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Study of Seawater Intrusion in Deep Aquifers of Semarang Coast Using Natural Isotopes and Hydrochemicals

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Abstract - Seawater intrusion in deep aquifers of Semarang Coast is important to be investigated, because Semarang is one of big cities in Indonesia. Besides its dense population, the growth of industries also increases rapidly with the increase of withdrawal of groundwater either from shallow or deep aquifers. Over-exploitation of groundwater can cause a decreasing groundwater quality due to seawater intrusion. Through this study, the salinization from seawater into the deep aquifer system can be observed. Groundwater samples were collected from deep aquifers with the depth around 40-120 m, and then the isotope contents of ^{18}O and ^{2}H as well as the hydrochemical were analyzed. The isotope and hydrochemical analysis results show that six of thirteen samples are of freshwater type. They are in S2, S5, S7, S8, S9, and S13 sites. While the others are supposed to be encroached by seawater. The slight encroached groundwater of S1, S6, and S10 had a fraction of seawater in the range of 0.15 to 0.26, whereas the moderate and high ones were of S3, S4, S11, and S12 which had seawater fraction between 0.25 and 0.34. Seemingly, salinization mechanism of groundwater by seawater does not depend on its distance from the shoreline and bore well depth. It is confirmed to the site of S5 and S7 located 680 m and 950 m from the shoreline, respectively, which were predominated as freshwater type. On the contrary, the groundwater of S10, S11, and S12 located at further sites about 5-6 km from shoreline is clearly indicated seawater intrusion.

Keywords: seawater intrusion, natural isotopes, hydrochemical, deep aquifer, Semarang

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Introduction

Semarang as a capital city of Central Java Province is well known as one of big cities in Indonesia. The economic growth of this city is increasing rapidly because of its strategic location in the centre of Java Island, and so it becomes the main pathway of trades. Besides as a trade centre, the city also experiences fast growth of industries, services, and residences. Administratively, Semarang City is bordered by Kendal Regency in the western part, Semarang Regency in the southern part, Demak Regency in the eastern part, and Java Sea in the northern part with its shoreline of 13.6 km long (RKPD Kota Semarang, 2014). Topographically, the Semarang City consists of hilly lands, plain lands, and coastal regions in which the slopes are around 0 to 40%, and the elevations are between 0.75 and 348 m asl. (Wardhana *et al*., 2014).

To support the economy and people activities in Semarang City, it is very important to develop groundwater resources. As well known, water is a basic need for human beings even for running their economic activities (Susanto *et al.*, 2015). The fast growth of Semarang City has increased the water demand. On the other side, treated water from surface water which is supplied by the local government can not fulfill all demands of clean drinking water both for domestics and industries. An easy step that can mostly be done by the local people to overcome the shortage of clean water is by taking groundwater from an unconfined aquifer. The groundwater withdrawal is not only conducted through a dug well, but also a bored well that can reach a deeper aquifer. Moreover, to take more capacities of clean water, some industries including hotels, hospitals, *etc*. fulfill their groundwater demands by taking it from confined aquifer due to its better quality (Sudaryanto *et al*., 2014).

A problem that usually comes up concerning the deep aquifer withdrawals is that industries or people do not have a license to do exploitation of confined aquifers. That illegal exploitation often turns to over-exploitation of groundwater. As the consequence, the system of the confined aquifer would be damaged in the future and this system can not be able to be recovered. Overexploitation of deep groundwater is manifested by the decline of water level, seawater intrusion, and land subsidence (Fahrudin and Nadjib, 2011; Katrinavia *et al*., 2015). Furthermore, the over-exploitation forms many empty spaces in the aquifer system, and the groundwater level becomes lower than the seawater level. Groundwater level is the upper surface or the top of a saturated zone. As water characteristic naturally flows to a lower level, seawater that contains a high concentration of salts like chloride (Cl^-) fills those empty spaces in the groundwater aquifer system. Thus, groundwater gets gradually contaminated by seawater as mostly happens in coastal regions (Latifiani and Widyawati, 2011; Suhartono *et al*., 2013).

Concerning this case, it is essential to study the flow patterns of seawater intrusion to the groundwater system, especially to the deep aquifers in Semarang City. The stable isotopes ($\delta^{18}O$, $\delta^{2}H$) can trace the groundwater-seawater interaction and hydrochemical techniques. In hydrological research, both isotopes are utilized as a fingerprint to determine a groundwater recharge area and to distinguish the sources of groundwater, whether groundwater investigated comes from rainwater, deep or shallow groundwater, seawater, magmatic water, or connate water (Satrio *et al*., 2014; West *et al*., 2014).

