the percentage of opening screen. When value of $K << K_1$ so that K was neglected and the value of α is not influenced by the hydraulic conductivity of aquifer (International Atomic Energy Agency, 1983).

2.3 Method of Double Well

The double well method can be used for determination of characteristics of aquifer by pumping it to one particular well and injection of radiotracer ^{82}Br or ^{131}I to the other well. The degradation of water level and the response of radiotracer are observerved at regular intervals. The radiotracer is injected at receiver borehole and the response was observed at the other borehole by using counting scintillation system (NaITl). From the result of water level, pumping time and response of radiotracer is evaluated for determination of aquifer characteristics such as effective porosity and dispersivity coefficient by using pollutant transport model and by Dupuit equation (Todd, 1980).

3. Results and Discussion

3.1 Bekasi groundwater flow direction

The experiments have been conducted for a period from January 2001 to July 2002 using carbon dating ^{14}C, ^{18}O, and ^{2}H along with analysis of hydrochemistry for Bekasi area and its surroundings and evaluation of geohydrology data. The results show that the groundwater of this area has 4 layers of aquifer and the direction of groundwater flow is from the South to North and from the North, turn to the left (North-West direction) as shown in isoage-contour of Bekasi groundwater (Figure 2). The analysis of hydrochemistry presented by Ruchiyat et.al.(1997) using ions Ca^{+2} , Mg^{+2}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{-}, and Cl^{-} also shows that the origin of Bekasi groundwater is from South Bekasi. The results indicate that the location of disposal site will contribute to a very wide contamination in the North (which covers North Bekasi and North Jakarta) and mainly in part of East Jakarta that have relation with Bekasi groundwater. It has already been found from the evaluation of the location safety assessment, that the decision of the above site was made without considering the origin of groundwater, groundwater movement, and migration of leachate of solid waste coming from biological decay of domestic waste of Jakarta and without considering geology aspects or environmental hydrogeology contamination of the area (Syafalni et al., 2001, 2002, 2003).

3.2 Shallow groundwater flow direction

The results of radiotracer method (^{131}I) that supported by environmental isotope method (^{18}O, ^{2}H) and analysis of hydrochemistry (ion Ca^{2+} , Mg^{2+} , Na^{+} ,K^{+} , Fe^{3+} , HCO_3^{-} , SO_4^{-} , Cl^{-} , and NO_3^{-}) could predict the direction of movement of shallow groundwater around disposal site Bantar Gebang Bekasi as well as the mixing processes by leachate. The results indicate that the migrations of ion have extended about 3 km toward North of disposal site. The NO_3^{-} migration is accelerated by existence of Ciketing channel through disposal site to the North which perhaps will affect shallow ground water in this area. This area is a ground water recharge of Bekasi which is evaluated from protection zone of ground water (Syafalni et al. 2003).

From radiotracer method (^{131}I) with single well and double well techniques it is found that shallow ground water moves locally at three locations namely, Desa Sumur Batu, Desa Cikiwul and Desa Ciketing.The shallow groundwater movement of Sumur Batu, which is located North of disposal is to North-West at rainy season and to South-East at dry season. Desa Cikiwul which is located west of disposal site show opposing movement with that of Sumur Batu. Desa Ciketing shows same movement direction at both the seasons, that is to South-West (Figures 3.a and 3.b). The above results indicate that movement of shallow groundwater in the disposal area is influenced by solid waste accumulation at the site and exploitation of groundwater around it by industrial and domestic wells which also can cause leachate water flowing out of disposal site. This situation is very critical as the surrounding area of disposal site represent dynamic and expanding area.

Moreover the migration and movement of pollutant in this area could be simulated by using classic method and computer program by using disposal characteristics data (Table 1). The simulation results show good agreement with the realistic shallow groundwater movement of this area.

Hence it can be concluded that, there is significant dispersion of pollutants from the disposal site to its surroundings. If proper remedial actions are not taken, in the long run, these pollutants will contaminate the groundwater of Bekasi and north- east of Jakarta.

4. Safety analysis of disposal site

Protection of ground water from contamination is the key objective of disposal siting. The following short-term activities are required to be conducted as part of disposal siting:

1) Geodesy and infrastructure of location: covering mapping, land status, system of tranportation and building, study of energy resources and water resources.

2) Geology and mechanics of land covering; identify of layers and structure of land, study of stability of surface and subsurface, and measuring of characteristic of land for each layer

3) Hydrology and geohydrology covering study of surface, study of leakage and ground water, inclusive of old age groundwater determination.

4) Research of migration with tracer to evaluate natural barrier

5) Supporting activity (meteorology measurement).

