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# Study of Interaction of Shallow Groundwater and River along the Cisadane and Ciliwung River of Jakarta Basin and Its Management using Environmental Isotopes

# Penelitian Interaksi Airtanah Dangkal dengan Air Sungai Sepanjang Sungai Cisadane dan Ciliwung di Wilayah Jakarta dan Pengelolaannya Menggunakan Isotop Alam

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## ABSTRACT

**Study of Interaction of Shallow Groundwater and River along the Cisadane and Ciliwung River of Jakarta Basin and Its Management using Environmental Isotopes**. The environmental isotopes were employed to study the interaction of shallow groundwater and river along the Cisadane River and Ciliwung River in Jakarta basin. The rapid growth and development of Jakarta and its surrounding cities, coupled with increasing industrial and other business sectors have impacted on the demand of the water supply for the area. These investigations have been conducted to determine the interaction between shallow groundwater and the river. The $^{14}C$ results showed that the groundwater samples (above 40 m) which were close to the river influenced the iso-age contour of $^{14}C$, which indicated the contributions of river water. The analysis of stable isotopes $^{18}O$ and Deuterium from the river implied that the river water from upstream to downstream was influenced by the mixing of the river water with the human activities in the upstream (the isotopic compositions becoming enriched). Further, the $^{18}O$ and Deuterium data revealed that rivers of Cisadane and Ciliwung are contributing to recharge the shallow groundwater in Jakarta, especially in the nearby river bank. In general, the quality of the shallow groundwater along the rivers is good and is suitable as fresh water resource. Due to pollution and declining water table problems in the Jakarta basin, the artificial recharge wells is shown to be a good way out to delineate the problems as indicated by pilot project conducted at Kelurahan Kramat Jati, using infiltration basin method.

**Keywords :** isotope, shallow groundwater, interaction, river, quality, groundwater management

## ABSTRAK

**Penelitian Interaksi Airtanah Dangkal dengan Air Sungai Sepanjang Sungai Cisadane dan Ciliwung di Wilayah Jakarta dan Pengelolaannya Menggunakan Isotop Alam**. Isotop alam telah digunakan untuk mempelajari interaksi antara airtanah dangkal dengan air sungai sepanjang Sungai Cisadane dan Ciliwung di wilayah Jakarta. Pertumbuhan pembangunan, industri, sektor perdagangan yang relatif cepat di wilayah Jakarta dan sekitarnya telah mangakibatkan permintaan air yang terus meningkat. Penelitian ini bertujuan untuk menentukan interaksi antara airtanah dangkal dengan air sungai di wilayah Jakarta khususnya sepanjang Sungai Cisadane dan Ciliwung. Hasil analisis isotop $^{14}C$ dari contoh-contoh airtanah (di atas 40 m) yang dikumpulkan menunjukkan bahwa kontur *iso-age* $^{14}C$ dari airtanah sepanjang sungai telah mengalami distorsi akibat pengaruh air sungai. Hasil analisis dari isotop stabil $^{18}O$ dan D dari contoh air sungai menyiratkan bahwa percampuran antara airtanah dangkal dengan air sungai telah terjadi dan tingkat percampuran ini sangat dipengaruhi oleh aktifitas manusia di sekitarnya. Lebih jauh, hasil analisis $^{18}O$ dan D menunjukkan bahwa Sungai Cisadane dan Ciliwung mempunyai kontribusi yang sangat

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berarti untuk mengimbuh airtanah dangkal Jakarta, khususnya sepanjang sungai. Namun demikian, pada umumnya, kualitas airtanah dangkal masih baik untuk digunakan sebagai sumber air untuk pemenuhan kebutuhan penduduk. Akan tetapi akibat peningkatan permintaan air, permukaan air tanah telah mengalami penurunan yang tajam dan tercemar. Untuk itu, pengimbuhan buatan sangat diharapkan untuk menghindari penurunan muka air dan peningkatan pencemaran yang berkelanjutan. Pengimbuhan buatan telah memperlihatkan hasil yang sangat menjanjikan seperti yang telah ditunjukkan proyek percontohan pengimbuhan buatan di daerah Kelurahan Kramat Jati.

