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# The interrelationship between ISTN lake, Babakan lake and the surrounding wells of shallow groundwater using stable isotopes δ $^2$H and δ $^{18}$O for the lake bank filtration potential

*W.* Marsiano[1], *S.* Syafalni[1,*], *Wawan* Kuswaya[1], *M. Falaqi* Djamhuri[1], and *BungKus* Pratikno[2]

[1]Department of Civil Engineering, Institut Sains dan Teknologi Nasional, Jakarta, Indonesia
[2]Hydrology Section, National Nuclear Energy Agency, Jakarta

**Abstract.** The investigation of the interrelationship between shallow groundwater and lake water is one of the important characteristics in groundwater basin research. An understanding of the location properties can be used for the lakebank fitration pontential evaluation. The objective of this research was to describe the interrelationship of shallow groundwater and the lake water from ISTN lake and Babakan lake. An effective tracer in groundwater basin research can use the environmental isotopes method for revealing the interrelationship between lake water and surrounding shallow groundwater. This research was conducted by taking samples of shallow groundwater from the surrounding wells around the ISTN and Babakan lakes. Based on isotopes δ $^2$H vs. δ $^{18}$O results, the shallow groundwater of the surrounding wells originated from the lake water. The results were verified with a student test distribution using 95% confidence level which showed that all samples were in one cluster. From the analysis of Total Dissolved Solids (TDS) of the samples locations, all of the samples were in range of fresh water but the pH of some samples was lower than the pH requirement for drinking water, so the pH should be improved before consumption.

## 1 Introduction

The development of a city will increase its population, resulting in an increased need for the availability and supply of good quality water for society, industry and agriculture. To date, several advanced processing technologies have been developed and implemented by drinking water companies to treat water. Such methods include adsorption, ion exchange, membrane filtration, groundwater treatment, and advanced oxidation techniques. Despite the effectiveness of this technology, there is a broad challenge to its application in developing countries. This is mainly due to costs, especially for processing in large quantities. The costs incurred from treating water in large amounts will be very uneconomical. An alternative method of water treatment is necessary to meet the needs of the increasing demand for water

*Corresponding author: syafalni.s@istn.ac.id

consumption [1, 2]. Lakebank filtration (LBF) is an efficient and natural alternative technology for low-cost development of lake water/surface water and is an old method for obtaining drinking water by using sub-surface capacity near lakebanks as a natural filter in which lake water is taken through a pump [3, 4]. During infiltration through the soil layer, surface water is exposed to a combination of physical, chemical, and biological processes such as filtration, dilution, adsorption, and biodegradation that can significantly improve the quality of raw water for water requirements in domestic, agricultural and industrial consumption [2, 5, 6].

To retain sustainability of water resources in the area, it is important investigate the interrelation between shallow groundwater in the surrounding area with lake water in order to describe the origin of shallow groundwater. The natural stable isotopes technique offers finger printing tools to provide information about the interrelation between lake water and the surrounding shallow groundwater. Water has "finger printing" of naturally occurring isotopes that can provide information about its origin [7]. In lake water infiltration, during evaporation (e.g. from lake surfaces), heavy isotopes get enriched in the remaining liquid phase. In such phase transformations $^{18}O$ gets more enriched than $^{2}H$. Therefore, the ratios of the $\delta^2H$- to the $\delta^{18}O$ values are shifted apart from the general relation given by $\delta^2H = 7.8\ \delta^{18}O + 13$ (so called local meteoric water line) [8]. The shift causes the $\delta^2H$ to the $\delta^{18}O$ ratio values to plot along a line with lower slope (so called evaporation line) and due to physical, chemical and biological processes, the isotope ratios can be changed (isotope effects).

For a better understanding of the lakebank filtration process in the shallow groundwater system, research was conducted around the ISTN and Babakan lake basins, with random sampling techniques for stable isotopes ($\delta^{18}O$ and $\delta^2H$) analysis in conjunction with pH and TDS evaluations which can explain the interrelationship between the lake water and the shallow groundwater around the lakes. The purpose of this research is to study the lakebank filtration potential of shallow groundwater as a sustainable drinking water resource for urban and rural areas. The research locations were at the ISTN and Babakan lake areas, located in the south of DKI Jakarta, Indonesia.

