Study of Susceptibility of Pari Island Groundwater – To
Surface Water Using Natural Isotopes and Hydrochemicals
(E. Ristin Pujiindiyati, etc.)

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Study of Susceptibility of Pari Island Groundwater – To Surface Water Using Natural Isotopes and Hydrochemicals

Studi Kerentanan Air Tanah Pulau Pari - untuk Permukaan Air Menggunakan Isotop Alam dan Hidrokimia

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ABSTRACT

Study of Susceptibility of Pari Island Groundwater – To Surface Water Using Natural Isotopes and Hydrochemicals. The Pari Island with a total area of 40,32 ha is situated at the southern end of a chain of more than a hundred islands, commonly known as Seribu Islands, in Java Sea. Its topography is flat land and mainly consists of coral reefs such that fresh water supply for local people is very limited. The scarcity of fresh water to the local people is still worsen by the intrusion of sea water to the aquifer system. The objective of this study is to get a better understanding of mixing process between sea water and ground water and to trace the sources of salinity in shallow groundwater of Pari Island. The combinations of natural isotopes of ^{18}O and ^{2}H in water and hydrochemical (such as Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} and HCO_3^-) content were used in this study. Results of hydrochemicals showed that almost all of the shallow groundwaters of Pari island had undergone mixing process with sea water. Mostly, they were classified as brackish water and gradually changed to saline water along the flowpath of the water. Only two groundwater samples were still characterized as fresh water type. Mixing ratios of seawater-groundwater water were estimated to be between 2% and 38%. Isotopic results of ^{18}O and ^{2}H revealed that slope of groundwater samples had decreased compared to local water meteoric line. Obviously, those distributions a long the mixing line of sea water – rain water, indicated that high salinity of groundwaters in Pari Island originated from encroachment of sea water. It implied that the salinity was caused by flushing of minerals into soil by direct precipitation could not be taken into consideration.

Key words: Pari Island, groundwater, sea water intrusion, natural isotopes, hydrochemicals

ABSTRAK

Studi Kerentanan Air Tanah Pulau Pari - untuk Permukaan Air Menggunakan Isotop Alam dan Hidrokimia. Pulau Pari merupakan salah satu dari rangkaian pulau yang terletak di sebelah selatan Kepulauan Seribu. Luas wilayahnya sekitar 40,32 ha yang dikelilingi oleh laut Jawa dengan topografi adalah tanah datar yang umumnya tersusun atas batuan koral. Karena kondisi inilah maka persediaan air tawar menjadi masalah utama di Pulau Pari yang kualitasnya semakin menurun. Tujuan dari penelitian ini adalah memahami proses percampuran air laut terhadap air tawar dan merunut sumber air asin di air tanah dangkal di Pulau Pari. Dalam penelitian ini digunakan parameter isotop alam (^{18}O dan ^{2}H) dan hidrokimia (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^- dan SO_4^{2-}). Hasil dari kandungan hidrokimia menunjukkan bahwa umumnya air tanah dangkal di Pulau Pari telah mengalami percampuran dengan air laut. Klasifikasi air tanahnya adalah berupa air payau, akan tetapi seiring dengan pergerakkan air tanah maka air payau tersebut berubah menjadi air asin.

Hanya ada 2 lokasi yang masih terindikasi sebagai air tawar. Perbandingan air laut dan air hujan pada air tanah dangkal di Pulau Pari diperkirakan antara 2% hingga 38%. Distribusi kandungan isotop alam ^{18}O dan ^{2}H pada air tanah telah bergeser dari garis air meteorik lokal dan terletak pada garis percampuran air laut-air hujan. Hal ini menunjukkan bahwa salinitas pada air tanah dangkal di Pulau Pari berasal dari gangguan air laut dan bukan berasal dari proses pencucian garam di formasi tanah oleh air hujan.

Kata Kunci: Pulau Pari, air tanah, intrusi air laut, isotop alam, hidrokimia.

INTRODUCTION

Lowering water table due to continuous exploitation in coastal aquifer can cause sea water intrusion to groundwater system. Consequently, groundwater quality will gradually decrease and does not qualify to be used as drinking water because of its worsen quality. For the sustainability of human being and environmental health, it is very important to understand not only how geological conditions control groundwater flow dynamic in coastal aquifer but also how water and chemicals flux change interface in groundwater-sea water. In hydrogeological study, combination of chemical and isotope indicators can be applied to characterize sea water flow into groundwater circulation. This technique is applied to understand groundwater salinisation and the origin of groundwater, to examine migration of groundwater – sea water interface and mixture ratio between sea water and fresh water in coastal area [1,2].