The long- term activities required include monitoring of ground water level, measurement of pollutant movement around Disposal site, meteorology measurement, and study of prevention and treatment of pollutants from disposal system. These requirements are not yet fulfilled for Disposal system at Bantar Gebang, Bekasi.

5. Conclusion

The isotopes technique (^{14}C and ^{131}I) is successfully applied to study the ground water characteristics of a typical waste disposal site near Jakarta, Indonesia. The results of ^{14}C dating are also supported by single and double well method for calculation of pollutant movement in the study area. The following conclusions may be drawn from the result analysis:

1) Ground water of Bekasi comes from the South of disposal site and moves to the North and then turns to North-West at centre of Jakarta.

2) The movement of shallow grounwater around the disposal site is highly influenced by hydrology and groundwater exploitation by domestic, and industrial wells.

3) The decision maker of the disposal site is advised to give high priority to geohydrology, environmental geohydrology contamination and to determine the location of Disposal site on the basis of environmental safety analysis.

4) Shallow groundwater of disposal site and the surrounding area have been contaminated by leachate water which is proved by ^{18}O, ^{2}H, hydrochemistry, and nitrate content in the area of investigation.

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Table 1. The result of shallow groundwater characteristics at Bantar Gebang Disposal Site (February and May 2002)

Locations	Flow directions		Darcy velocity (m/s)		Hydraulic conductivity (m/day)	Disperssivity (α_L) (m)	Effective Porrosity (n_{eff})
	February 2002	May 2002	February 2002	May 2002			
Desa Sumur Batu (A)	North-West	South- East	6.72×10^{-8}	1.84×10^{-8}	2.264	0.5157	0.137
Desa Cikiwul (B)	South- East	West	1.03×10^{-7}	9.8×10^{-8}	8.061	0.5864	0.124
Desa Ciketing Udik(C)	South-West	South-West	1.18×10^{-7}	1.27×10^{-7}	14.515	0.55	0.131