## 2 Materials and methods

The sampling was done on 29 December 2016 and 6 January 2017 in shallow groundwater from 10 locations of the area surounding the ISTN and Babakan lakes and 6 locations in the ISTN and Babakan lakes. Fig.1 shows the locations of sampling points in the study area. During sampling at the sites, the shallow groundwater quality parameter was also taken on the spot using pH and electric conductivity field probes. Shallow groundwater from 10 boreholes was sampled in the area surounding the ISTN and Babakan lakes for R1 until R10. For D1, D2, and D3 the samples were taken from the ISTN lake and for S1, S2, and S3 the samples were taken from the Babakan lake.

All the samples for stable isotopes were measured for $\delta^2H$, and $\delta^{18}O$ using Spektrometer Laser type LGR DLT-100 made by Los Gatos Research Inc. The stable isotopic composition of $\delta^{18}O$ and $\delta^2H$ is expressed as per mil deviation (δ ‰) of the ratio $^{18}O/^{16}O$ or $^2H/^1H$ with reference to the Standard Mean Ocean Water. δ‰ is computed in the equation below where R represents the ratio of $^{18}O/^{16}O$ or $^2H/^1H$. The analytical errors for $\delta^{18}O$ and $\delta^2H$ are ±0.1‰ and ±1.0‰, respectively.

$$\delta\ (^{o}/_{oo}) = \left(\frac{R_{sample} - R_{standard}}{R_{standard}}\right) x1{,}000 \quad (1)$$