Similar to other coastal areas, sea water intrusion in Pari island is also an interesting phenomena to be investigated. Moreover, Pari Island just cover a small area of 40,32 ha with its topography of flat land approximately 2 m a.s.l making its groundwater more easily to be intruded by sea water. Geographically, Pari Island is one of hundred islands in Seribu Island located in the nothern part of Jakarta Bay which is a part of a group of island, consisting of Tikus Island, Tengah Island, Burung Island, Biawak Island and Kongsi Island. The islands are separated from each other by one lagoon system and surrounded by developed fringing reefs with prominent banks of rocks on the north and east rim. There are a small number of 625 people living in Pari Island [3] and the population will increase with the developing of tourism in Seribu Islands, meaning, fresh groundwater demand will also increase.

Pari Island that is composed by reef flats has a problem concerning to the limited availability of groundwater resources. Besides encroachment of sea water as common occurs in small islands, other problem of groundwater is a shorter time residence of groundwater before flowing to the ocean such that the groundwater availability decreases more quickly. Most of its groundwater is exploited from an unconfined aquifer with a depth of 0.5 to 4 m. But in a few places, other groundwater can be pumped out from a confined aquifer with depth of 150 m. The lack of fresh water resources is accompanied by none of fresh water contribution from the surface like rivers or springs. Thus, the availibility of fresh water in Pari Island solely depends on a amount of rainfall which the highest rainfall is in January and its annual average reachs to 1700 mm [4].

To get comprehensive information about source of salinity and how far the salinity has influenced to groundwater system in Pari Island, natural isotopes and hydrochemical parameters are used in this study. The anions of Cl^-, SO_4^{2-}, HCO_3^-, and cations of Na^+, K^+, Ca^{2+} and Mg^{2+} are major chemicals dissolved in water. Increasing Cl^- and SO_4^{2-} contents in groundwater is a good indication of sea water intrusion but it is not a sole indication of it. Besides sea water intrusion, the most common pathways of introductions of salinity into the fresh water system could be

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from 1) wash out and flushing salts directly by precipitation or dissolution of minerals from the surface, the soil or aquifer formation, 2) concentration of salt by evaporation, 3) anthropogenic sources. When the solubility product of the major dissolved salts is reached, it is very difficult to follow the chemical evolution of solution and to draw the information of its origin. In this case, isotopic techniques are very useful to evaluate the respective contribution of different salinisation processes [5,6,7].

Natural isotopes like ^{18}O and Deuterium (or ^{2}H) have been applied in sea water intrusion studies in many countries [1,2,8,9,10,11] and in Indonesia [5,12,13]. It utilizes a different isotopic composition of ^{18}O and D associated with sea water and fresh water that is caused by fractionation effect between heavier isotope (^{18}O and ^{2}H) and lighter isotope (^{16}O and ^{1}H) in water molecules. It starts from water molecules in the ocean that evaporate continuously such that heavier isotopes are concentrated in water fraction (sea water) whereas lighter isotopes are concentrated in vapor fraction (precipitation). The vapor fractions with more depleted isotope compositions recharge into the soil in given elevations while in the same time bring those isotope values. Groundwater recharged from precipitation in higher elevation has more depleted isotope values. The relationship between ^{18}O and ^{2}H in precipitation collected around the world is defined as equation of D = 8 ^{18}O + 10, called as *Global Meteoric Water Line* (GMWL). Shifting ^{18}O and ^{2}H values in groundwater from the line could be associated with some processes such as evaporation, interaction with rocks, condensation, isotope exchange and mixing between two different kinds of water [14].

EXPERIMENTAL METHODS

Sampling of groundwater

Shallow groundwater samples were collected from discharges outlets that are mostly dug wells available in the area. There were 15 sampling points distributed along the island. The sampling points were selected such that the distribution of the sampling points can represent the study area that has the length of about 3 km from east to west and longest width about 0.5 km from north to south as presented in Figure 1. The closest and furthest sampling points from coast line were ST-5 (~ 10 m) and ST-8 (~ 140 m), respectively. The average depth of all the wells was approximately 4 m. The sampling period was in early rainy season of December 2012.

As much as 250 ml water sample was put into plastic bottles separately for analysis of anions and cations. The latter was added with a few drops of HNO_3 to prevent precipitation during its storage. For analysis of ^{18}O and D isotope, each water sample was poured to a 10 mL plastic bottle to full capacity such that no air bubbles were observed. After this was completely done, the filled bottle must be closed tightly with double caps to prevent evaporation during either its transportation or storage. Analysis for all parameters was carried out at the Hydrology Laboratory – Center for Isotopes and Radiation Application– National Nuclear Energy Agency (BATAN).