**Kata kunci :** isotop, airtanah dangkal, interaksi, sungai, kualitas, pengelolaan airtanah

## INTRODUCTION

Metropolitan of Jakarta and its vicinity, known as JABODETABEK (Jakarta, Bogor, Depok, Tangerang, and Bekasi), in the past quarter of the century has been growing and developing rapidly, particularly in the activities of the industrial and other business sectors. As a consequence to this development, followed by increasing population, the need for good water quality increases many folds [1]. Since the provision of water from the purification process of surface water is not enough to fulfill the overall demand, the alternative way is to withdraw water from the aquifer. Water for domestic use is pumped from the shallow groundwater, and water for industrial need is pumped from the deeper groundwater. The growth rate of the population is 3.6 %, or about twice the average of national population growth due to the urbanization. Presently, the total population is around 12 million, and living in an administrative area of about 3000 square kilometers. The highly dense population in the region exceeds the capacity for this region to support normal livelihood. The administrative regions around Jakarta, namely Bekasi, Tangerang, Depok and Bogor have to bear and furnish the excessive load of Jakarta. Over exploitation of groundwater in the basin has led to many deleterious effects including lowering of the piezometric heads, land subsidence and degradation of water quality due to the movement of surface water to groundwater or polluted water to the groundwater.

Based on the investigation of the groundwater conservation the piezometric heads has dropped very sharply to the north of Jakarta [2]. The water level in the area dropped to –40 m until – 53 m below sea level for the aquifer 40-140 meters deep. Many problems related to groundwater environment emerged in the north of Jakarta. The decline of Jakarta groundwater piezometric resulted in land subsidence in the north of Jakarta, estimated to have been >70 cm in 1997 [3].

The decrease of groundwater piezometric in many area of Jakarta was caused by over exploitation of groundwater due to the development of the city. Investigation has been done by Department of Public work to avoid continuous decreasing of piezometric and water level. A pilot study of artificial recharge using infiltration basin has been conducted by Department of Public Work in Kramat Jati district, East Jakarta and its impact on groundwater piezometric in the local aquifers has been carried out [4].

According to previous study, the shallow groundwater in Jakarta area is fed by local recharge [5]. Considering these phenomena there is a possibility that river water in Jakarta also contribute to recharge the shallow groundwater, especially in the nearby bank of the river. A study on the shallow groundwater dynamic of a sanitary landfill in Bantar Gebang, Bekasi, located at the eastern part of Jakarta, was conducted in 2001/2002 in which it explained that the movement of the groundwater flow in Bekasi was from the south to the north of Bekasi [2]. There are a number of conventional methods available to study the hydrological processes, but Environmental Isotopes methods have been proved to be an

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effective tool for solving many critical hydrological problems in many cases, provide information that could not be obtained by any other means [6,7]. Carbon-14 ($^{14}C$) is one of the most routinely applied dating tool pre-modern (pre-1950) groundwater and has been used in numerous studies to characterize flow in regional aquifer in combination with stable isotopes ($\delta^{18}O$, and $\delta^{2}D$) as environmental isotopes methods will explain the interaction between surface water and groundwater system [8].

There are three main rivers flowing in this area; namely Cisadane River in the west, Bekasi River in the east, and the Ciliwung River that flows through the center of Jakarta. In addition to these three main rivers there are several smaller rivers flowing in between. There are a number of small rivers and streams that flow north, aiding in return flow and drainage. The origin of the river from the hill at the southern part will flow northward through the agricultural areas. The annual mean of rainfall varies from a low of 1700 mm in Jakarta coastal plain to a high of 4200 mm in the Bogor hilly region. Approaching Jakarta, the potential for pollutant to contaminate the river increases because the rivers flow through residential areas, business areas and industrial areas, where the drainage and sanitary infrastructures are becoming worse. The organic matters are the main sources of domestic pollution in the Ciliwung River, besides pesticides and heavy metals from industries [9].

The objective of the studies is to identify the interaction between shallow groundwater and rivers, and to define the appropriate groundwater management in the area of investigation.

## METHODOLOGY

Hydrology Isotopes techniques in conjunction with hydrochemistry analysis and hydrogeological information were employed to understand groundwater pollution as an impact of industrial, domestic and agricultural waste in Jakarta and its vicinity. The groundwater samples for $^{14}C$ analysis were collected from Jakarta and its vicinity that could show the direction of groundwater movement in the catchment area which is known as JABODETABEK. The samples for river and shallow groundwater interaction were collected for hydrochemistry analysis (major ion & $NO_3^-$) and stable isotopes $\delta D$ & $\delta^{18}O$, which will explain about the interactions between water bodies and the quality of groundwater. Hydrochemistry analysis for major elements has been analyzed in the Hydrology Laboratory at the Center for the Application of Isotopes and Radiation Technology, National Nuclear Energy Agency, Jakarta.