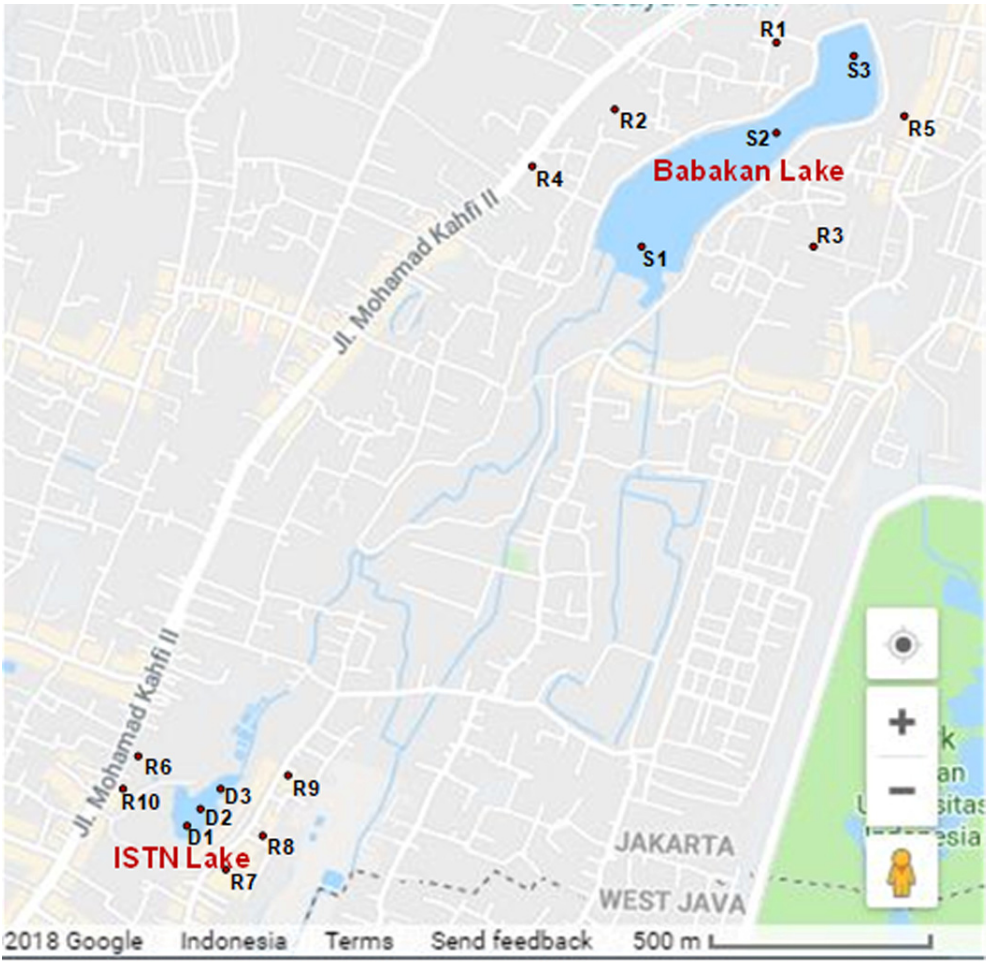


**Fig. 1.** Sampling locations for ISTN lake, Babakan lake and surrounding shallow groundwater.

The isotopic composition of groundwater is generally controlled by meteorological processes and is intended for the analysis of $\delta^{18}O$ and $\delta^{2}H$ in the groundwater system. According to Clark and Fritz [9], who explained the isotope exchange process by using a $\delta^{18}O$-$\delta^{2}H$ diagram, the result of $\delta^{18}O$ and $\delta^{2}H$ is a deviation from the meteroric water line along a line with lower slope, which depends on the relative humidity. There exists, however, some extreme geological environments where the reaction between groundwater and the aquifer matrix or subsurface gasses can modify the water's meteoric signature. Some typical processes are shown in Fig.2**,** which explains the water sample for certain locations in the study area will shift to a certain value depending on underground reaction.

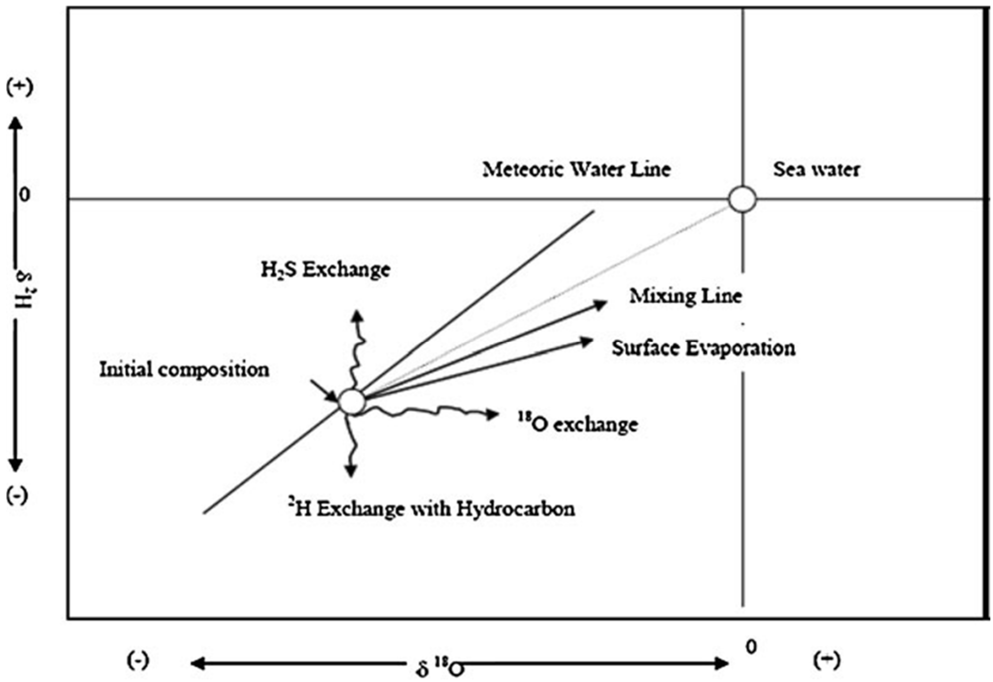


**Fig. 2.** Isotope exchange processes that modify the isotopic composition of meteoric water [8].

## 3 Results and discussion

Water sampling was collected from ISTN lake, Babakan lake and the shallow groundwater in the surrounding areas. From the determination of the water samples, the following results were obtained:

### 3.1 Sampling for ISTN lake, Babakan lake and shallow groundwater in the areas surrounding ISTN and Babakan lakes

At each point of the study area the sampling for pH, EC and TDS analysis was done for both lake water sample data and the surrounding shallow groundwater. Samples were taken at 6 points from ISTN and Babakan lakes and at 10 points from the surrounding shallow groundwater. The analysis results of these 16 points can be seen in Table 1. Electrical Conductivity (EC) is the measure of water's ability to conduct an electrical current and is closely related to the total dissolved solids (TDS) in the water, usually measured as µS/cm. The conductivity value of water increases with the increase in the amount of dissolved solids in the water. Both tests can be used to monitor the consistency of quality of the shallow groundwater as they indicate the total inorganic mineral content in the water. EC is proportional to TDS with the relation of TDS= 0.64 x EC, as proved in the findings from the research of hydrogeochemical quality of groundwater in Vedaraniyam Town, Tamil Nadu, India [10].

**Table 1.** Results of δ 18O and δ 2H & Water Quality Analysis for ISTN lake, Babakan lake and the shallow groundwater of the area surrounding ISTN and Babakan lakes.

| Sample Code | Sampling Time | pH | EC (μS/cm) | TDS (ppm) | δ $^{2}$H ‰ | δ$^{18}$O ‰ |
|---|---|---|---|---|---|---|
| D1 | 06-Jan-17 | 7.08 | 328 | 175 | -47.0±2.0 | -6.23±0.19 |
| D2 | 06-Jan-17 | 7.10 | 330 | 173 | -44.2±1.7 | -6.16±0.20 |
| D3 | 06-Jan-17 | 7.09 | 335 | 174 | -42.7±1.2 | -6.38±0.57 |
| S1 | 29-Des-16 | 7.08 | 337 | 175 | -36.6±0.8 | -5.56±0.17 |
| S2 | 29-Des-16 | 7.08 | 333 | 176 | -37.4±0.2 | -5.02±0.23 |
| S3 | 29-Des-16 | 7.08 | 334 | 177 | -39.8±2.7 | -4.32±0.24 |
| R1 | 29-Des-16 | 4.87 | 430 | 280 | -43.7±1.1 | -5.23±0.22 |
| R2 | 29-Des-16 | 4.76 | 210 | 137 | -40.4±0.5 | -5.42±0.18 |
| R3 | 29-Des-16 | 4.46 | 370 | 237 | -37.4±0.8 | -4.89±0.39 |
| R4 | 29-Des-16 | 5.48 | 120 | 78 | -43.6±1.6 | -5.73±0.33 |
| R5 | 29-Des-16 | 6.83 | 340 | 218 | -40.2±2.2 | -6.25±0.05 |
| R6 | 06-Jan-17 | 6.01 | 410 | 267 | -42.4±0.3 | -7.25±0.20 |
| R7 | 06-Jan-17 | 6.46 | 270 | 120 | -48.9±0.7 | -8.67±0.32 |
| R8 | 06-Jan-17 | 7.02 | 90 | 59 | -39.7±1.0 | -7.11±012 |
| R9 | 06-Jan-17 | 4.68 | 240 | 155 | -41.4±1.9 | -6.72±035 |
| R10 | 06-Jan-17 | 4.74 | 200 | 128 | -45.5±1.9 | -7.18±030 |

Based on the conductivity analysis (TDS value), it was observed that the quality of lake water and shallow groundwater was in the range of fresh water, with TDS values between 59 and 280 ppm.

The pH parameter for shallow groundwater surrounding the lakes was less than the water quality standard (pH 6.5-8.5) except for samples R5 and R8 which have pH 6.83 and 7.02 respectively.