Analysis of anion

In most hydrogeological study, Cl^-, SO_4^{2-} and HCO_3^- as major anions dissolved in water are usually analyzed to be used as indicators for sea water intrusion. Chloride and sulfate in each water sample were analyzed by using Ionic Chromatography 883 Basic IC plus Metrohm with its specification of Metrosep A supp 5 coloumn (150/4.0) 6.1006.520 serial No. 7103580 and also equipped by Compact Autosampler Metrohm 863. Each 10 ml of water sample that had been filtered in microspores size of 0.45 µm and standard solutions were arranged in auto sampler. As much as 20 µL of each sample was injected to Ionic Chromatography that had been conditioned for approximately 1 hour. The eluent solutions used were a 382 mg Na_2CO_3 and 286 mg $NaHCO_3$ added by 40 mL aseton and
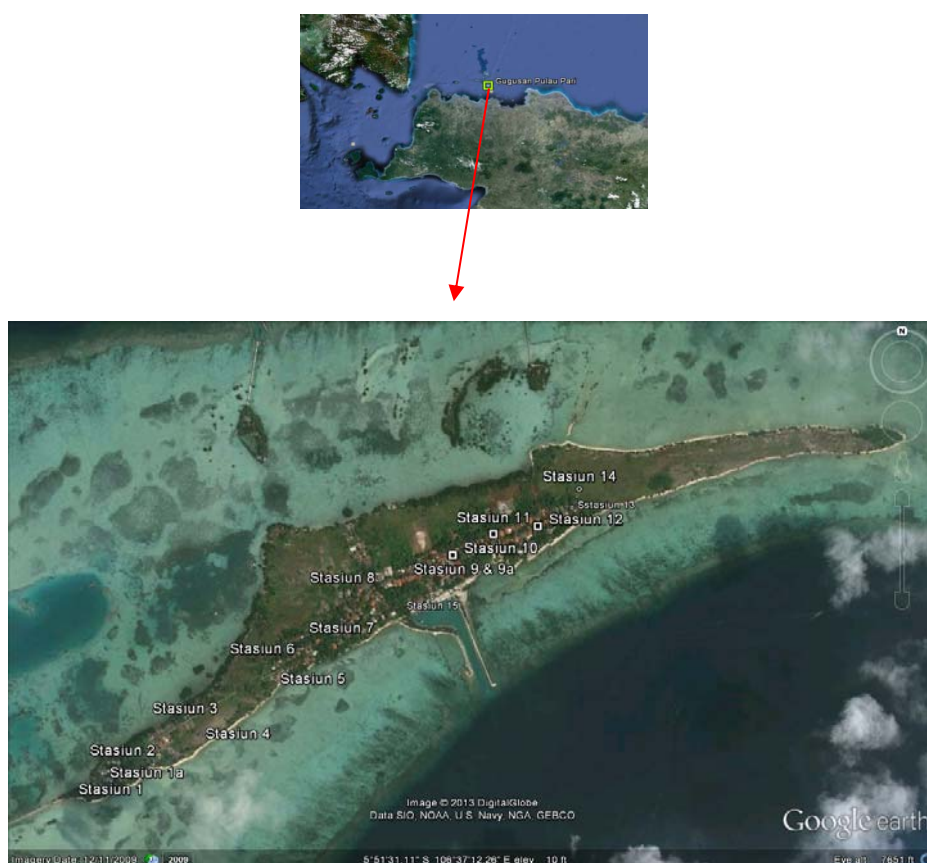
Figure 1. Map of sampling locations for shallow groundwater in Pari Island

dissolved with aquabidest in 2 L flask, H_2SO_4 50 µmol/L and filtered aquabidest. Qualitative tests were conducted by the comparison of retention time of each element in water samples toward standard solutions. Quantitative tests were conducted by plotting the peak area of each element in water samples to the each calibration curve of standard solution [15]. Analysis of bicarbonates was carried out by tetrimetri methods in which the solution of 0.02 N HCl was dropped slowly to the water samples and methyl orange solution was used or when the pH solution of 4.5 had been reached as the indicator of the end point [13].

Analysis of cations

In this research, some cations analyzed were Na^+, K^+, Ca^{2+} and Mg^{2+} using IC 883 Basic IC plus Metrohm with its coloumn specifications of Metrosep C4 250/4.0 (6.1050.430) serial no. 0129.3043 that had been equipped by Compact Autosampler Metrohm 863. Qualitative and quantitative tests of cations were similar to those of anion analysis [15].