Topography of the Studied Site

The topography of Semarang City is strongly influenced by its natural conditions that form a city, characterized as hilly, plain, and coastal areas with elevations are in the range of 0 m asl. to 348 m asl. Because of such topography, Semarang is classified into two sites which are called upper and lower cities. The upper city consists of hilly lands in the southern part overlying an elevation of 90.56 m to 348 m asl. which the highest regions are located in Jatingaleh and Gombel, South Semarang, Tugu, Mijen, and Gunungpati. The slopes of those regions widely vary from 5% to 40%. While the lower city of Semarang has an elevation of 0.75 m asl. consisting of more flatlands and coastal regions in the northern part with the slopes are in the range of 0% to 5% (RKPD Kota Semarang, 2012).

Hydrogeology of Semarang-Demak

The aquifers have been defined using geological and groundwater head relationship and a general hydrogeological cross-section shown in Figure 1 (Putranto and Rüde, 2011).

Based on Figure 1, aquifer systems in Semarang-Demak groundwater basin area can be distinguished by their compositions into three groups, which are:

(a) Alluvium aquifers which consist of clayey sand, sand, and gravel. The depth of the aquifers in the western of Semarang is about 30 to 90 m, while the depth of the aquifers

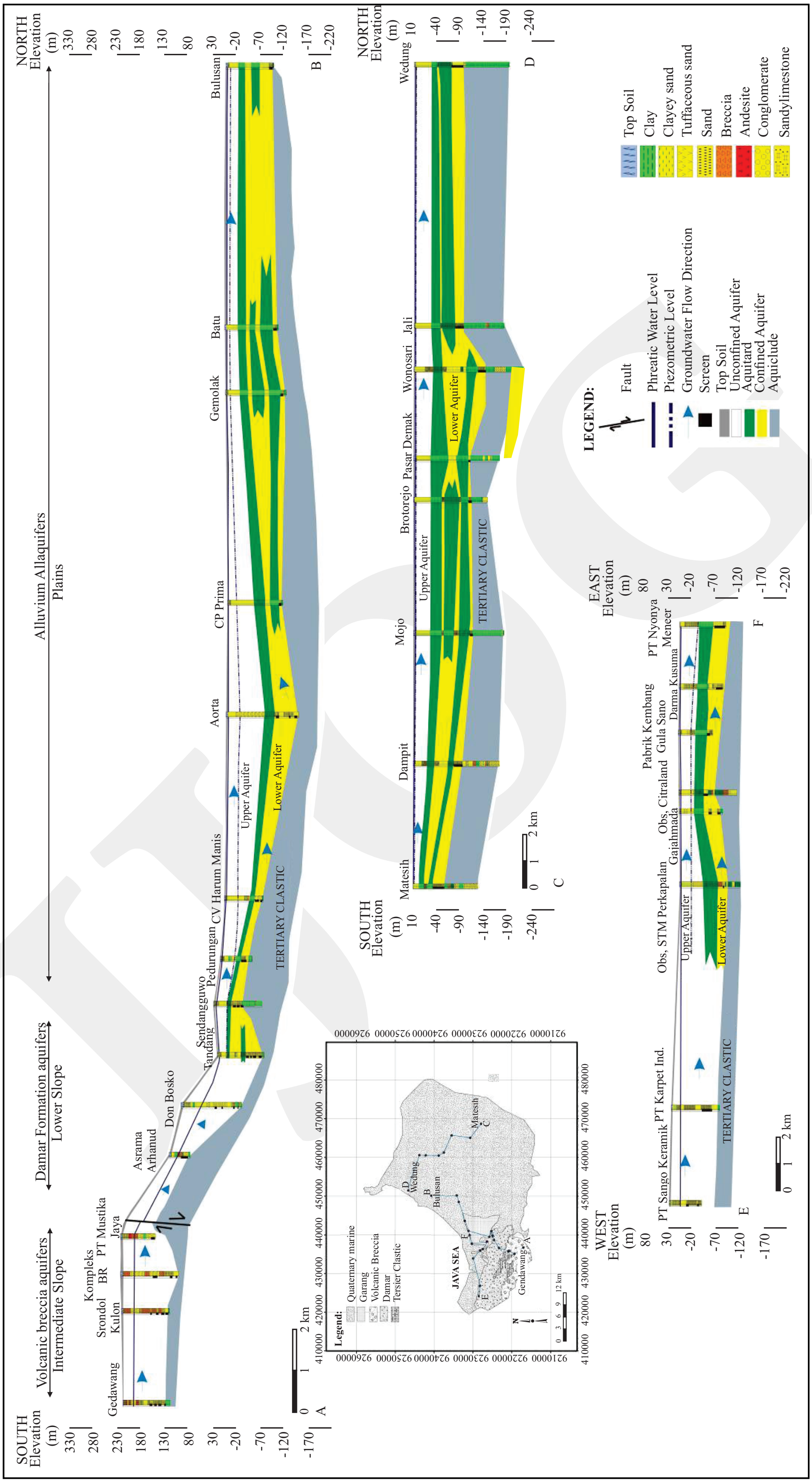

Figure 1. Conceptual diagram of the hydrogeology in the coastal site of Semarang.(Putranto and Rüde, 2011)

in the eastern is more than 90 m below the ground surface. According to Sihwanto *et al*. (1988) and Mamlucky and Harnadi (2007), alluvium aquifers comprise two groups, which are Garang aquifer and Quaternary marine aquifer. The lithologic characteristics between the two aquifers are almost similar, but Garang aquifer contains freshwater. On the other hand, Quaternary marine aquifer contains brackish or salt water (Pasaribu, 2003; Mamlucky and Harnadi 2007).