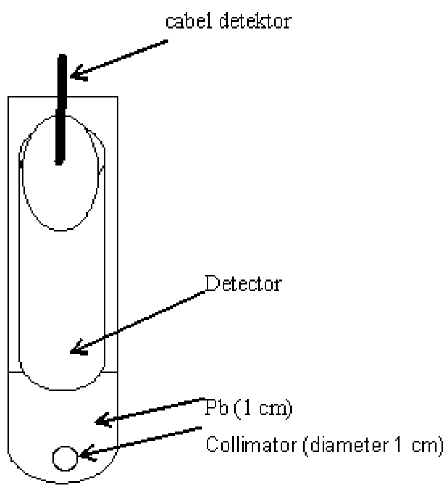

Figure 1. The Single well techniques for groundwater flow measurements

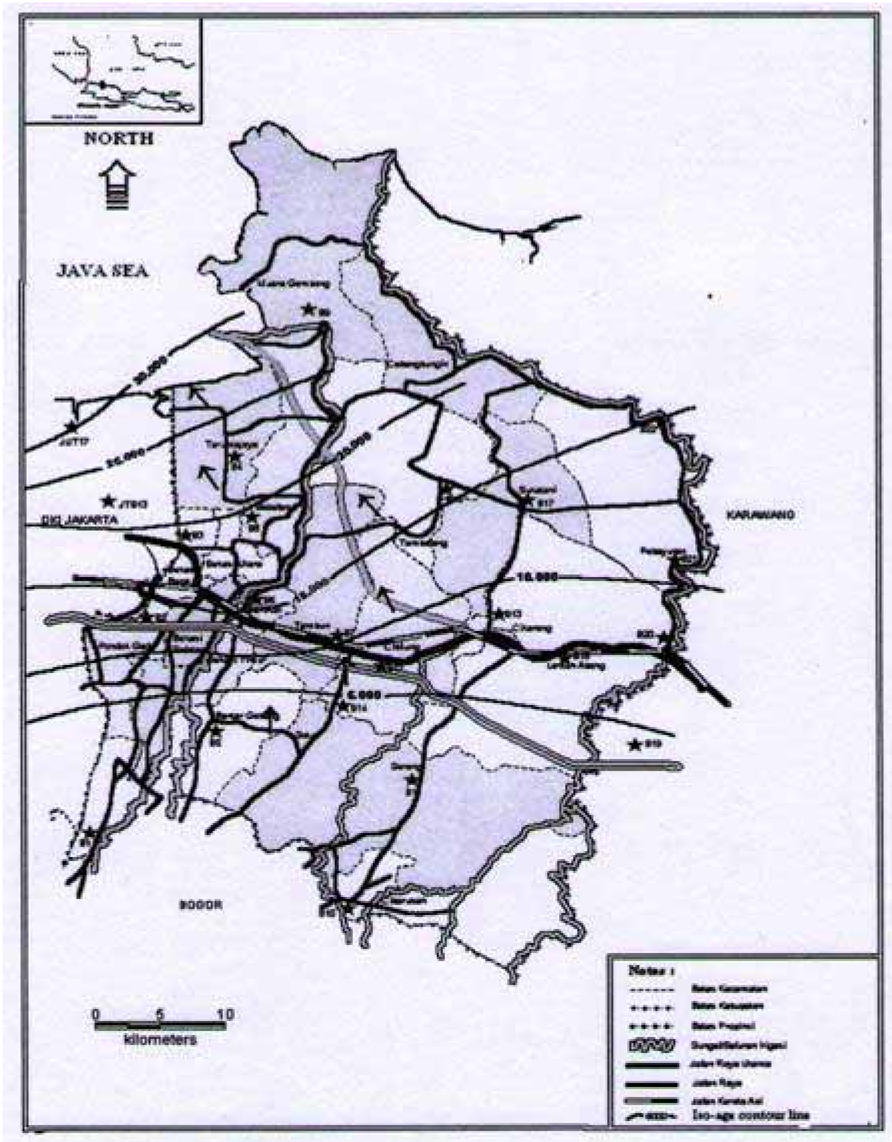

Figure 2. Iso-age map for Bekasi groundwater (Syafalni et al. 2001)