Analysis of O-18 and Deuterium (D)

Analysis of ^{18}O and deuterium was carried out by using liquid-water stable isotope analyzer LGR (Los Gatos Research) DLT-100. As much as 1 ml of each filtered water samples was poured off to glass vial and closed with double cap tightly. Regularly samples were placed in sampler tray such that each five samples are followed by three standard solutions consisting of enriched to depleted values of ^{18}O and D. In the LGR equipment, as much as 0.75 µl of water sample was evaporated and then transferred to evacuated mirrored chamber. A laser beam is directed to vapor and mole fraction is determined by the

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absorption measured using Beer's Law. In this equipment, *Off Axis Integrated Cavity Spectroscopy* (*Off Axis ICOS*) which can produce optical pathway with length of 2500 m in a 25 cm cell and to get a good precision, it is also replenished. Concentration of ^2HHO, $HH^{18}O$ and HHO molecules in each sample is calculated through its absorption measured at wave length of 1390 nm [16].

The concentration of each molecule is converted to isotopic ratio of $^2H/^1H$ and $^{18}O/^{16}O$ that both have relative value to Standard Mean Ocean Water (SMOW). Notation used in isotopic ratio measurement is delta (δ) in permill ($^o/_{oo}$) unit, for instance, δ ^2H is for $^2H/^1H$ and δ ^{18}O is for $^{18}O/^{16}O$. The δ value is calculated according to this equation [15,17]:

$$\delta = \frac{\left[\dfrac{^{18}O}{^{16}O}\right]_{sample}}{\left[\dfrac{^{18}O}{^{16}O}\right]_{s\tan dard}} \times 1000 \ ^o/_{oo}$$

RESULTS AND DISCUSSION

Results of anion (Cl^-, SO_4^{2-}, HCO_3^-) and cation (Na^+, K^+, Ca^{2+}, Mg^{2+}) analysis taken from shallow groundwater are shown at Table 1. Those anion and cation concentrations are integrated to an Aquachem program in order to have some visual graphics such as Piper and Schoeller and to calculate mixing of groundwater and sea water. Piper diagram are usually used to classify many water samples in one diagram and to identify mixing of the waters

Table 1. Analysis results of major chemicals dissolved in shallow groundwater of Pari Island

No.	Sample ID	HCO3 ppm	Cl ppm	SO4 ppm	K ppm	Na ppm	Ca ppm	Mg ppm
1	ST-1 (LIPI's bath room well)	250.14	1136.15	51.82	4.68	366.62	586.02	240.48
2	ST-1a (LIPI's kitchen well)	215.46	6731.14	1019.78	1930.92	3600.99	1208.60	1347.25
3	ST-2	267.47	2324.60	412.86	303.30	1103.22	1893.07	734.14
4	ST-3	354.15	5256.00	357.90	47.48	1864.41	1054.52	394.43
5	ST-4	156.03	7181.00	898.00	37.88	2671.30	361.08	445.13
6	ST-5	208.03	4502.74	366.04	24.97	1640.07	176.13	368.64
7	ST-6	126.31	1618.42	101.42	78.67	519.79	129.21	184.06
8	ST-7	354.15	1482.41	113.36	47.32	102.38	90.21	206.67
9	ST-8	292.24	43.75	57.91	4.27	23.22	40.55	27.08
10	ST-9	537.42	7787.80	63.00	50.62	3512.85	35.76	277.63
11	ST-9a (rev. osmosis)	32.20	212.74	7.47	2.75	198.58	1.80	7.40
12	ST-10	185.75	92.10	37.83	15.28	59.97	32.65	33.55
13	ST-11	284.81	613.05	74.46	23.58	484.34	49.87	475.58
14	ST-12	361.58	531.97	54.59	17.19	469.59	49.77	450.12
15	ST-13	351.68	2063.05	105.61	50.25	1020.24	214.59	275.05
16	ST-14	482.94	1163.32	113.95	15.72	2460.46	218.26	773.48
17	ST-15	386.25	698.42	94.89	36.60	422.94	109.88	153.02
18	Sea water [11]	142.00	19353.00	2712.00	399.00	10768	412.30	1291.80

[2,6,11,17]. However, disadvantage of Piper diagram is that it cannot easily accommodate waters where other cations or anions may be significant. In that case, Schoeller diagram can provide more detailed concentration of major ions for selected record in the database [17].