Analysis of $^{14}C$ is performed by converting $BaCO_3$ into $C_6H_6$ in a benzene synthesis unit by the following chemical reactions:

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

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

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

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

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

The radioactivity of $^{14}C$ in benzene compound was measured by liquid scintillation. Thus, the observed $^{14}C$ distribution in the studied area was expressed in percent modern carbon, i.e. the carbon content in 1 g modern carbon of 1950 (13.56 ± 0,06 dpm) with oxalic acid standard RM49. The age groundwater was evaluated by using formula [8]:

$$t = 8267 \ln\left(C_o / C\right) \quad (1)$$

$C$ = *the value of* % modern carbon of the sample

$C_o$ = the initial $^{14}C$ content

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The age calculated from the values of $^{14}C$ needs to be adjusted by the correction of $C_o$, using the following formula :

$$C_0 = \left[\frac{100(\delta - \delta_c)}{\delta_G - \delta_c - \varepsilon}\right]\left[\frac{2\varepsilon}{1000}\right], \qquad (2)$$

where $\delta$, $\delta_C$, and $\delta_G$ are the $^{13}C$ content of carbonate species dissolved in sample, aquifer carbonate, and soil $CO_2$ at the time of recharge, respectively, and ε is the fractionation factor between bicarbonate and soil $CO_2$. The adopted values for the calculation were $\delta_c = 0$, $\delta_G = -25 \pm 1$ ‰ , ε = 8 ± 0.5 ‰

## RESULTS AND DISCUSSION

In this study, the samples have been collected from 36 locations for $^{14}C$ analysis. The corrected age of groundwater was calculated based on $^{14}C$ percent modern carbon (PMC). The sampling point location together with the iso-contour of groundwater age is given in Figure 1. From this figure, it can be seen that the groundwater movement is from south to the north. Table 1 shows selected data for $^{14}C$ (PMC) and corrected groundwater age for selected sampling points. From Table 1, it can also be seen that the ages were varying from modern to about 35000 years old distributed throughout the investigation area.

The results of analysis showed that there is no relationship between age and the depth of the aquifer. It can be estimated that actual groundwater velocity by using $^{14}C$ data was about 1 m/year. From the results, it can also be verified that the recharge area of groundwater for Jakarta basin is at the south of Jakarta, namely Parung, and Depok as also indicated by previous studies [5, 10].

Hydro-chemical and stable isotopic investigations were conducted in May 2003 until August 2004 and samples were taken from various locations in the rivers and groundwater in the study areas of Jakarta basin as shown in Figure 1. The results can be seen in Tables 1, 2, and 3 as well as in Figure 1. Table 2 shows the stable isotopes composition of water samples in the studied area which have been taken from Ciliwung River, Cisadane River and shallow groundwater at the vicinity of Cisadane River. Figure 2a indicated that the shallow groundwater samples (Tg) along the river seemed to be contributed by Cisadane River. They are grouped together closely between Jakarta Local Meteoric Water Line ($\delta D = 8.28\ \delta^{18}O + 15$) and Cisadane River line ($\delta D = 3.59\ \delta^{18}O - 25.3$). The same trend is also observed at Figure 2b, in which shallow groundwater surrounding the river (SB) were also fed by Ciliwung river. It is also observed that the stable isotope composition