### 3.2 Interrelationship between the surrounding shallow groundwater and Lakes water by using stable isotopes

Using the data in Table 1, Fig.3 shows the plotting Graph $\delta^2$H to $\delta^{18}$O. From Fig.3, it can be seen that the plotting of data is in the area along the Local Mean Water Line, LMWL ($\delta^2H = 7.8\ \delta^{18}O + 13$) that was obtained from pervious research by Satrio et al.(8). That is, the shallow groundwater and lake water comes from one common source. Regarding the data plot results of ISTN and Babakan lakes and the shallow groundwater samples, the value of δ obtained still shows a varied value, so the value of each sampling point of lake water needs to be averaged to see whether or not there is interconnection between the lake water and the surrounding shallow ground water [11]. This shows that the overall data is contained in one cluster or in the same origin. All shallow groundwater and lake water samples are distributed along the line of $\delta^2H = 2.016\delta^{18}O - 29.57$, which indicates surface evaporation and other processes occurred. Furthermore, after a statistical analysis using $t_{student}$ test approach with 95% confidence level, the upper and lower limits of $\delta^2H = 2.016\delta^{18}O - 21.4$ and $\delta^2H = 2.016\delta^{18}O - 37.72$ were obtained (as shown in Fig.3). It can also be seen that the data plot is in the area along the linear regression line samples taken around ISTN lake and Babakan lake. That is, the groundwater and lake water come from one common source. In the data plot of ISTN lake, Babakan lake water and the surrounding area shallow groundwater samples, the δ values obtained are within the upper and lower limits that explains the relationship between lake water and the surrounding shallow groundwater.

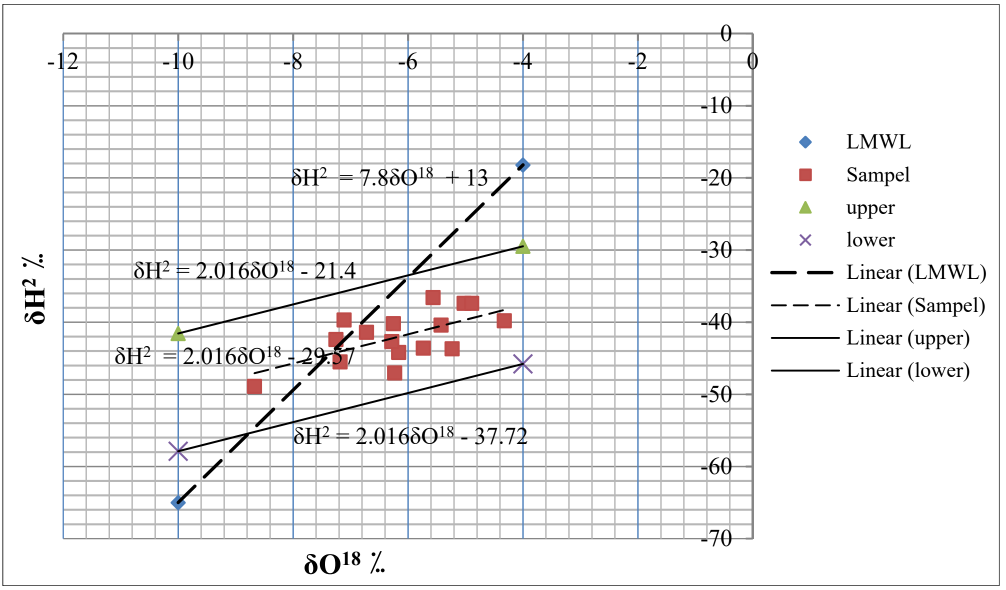


**Fig. 3.** Correlation $\delta^2H$ and $\delta^{18}O$ from water samples of ISTN lake, Babakan lake and the area surrounding ISTN lake and Babakan lake.

## 4 Conclusions

The stable isotopes $\delta^2H$ and $\delta^{18}O$ show a favorable relationship between the water of the lakes and the water from the wells of the residents surrounding the lake. This clearly shows that the well water (shallow groundwater) of the area surrounding the ISTN and Babakan lakes is from the two lakes, and so should be protected from environmental pollution. Inwater quality analysis indicated by total dissolved solid, which have in range of “fresh” water and “very good for drinking” water criteria and based on pH evaluation from some samples, the well water needs to be improved by doing advanced processing before consumption.

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