On Piper diagram, anion and cation concentrations (meq/L unit) are plotted on each triangle as percentages and those points are projected upward to where they intersect on the diamond. Plotting anion and cation concentrations for shallow groundwater taken from Pari Island is revealed in Figure 2. Generally, those samples tend to become Na-Cl water type along the flow-path. General reports in

of ST-8 and ST-10 which have Mg-Ca-HCO_3 and Mg-Na-Ca-HCO_3-Cl water types respectively, indicating that they still could be characterized as fresh water type. As mapped in Figure 1, ST-8 site is located at the farthest distance (approximately 140 m) away from coastline then followed by ST-10 site as the second for distance away from shoreline (approximately 90 m).

Schoeller diagram in logarithmic scale in Figure 3 shows more clearly in plotting anion and cation concentrations for each water samples. It describes that shallow groundwater in Pari Island grouped at three salinity level based on its chloride concentrations. Brackish groundwater group seems to dominate for all most water
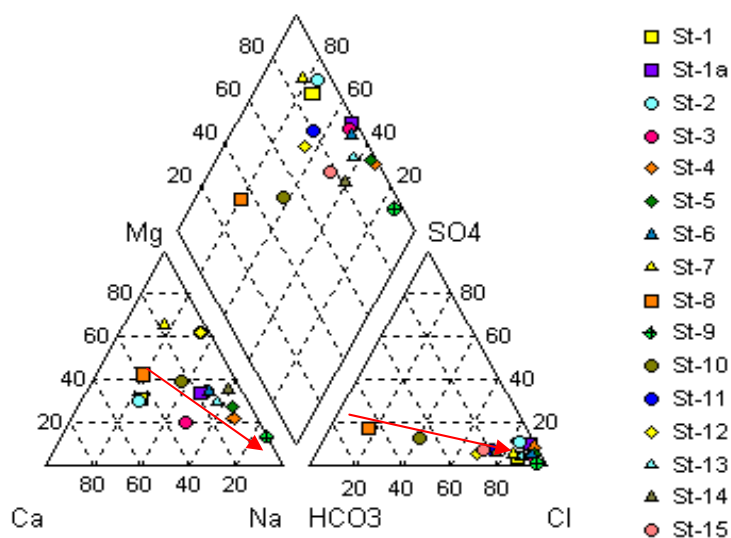

Figure 2. Piper diagram for shallow groundwater in Pari Island

Aquachem program inform that locations of ST-4 and ST-9 are exactly dominated by Na-Cl water type whereas most water samples have a water type of either Na-Mg-Cl or Ca-Mg-Na-Cl as visually presented at Piper diagram. Both water types could increase their salinity along groundwater flow due to closer distance from shore and change their water type to become Na-Cl dominant. Nevertheless, there are two water samples

samples and five locations of ST-9, ST-4, ST-5, ST-3 and ST-1a are classified as saline groundwater, the rest of ST-8 and ST-10 are grouped as fresh water. The salinity categories of groundwater are related to chloride concentration as follows: 5000-19.000 mg/L is saline water, 500-5000 mg/L is brackish water and <500 mg/L is fresh water [18].
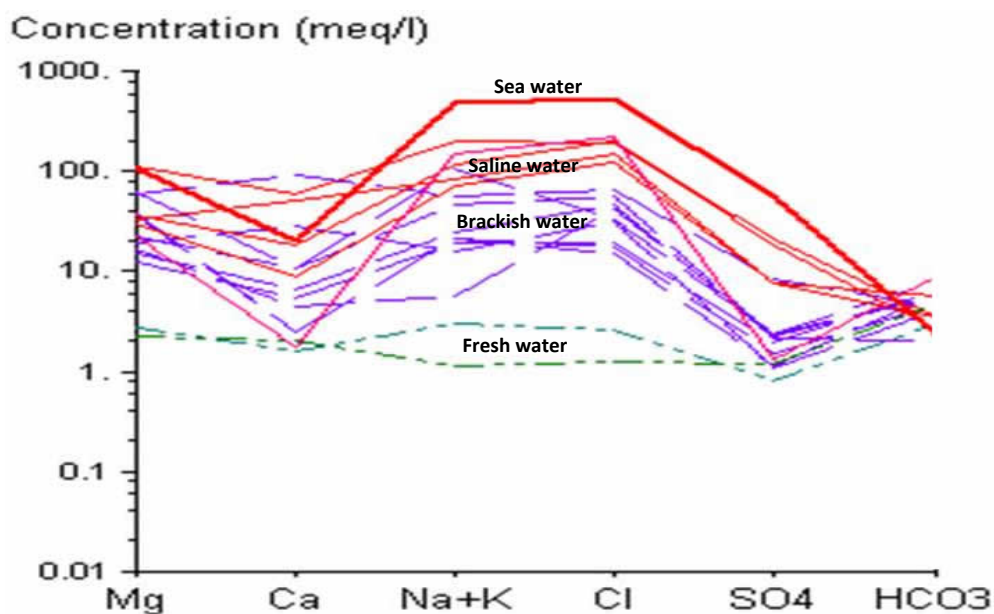
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**Figure 3**. Classification of shallow groundwater in Pari Island related to chloride content