**Table 1**. Results of $^{14}C$ (PMC) and corrected age for Jakarta groundwater and vicinity

| No. | Code | Location | Depth (m) | $\delta^{13}C$ | % Modern Carbon (PMC) | Corrected Age (years) |
|---|---|---|---|---|---|---|
| 1 | JUT-16 | PT. Kian Hin | 83 | -12.30 | 6.0±1.11 | 21935±1520 |
| 2 | JUT-18 | PT. Tancho Ind | 117 | -13.00 | 1.3±0.71 | 34720±4550 |
| 3 | JUT-19 | PT. Diamond | 128 | -12.50 | 1.8±0.87 | 32070± 4060 |
| 4 | JTT-14 | PT. Wonderful | 75 | -14.90 | 71.1±1.27 | 1600±200 |
| 5 | JTT-15 | PT. Essence | 60 | -14.00 | 21.9±1.47 | 11320±560 |
| 6 | JTT-16 | PT. Susu Bendera | 55 | -14.00 | 80.0±1.60 | 610±200 |
| 7 | JST-17 | Lemigas | 118 | -13.80 | 5.8±0.81 | 22250±160 |
| 8 | BgT-22 | PT. YKK Zipper | 69 | -15.00 | 75.71±1.77 | 1055± 195 |
| 10 | TgT-12 | PT. Yuasa Bat. | 60 | -14.00 | 21.61±1.29 | 11410±500 |
| 11 | TgT-13 | Puri Beta Real Estat | 130 | -14.00 | 18..21±1.42 | 12860±650 |

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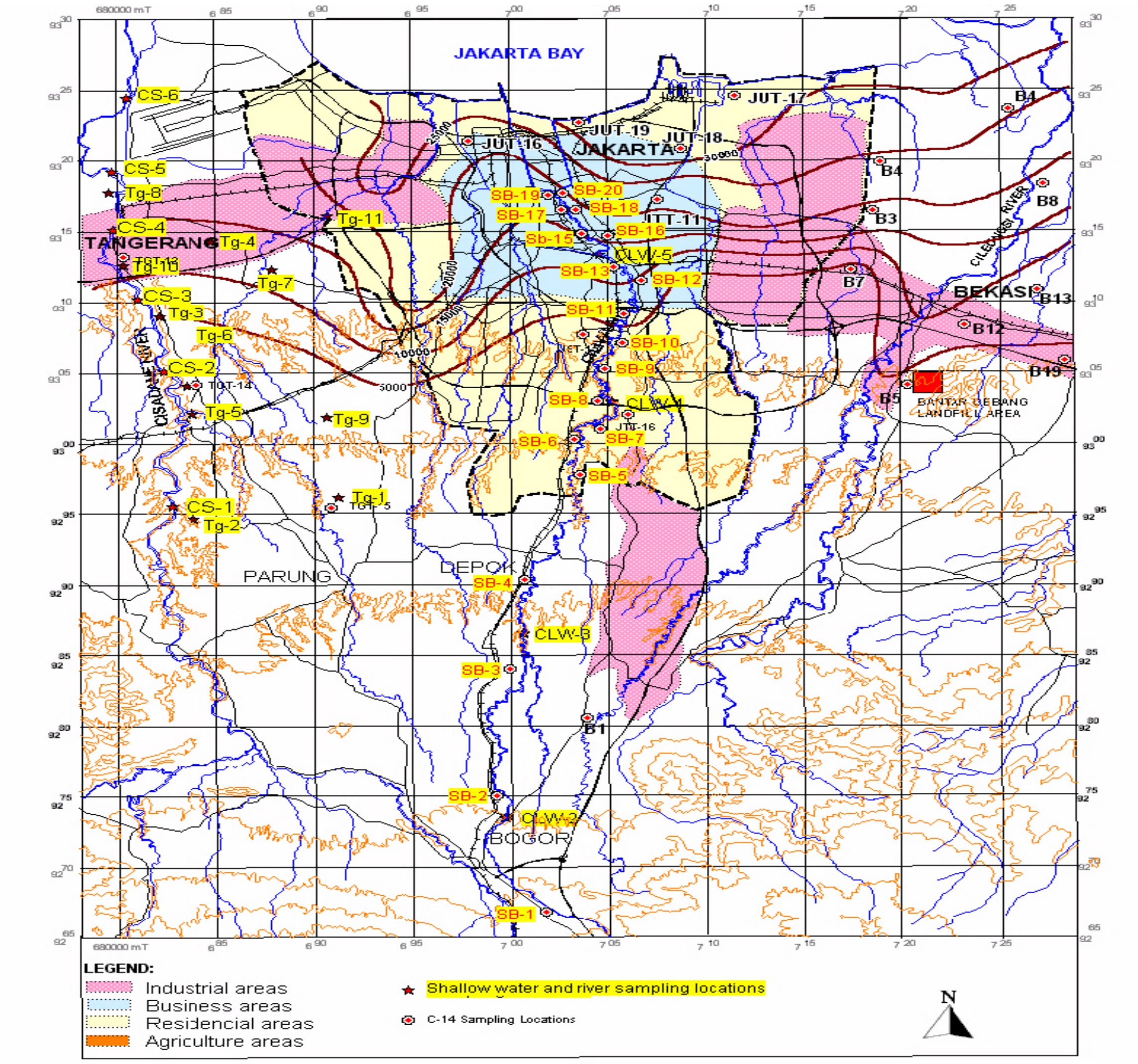