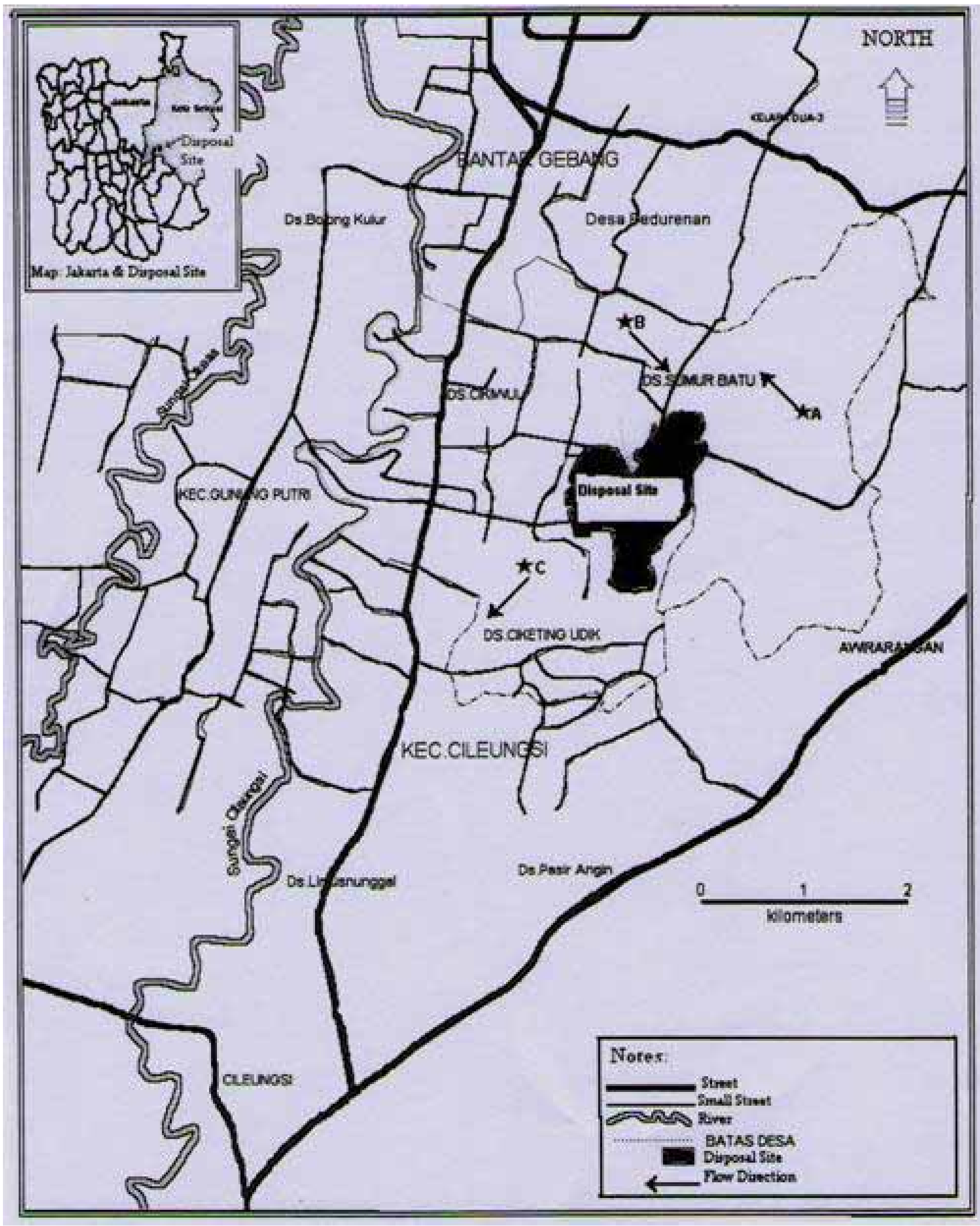

Figure 3a. Shallow groundwater flow directions at rainy season (February 2002)

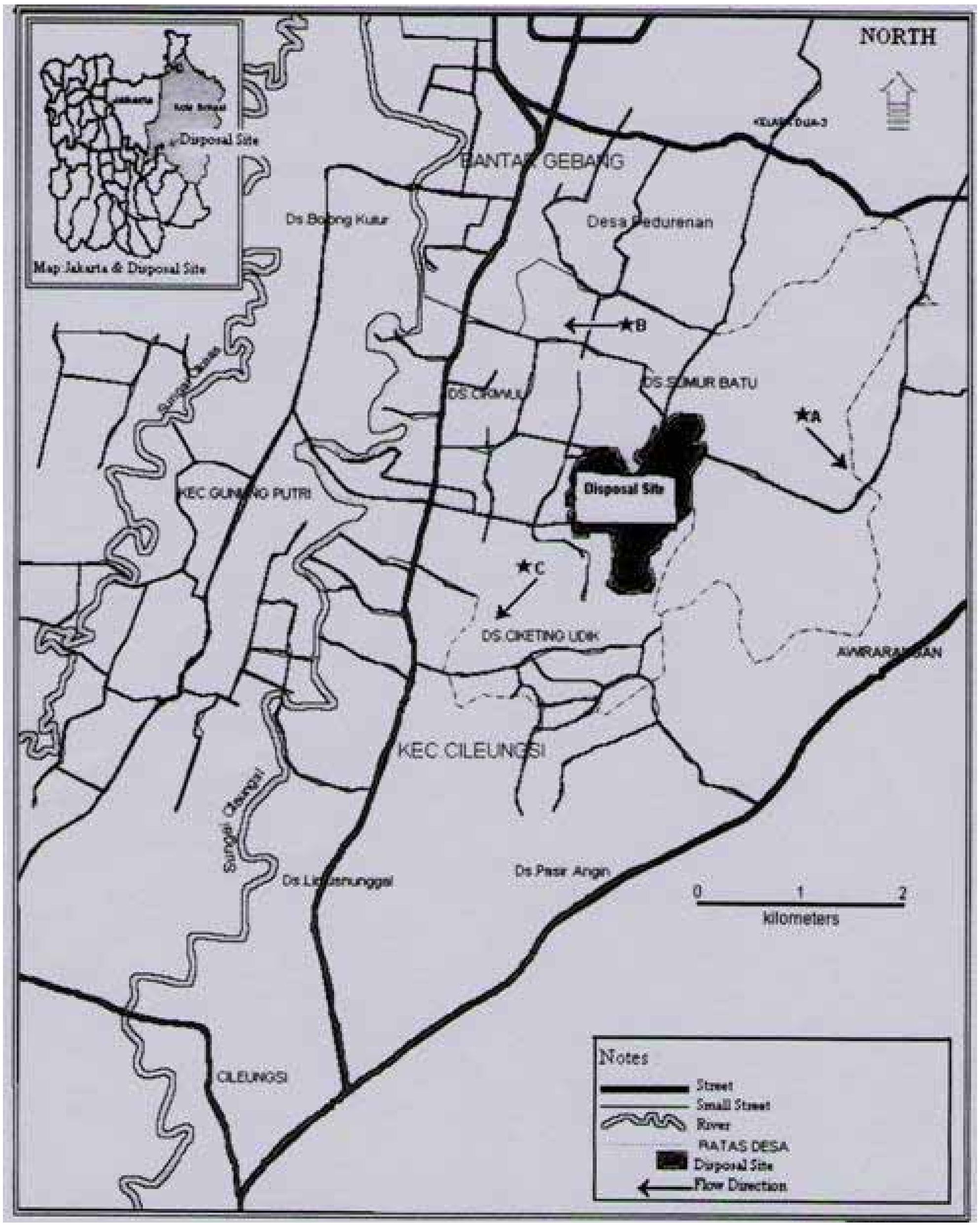

Figure 3b. Shallow groundwater flow directions at dry season (May, 2002)