In hydrological study, Aquachem programme also can be used to calculate mixing percentage between each water samples and sea water. Fundamental equation for mixing between two water samples is $C_1(1-n) + C_2n = C_{mix}$, where C_1 and C_2 are concentration of solution 1 and solution 2, in this case those are sea water and fresh water, respectively. Hence, increasing anion and cation concentrations for each step of mixing percentage can be calculated and then the calculated mixtures can be graphed as a linear line. Through the measured compositions of major anion and cation in water sample and its mixture with sea water can be estimated by optimizing to the mixing step order [17]. Calculated results define that water samples classified as saline water has a mixture with sea water as much as 22% for ST-5 and 38% for ST-9, respectively. The contributions of sea water to water samples classified as brackish water are in the range of 4% to 12% whereas fresh water of ST-8 and ST-10 sites has 2% of sea water mixture.

The most common pathways of intrusion of salinity to the ground water system in coastal area like Pari Island are encroachment of sea water and flushing of dry salts directly by precipitation [1,2]. Brackish waters resulted from those processes are different in its chemical contents because of different flow direction of salinity in to aquifer as described in Figure 4. Excess of Cl compared to Na was observed in brackish water with $CaCl_2$ type, indicating exchange of Na by Ca desorbed from mineral in the surface. This is a common process for encroachment of sea water to the fresh water that was previously in equilibrium with less mineralized water of $Ca(HCO_3)$ type. The reverse pathway is flushing of dry salt by precipitation observed in brackish water with $NaHCO_3$ type. In this process, Ca from fresh water of $Ca(HCO_3)$ type is exchanged by Na desorbed from mineral surfaces due to fresh water entering in the aquifer that was previously in equilibrium with more mineralized water of Na-Cl type [18,19]. As seen in Figure 3, brackish water mostly observed in shallow groundwater in Pari Island has Na-Mg-Cl water type that is signified by higher chloride content. Thus, the salinisation process occurring in shallow groundwater of Pari Island is undoubtedly from

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encroachment of seawater. This has a relation to total area of Pari Island which covers only 40.32 ha and is surrounded by sea, such that the movement of sea water to ground water system is more rapidly than the reverse flow.

natural isotopes usually used are ^{18}O and ^{2}H that are as constituents of water compound [1,2,8,9,10,11]. As mentioned before, the main possibilities of salinisation in groundwater are flushing of dry salts by precipitation and encroachment of sea water
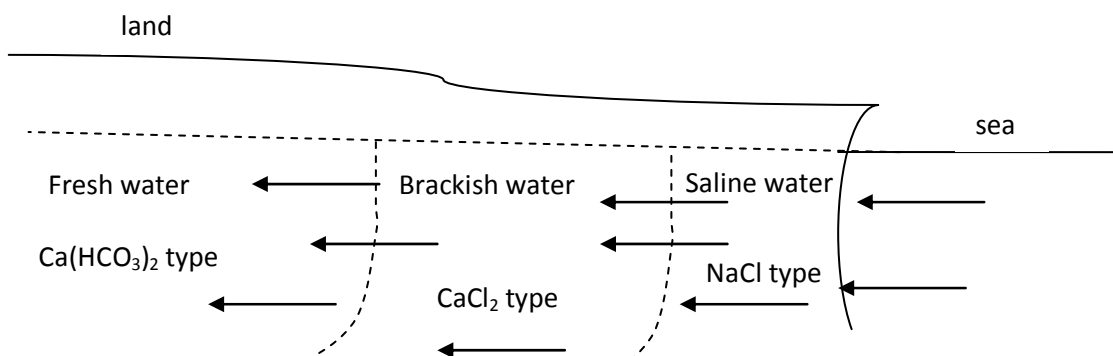
Scheme of cation exchange due to sea water intrusion where brackish water is signified by $CaCl_2$ type.
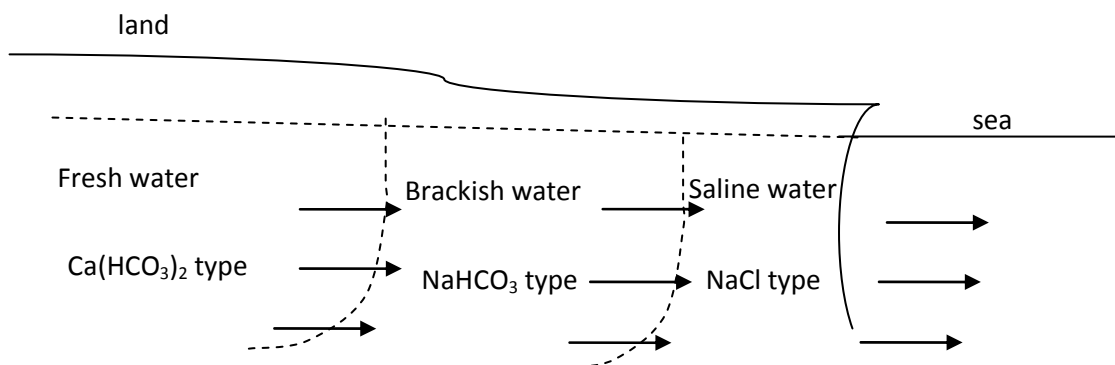
Scheme of cation exchange due to flushing of dry salts where brackish water is signified by $NaHCO_3$ type.