**Figure 1**. Sampling location and iso-ages lines of Jakarta basin

of shallow groundwater samples is more enrich toward downstream. This phenomenon is an indication that the shallow groundwater at the vicinity of the river receives replenishment along its path toward downstream.

Investigation of hydrochemical composition (Table 3) of sample water from shallow groundwater and river water can be explained that the quality of shallow groundwater is in the range of fresh water in term of total dissolved solids (TDS), except for the sample Tg-15 and SB-19 with TDS > 1000 mg/L (brackish water). From the results of nitrate, $NO_3^-$ of shallow groundwater around the Ciliwung River it can be considered that there is contamination from the interaction of the unconfined aquifer and the river. The nitrate concentrations were still under the maximum permissible concentration.

Over exploitation of groundwater resources has caused water table or piezometric head decline and pollution in Jakarta basin. Therefore, for Jakarta basin groundwater management, artificial groundwater recharge wells need to be considered through infiltration basin. Pilot project about infiltration basin has been conducted to alleviate shallow groundwater problem at Kramat Jati district, east Jakarta [4].

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**Table 2.** The Results of O18 and D analysis of Jakarta shallow groundwater along the Ciliwung river

| No. | Code | Location | Depth (m) | $\delta O^{18}$ (°/oo) | $\delta D$ (°/oo) |
|---|---|---|---|---|---|
| 1 | SB-1 | Katulampa | 6 | -5.86 | -36.8 |
| 2 | SB-2 | Kd Badak | 5 | -5.11 | -35.2 |
| 3 | SB-3 | Bj Depok Baru | 15 | -5.16 | -33.2 |
| 4 | SB-4 | Ratu Jaya Depok | 30 | -5.29 | -39.2 |
| 5 | SB-5 | Depok | 15 | -5.82 | -30.4 |
| 6 | SB-6 | Lenteng Agung | 28 | -6.28 | -43.4 |
| 7 | SB-7 | Cililitan | 20 | -5.94 | -24.5 |
| 8 | SB-8 | Psr Rebo | 15 | -7.36 | -31.0 |
| 9 | SB-10 | Psr Minggu | 25 | -4.36 | -28.5 |
| 10 | SB-11 | Kalibata | 20 | -4.81 | -28.0 |
| 11 | SB-12 | Otista | 30 | -7.93 | -28.9 |
| 12 | SB-13 | Manggarai | 12 | -5.51 | -33.6 |
| 13 | SB-14 | Slamet Riyadi | 12 | -3.98 | -27.5 |
| 14 | SB-15 | Cikini | 7 | -4.95 | -24.7 |
| 15 | SB-16 | Diponegoro | 15 | -7.66 | -39.5 |
| 16 | SB-17 | Kwitang | 30 | -6.05 | -37.1 |
| 17 | SB-18 | Tugu Tani | 100 | -3.87 | -27.1 |
| 18 | SB-19 | Kartini | 10 | -5.16 | -37.1 |
| 19 | SB-20 | Gn Sahari | 9 | -7.86 | -42.3 |
| 20 | CLW-1 | Ciliwung (upstream) | River | -7.83 | -53.0 |
| 21 | CLW-2 | Ciliwung | River | -7.21 | -52.0 |
| 22 | CLW-3 | Ciliwung | River | -6.73 | -48.5 |
| 23 | CLW-4 | Ciliwung | River | -5.19 | -40.4 |
| 24 | CLW-5 | Ciliwung (downstream) | River | -5.37 | -41.5 |
| 25 | CS-1 | Cisadane (upstream) | River | -5.72 | -48.1 |
| 26 | CS -2 | Cisadane | River | -5.66 | -48.0 |
| 27 | CS -3 | Cisadane | River | -5.64 | -43.0 |
| 28 | CS -4 | Cisadane | River | -5.65 | -47.9 |
| 29 | CS -5 | Cisadane | River | -5.65 | -42.0 |
| 30 | CS -6 | Cisadane (downstream) | River | -5.87 | -45.4 |
| 31 | Tg-1 | Along Cisadane | Shallow GW | -6.37 | -44.6 |
| 32 | Tg-2 | Along Cisadane | Shallow GW | -5.74 | -35.8 |
| 33 | Tg-5 | Along Cisadane | Shallow GW | -6.82 | -42.1 |
| 34 | Tg-7 | Along Cisadane | Shallow GW | -6.66 | -36.4 |
| 35 | Tg-8 | Along Cisadane | Shallow GW | -5.96 | -41.3 |
| 36 | Tg-10 | Along Cisadane | Shallow GW | -7.11 | -39.8 |
| 37 | Tg-14 | Along Cisadane | Shallow GW | -6.54 | -38.5 |
| 38 | Tg-15 | Along Cisadane | Shallow GW | -5.93 | -36.5 |
| 39 | Tg-16 | Along Cisadane | Shallow GW | -5.97 | -41.9 |

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**Table 3**. Chemical compositions of Cisadane, and Ciliwung rivers together with shallow groundwater samples

| No. | Code | Anions (mg/L) | | | | Cations (mg/L) | | | | TDS (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Cisadane River and surrounding groundwater** | | | | | | | | |
| | | $NO_3^-$ | $Cl^-$ | $SO_4^{2-}$ | $HCO_3^-$ | Na | K | Mg | Ca | |
| 1 | CS1 | 0.11 | 2.04 | 10.34 | 23.06 | 3.42 | 1.42 | 1.98 | 0.45 | 42.8 |
| 2 | CS-2 | 0 | 2.83 | 11.70 | 21.08 | 3.42 | 1.50 | 1.93 | 0.40 | 42.8 |
| 3 | CS-3 | 0 | 2.60 | 11.70 | 21.08 | 3.51 | 1.50 | 1.92 | 0.40 | 42.86 |
| 4 | CS-4 | 0.02 | 2.09 | 13.43 | 9.22 | 3.07 | 1.34 | 1.82 | 0.40 | 42.71 |
| 5 | CS-5 | 0.11 | 1.60 | 13.43 | 16.47 | 3.07 | 1.33 | 1.79 | 0.35 | 31.37 |
| 6 | CS-6 | 0 | 3.44 | 9.38 | 27.01 | 4.56 | 1.51 | 2.11 | 0.45 | 38.04 |
| 7 | Tg-1 | 2.95 | 10.20 | 3.83 | 0.00 | 4.83 | 0.10 | 2.17 | 1.48 | 48.46 |
| 8 | Tg-2 | 1.45 | 10.69 | 14.59 | 33.60 | 2.28 | 1.38 | 4.55 | 0.82 | 22.61 |
| 9 | Tg-3 | 2.42 | 27.60 | 28.78 | 114.63 | 6.28 | 10.68 | 11.77 | 3.69 | 67.91 |
| 10 | Tg-4 | 2.67 | 25.11 | 2.50 | 7.250 | 3.65 | 0.48 | 6.21 | 5.89 | 203.43 |
| 11 | Tg-5 | 1.22 | 18.91 | 1.50 | 3.29 | 8.84 | 0.16 | 16.34 | 1.21 | 51.09 |
| 12 | Tg-6 | 0.27 | 5.94 | 23.42 | 90.91 | 7.32 | 1.23 | 8.36 | 0.44 | 50.25 |
| 13 | Tg-7 | 2.43 | 27.74 | 3.00 | 108.70 | 11.13 | 2.15 | 10.13 | 0.93 | 137.62 |
| 14 | Tg-8 | 1.07 | 29.47 | 19.09 | 176.56 | 24.43 | 3.20 | 12.34 | 1.26 | 163.78 |
| 15 | Tg-9 | 0.20 | 10.26 | 3.83 | 117.27 | 8.42 | 1.97 | 9.64 | 0.40 | 266.35 |
| 16 | Tg-10 | 0.08 | 3.02 | 10.57 | 220.70 | 27.60 | 7.90 | 14.55 | 0.35 | 151.79 |
| 17 | Tg-11 | 0.02 | 4.49 | 8.37 | 428.88 | 147.06 | 9.19 | 5.66 | 0.20 | 284.69 |
| 18 | Tg-12 | 0.11 | 15.99 | 37.50 | 222.02 | 91.40 | 6.25 | 4.94 | 0.0 | 603.85 |
| 19 | Tg-13 | 0.38 | 26.96 | 49.11 | 173.92 | 28.23 | 7.30 | 37.56 | 1.54 | 378.1 |
| 20 | Tg-14 | 0.05 | 177.93 | 250.70 | 650.89 | 301.42 | 26.60 | 25.14 | 1.42 | 324.62 |
| 21 | Tg-15 | 0.28 | 93.65 | 38.99 | 285.26 | 37.10 | 47.34 | 44.42 | 3.14 | 1434.1 |