Figure 4. Exchange processes of water chemical types in most coastal aquifer

To have a more clearly understanding of the salinisation process which takes place in shallow groundwater of Pari Island, it is essential to analyze its natural isotopes dissolved in water. Isotope techniques are useful to trace the origin of salinitation in groundwater. In hydrological studies, natural tracer using isotopes provide independent means for corroborating or evenly refuting based on traditional investigation using dissolved chemicals. The

to ground water system. Obviously, flushing of dry salt into the surface by precipitation will not result in any changes in the water's isotope composition. On the other hand, the change of isotopic composition in ground water could be due to the mixing of sea water besides evaporation and ^{18}O isotopic exchange due to water rock interaction and ^{2}H isotopic exchange with hydrocarbons [2,14].

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Table 2. Results of O-18 and deuterium (^{2}H) isotopes in shallow groundwater of Pari Island

No.	Sample ID	O-18 (‰) SMOW	H-2 (‰) SMOW
1	ST-1	-5.76	-39.88
2	ST-1a	-5.51	-38.50
3	ST-2	-5.47	-37.00
4	ST-3	-5.00	-31.03
5	ST-4	-4.43	-28.21
6	ST-5	-4.47	-30.87
7	ST-6	-5.14	-30.69
8	ST-7	-5.83	-35.58
9	ST-8	-5.42	-32.65
10	ST-9	-4.46	-27.16
11	ST-9a	-5.00	-33.05
12	ST-10	-6.16	-38.80
13	ST-11	-5.16	-33.90
14	ST-12	-5.45	-34.45
15	ST-13	-5.85	-36.37
16	ST-14	-5.28	-35.90
17	ST-15	-5.70	-36,40
18	Sea water in Banten Bay [18]	-0.66	-3.53
19	Precipitation in Tugu (1020 m dpl) [9]	-8.14	-50.70

Isotopic composition of ^{18}O and ^{2}H in shallow groundwater of Pari Island is in the range of -4.43 ‰ to -6.16 ‰ SMOW and -27.10 ‰ to -39.88 ‰ SMOW, respectively as revealed in Table 2. Relationship between ^{18}O and ^{2}H data resulted in groundwater line which the points are distributed along linear regresion equation of δ ^{2}H= 6.29 δ ^{18}O+ 0.83 as seen in Figure 5. Local meteoric water line (LMWL) and seawater - rain water mixing line are also shown in this figure. LMWL is useful as an input function of local precipitation recharging into soil and provides a baseline in order to understand physical and chemical processes influencing to groundwater along the flowpath [14]. In the study of Pari groundwater, LMWL refers to Jakarta rainfalls which were monthly collected from gradual elevations starting from Tongkol-Jakarta (elevation of 10 m) to Tugu-Bogor (elevation of 1020 m) during one year, its line obtained was δ ^{2}H = 7.78 δ^{18}O

+ 12.93 [12]. The average of isotopic composition of ^{18}O and ^{2}H from Banten Bay collected for one year were -0.66 ‰ and -3.53 ‰ respectively, those are utilized as sea water database [20]. If the isotopic compositions of Banten Bay sea water and those of Tugu rainfall are connected, a sea water - rain water mixing line with regression equation of δ ^{2}H = 6.31 δ^{18}O + 0.63 is obtained.