| 22 | Tg-16 | 0.16 | 28.37 | 129.26 | 150.87 | 55.97 | 7.42 | 29.76 | 0.27 | 549.9 |
| | | **Ciliwung River and surrounding groundwater** | | | | | | | | |
| 23 | Clw1 | 0 | 1.08 | 10.00 | 28.33 | 34.95 | 0.26 | 1.75 | 1.51 | 77.9 |
| 24 | Clw-2 | 0.25 | 1.58 | 6.73 | 41.50 | 3.20 | 1.62 | 3.01 | 0.70 | 58.0 |
| 25 | Clw-3 | 0.34 | 1.70 | 7.50 | 44.80 | 7.97 | 1.90 | 3.08 | 0.70 | 68.3 |
| 26 | Clw-4 | 0.06 | 1.15 | 7.50 | 30.30 | 5.06 | 1.76 | 2.04 | 1.44 | 49.3 |
| 27 | Clw-5 | 0.08 | 1.65 | 10.34 | 43.48 | 7.52 | 2.67 | 2.64 | 3.73 | 72.1 |
| 28 | SB-1 | 0.69 | 8.13 | 7.04 | 54.96 | 1.86 | 1.42 | 7.36 | 13.55 | 95.01 |
| 39 | SB-2 | 0.41 | 14.82 | 15.42 | 139.02 | 22.93 | 2.35 | 17.47 | 27.71 | 240.13 |
| 30 | SB-3 | 6.87 | 14.58 | 7.04 | 54.96 | 4.36 | 0.97 | 10.73 | 20.94 | 120.58 |
| 31 | SB-4 | 2.86 | 15.65 | 0 | 12.93 | 8.86 | 0.28 | 2.73 | 9.24 | 51.65 |
| 32 | SB-5 | 0.48 | 2.40 | 0 | 187.51 | 28.93 | 3.98 | 9.14 | 25.86 | 258.30 |
| 33 | SB-6 | 13.50 | 38.17 | 0 | 80.83 | 7.44 | 1.90 | 16.74 | 46.80 | 205.28 |
| 34 | SB-7 | 3.95 | 24.28 | 5.49 | 67.89 | 16.32 | 2.18 | 5.71 | 24.63 | 150.45 |
| 35 | SB-8 | 7.12 | 39.04 | 25.43 | 210.15 | 29.82 | 5.49 | 21.57 | 64.04 | 402.66 |
| 36 | SB-9 | 5.22 | 45.39 | 3.57 | 73.36 | 16.97 | 1.84 | 19.92 | 49.88 | 216.05 |
| 37 | SB-10 | 0.98 | 15.94 | 2.84 | 155.18 | 17.66 | 2.18 | 8.02 | 49.88 | 252.68 |
| 38 | SB-11 | 0.26 | 30.37 | 126.59 | 226.31 | 39.93 | 4.34 | 14.01 | 83.13 | 524.94 |
| 39 | SB-12 | 2.58 | 42.06 | 27.14 | 113.16 | 35.74 | 4.00 | 10.93 | 46.80 | 282.41 |
| 40 | SB-13 | 0.28 | 22.29 | 4.93 | 248.94 | 35.09 | 2.84 | 14.48 | 22.17 | 351.02 |
| 41 | SB-14 | 0.55 | 34.50 | 26.16 | 216.61 | 15.60 | 2.48 | 32.60 | 34.48 | 362.98 |
| 42 | SB-15 | 0.35 | 22.56 | 92.14 | 48.49 | 31.20 | 3.61 | 14.83 | 33.87 | 247.05 |
| 43 | SB-16 | 0.31 | 277.22 | 25.71 | 287.74 | 60.12 | 3.48 | 48.33 | 68.97 | 771.88 |
| 44 | SB-17 | 4.02 | 42.35 | 26.62 | 235.01 | 29.55 | 3.86 | 22.43 | 52.34 | 416.18 |
| 45 | SB-18 | 0.71 | 25.43 | 21.56 | 164.88 | 26.83 | 3.52 | 17.47 | 38.79 | 298.19 |
| 46 | SB-19 | 0 | 321.06 | 106.83 | 475.25 | 410.55 | 4.67 | 8.42 | 6.77 | 1333.45 |