Figure 5 shows that the distribution of groundwaters has shifted from the local meteoric line which is indicated by decreasing of its slope. Apparently, the slope value of the groundwater line is closed to that of sea water – rain water mixing line although it is slightly lower. However, most groundwaters in Pari fall along sea water – rain water mixing line, indicating that groundwater samples have been subjected to mixing significantly with sea water [1,2,8]. It also indicates that flushing of dry salt in soil
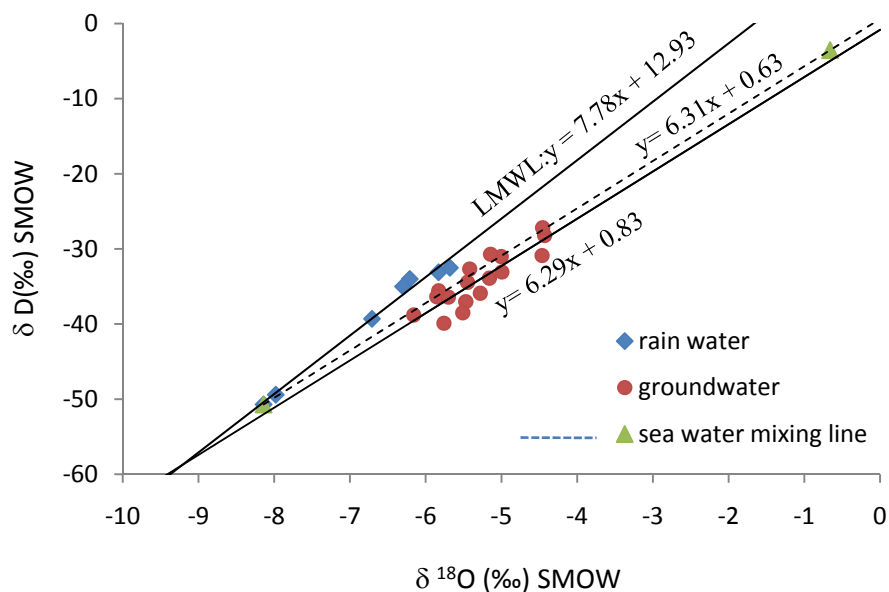
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Figure 5. Relationship between δ ^{18}O and δ ^2H in Pari Island shallow groundwater

or dissolution of mineral from surface by precipitation influencing high salinity in groundwater is almost impossible. In the case when the flushing of dry salts occurred, isotopic composition of ^{18}O in groundwater samples would constantly move along meteoric water line although increasing their salinities. Thus, the increasing salinity occurring in shallow groundwater from Pari Island would be from sea water encroachment.

The lower slope of groundwater line than that of sea water-rain water mixing line also indicates evaporation process. This is due to hot landscapes when there is a recharge of rain water on the surface water that have evaporated before infiltrating to soils. Therefore, evaporated water will result in the enrichment values of $\delta^{18}O$ and δ ^2H [14]. In this study, the mixture of evaporated water and direct rainwater infiltration moving along its flowpath is influenced by sea water intrusion. However, the slope of groundwater line which is very near to that of sea water-rain water mixing line indicates the dominant effect of sea water intrusion in spite of evaporation. In figure 5, the sites of ST-4, ST-5 and ST-9 lies down separately

from the other groundwater samples. The three groundwaters have more enriched values of $\delta^{18}O$ and δ ^2H that show they tend to move to a higher mixture with sea water that agrees with increasing salinity (chloride content).

CONCLUSION

Analysis of major anions (Cl^-, SO_4^{2-} and HCO_3^-) and cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) in dissolved water shows that most of the shallow groundwaters collected from Pari Island have been influenced by sea water encroachment. In general, they have typical brackish water of Na-Mg-Cl and two sites namely ST-4 and ST-9 are identified as Na-Cl water type. However, ST-8 and ST-10 that are located more toward inland from shoreline are classified as fresh water. Based on chloride content, the locations of ST-4, ST-9, ST-5 and ST-3 which are classified as saline water have mixing ratio of sea water ranging from 22% to 38%.

Isotopic composition of ^{18}O and Deuterium in Pari Island shallow groundwater is in the range of -4.43 ‰ to -

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6.16 ‰ SMOW and -27.10 ‰ to -39.88 ‰ SMOW, respectively. The distribution of those data have shifted away from local meteoric water line and fall along sea water – rain water mixing line. Thus, the presence of high concentration of chloride in most groundwaters are from the encroachment of sea water not from flushing of salt by rain water. This clearly confirms the analysis of major chemicals which results in Na-Mg-Cl water type for brackish water catagories.

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REFFERENCES

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