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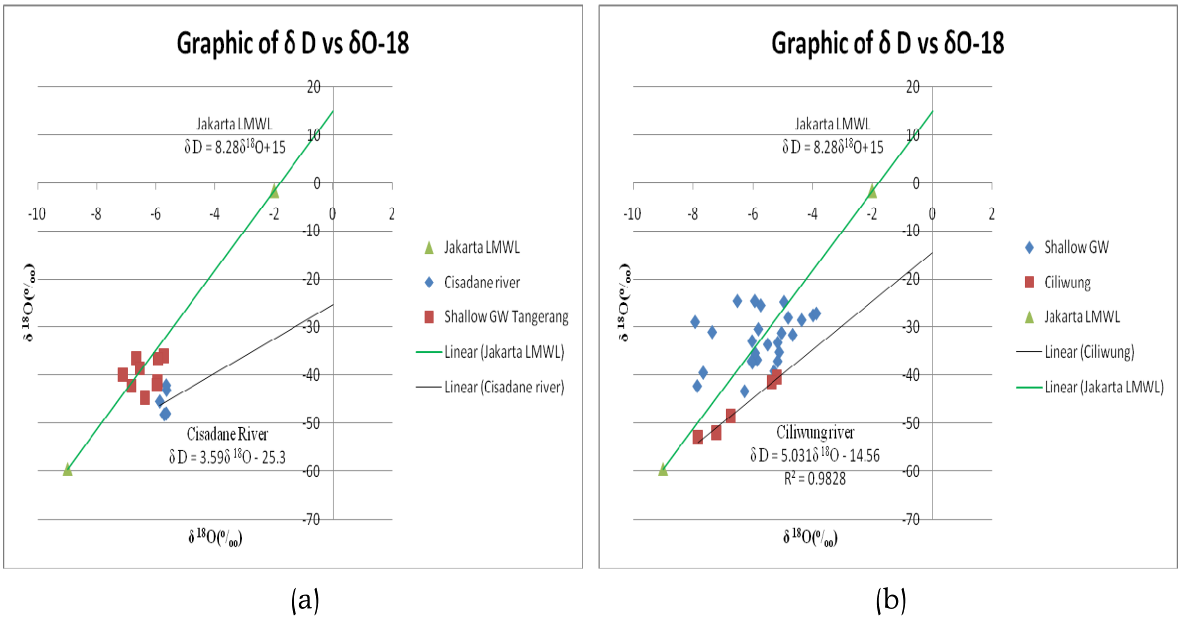


**Figure 2**. Relationship of δ D vs δO-18 of Cisadane and Ciliwung Rivers and shallow groundwater the vicinity

## CONCLUSIONS

From the results obtained the following conclusions are derived:

1. The direction of the groundwater flow for Jakarta basin from the south to the north which was indicated by iso-age line using radiocarbon dating.
2. The location of Bantar Gebang, Bekasi Landfill was unsuitable for domestic waste disposal because it is at the pathway of groundwater.
3. From the results of δ $^{18}$O and δ D compositions for Ciliwung river, it can be observed that the mixing of Ciliwung River become more and more increased by domestic, agricultural and industrial waste inflow to the river that flows form the south to the north.
4. From the hydrochemistry results the shallow groundwater along the river of Jakarta basin indicated to be good quality and from δ $^{18}$O and δ D data interpretation there occur interaction between shallow groundwater and the river (Ciliwung and Cisadane Rivers).
5. For management of shallow groundwater of Jakarta basin can be applied the infiltration basin method and for groundwater of Jakarta basin can be attempted recharge tube wells method.

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