(b) Damar Formation aquifers which dominantly consist of conglomerates and tuffaceous sand, sand underlies an impermeable layer of clay, tuff, and breccias (Mamlucky and Harnadi, 2007; Putranto and Rüde, 2011), (section A - B and E - F, Figure 1). The aquifer depth varies in the range of 30 - 100 m below the ground surface.

(c) Volcanic breccia aquifers which exist in the plateau area north of the hilly area in the lower slope (section A–B, Figure 1). The aquifers comprise conglomerate, tuffaceous sand, and breccia.

Methods

Collecting Samples

Sample collections for stable isotope ^{18}O and ^{2}H analyses were directly conducted at the water sources. Each 20 ml plastic bottle with an inner cap was fulfilled with water sample so that no more air bubbles inside, then the bottle was closed tightly to protect water samples from evaporation during the shipping or storage. While for hydrochemical analysis, no special treatments were required for collecting water samples. It just approximately 1 liter of water samples needed for the analysis (Satrio and Sidauruk, 2015).

Stable Isotopes (δ^2H, δ^2O) Analyses

Analyses of δ^2H and δ^2O in water samples were carried out by using the equipment of Liquid-Water Stable Isotope Analyzer LGR DLT-100 assembled by Los Gatos Research, USA. The results are expressed as delta notation (δ) in permit unit ($^{o}/_{oo}$) relative to *Vienna-Standard Mean Oceanic Water* (VSMOW) (Hamed, 2014) which are calculated as the following equation (Gaj *et al*, 2015):

$$\delta\ (^{o}/_{oo}) = (\frac{R_s}{R_{VSMOW}} - 1) \times 1000 \quad \text{.......................(1)}$$

Where:

R_S= the isotope ratio ($^2H/^1H$ or $^{18}O/^{16}O$) of the water sample

R_{VSMOW}= the isotope ratio ($^2H/^1H$ or $^{18}O/^{16}O$) of the standard

Delta (δ) = the divergence of the isotopic abundance ratio of a sample in relation to the standard, expressed in per mile ($^{o}/_{oo}$) deviation from a standard.

The following equation calculates the mole fraction of introducing seawater into the freshwater system (Nathenson, 2013; Sola *et al*., 2013).

$$(\delta^{18}O)_m = X\ (\delta^{18}O)_{sw} + (1 - X)\ (\delta^{18}O)_{rw} \quad \text{.....(2)}$$

Where:

$(\delta^{18}O)_m$: ^{18}O isotopic value in the water sample (‰)
$(\delta^{18}O)_{sw}$: ^{18}O isotopic value in the local seawater (‰)
$(\delta^{18}O)_{rw}$: ^{18}O isotopic value in the rainwater (‰)

Molar Ratio of Chloride-Bicarbonate (R)

Besides stable isotopes of ^{18}O and ^{2}H, molarity ratio between chloride and bicarbonate can be used to identify the mechanism of salinization in freshwater such as seawater encroachment (Ekhmaj *et al*., 2014; Klassen *et al*., 2014). Obviously, seawater is dominated by chloride content, whereas freshwater is dominated by CO_3^{2-} and HCO_3^-. The formula which is used to calculate the molar ratio of chloride and bicarbonate is the following equation:

$$R = \frac{Cl^-}{Co_3^{2-} + HCO_3^-} \quad \text{..............................(3)}$$

Table 1 can be used to assess the extent of seawater intrusion into freshwater based on the molar ratio between chloride and bicarbonate.

Table 1. Classification of Encroached Groundwater due to Seawater Intrusion

$R = \frac{Cl^-}{Co_3^{2-} + HCO_3^-}$	Groundwater quality
< 0,5	fresh groundwater
0,5 - 1,30	Slightly encroached
1,30 - 2,80	Moderately encroached
2,80 - 6,60	Injuriously encroached
6,60 - 15,50	Highly encroached
15,5 - 20	saline water

Results and Discussion

Investigated Sites

Geographically, the investigated sites represent a coastal plain of Semarang City that cover West Semarang, North Semarang, South Semarang, and Pedurungan Districts. They overlie between the areas of the south latitude of $6^{0}50'$-$7^{0}10'$ and east longitude of $109^{0}35'$-$110^{0}50'$. Groundwater samples were collected from bore wells of deep aquifers and selected at the nearest to the farthest sites from the shoreline.

The selected sites cover each part of the coastal plain of Semarang. Data of sampling locations, elevations, and the depth of bore wells, as well as the distance from shorelines, are revealed in Table 2, whereas the map of investigated sites is shown in Figure 2.

$\delta^{18}O$ and ^{2}H Isotopes

The results of stable isotopes of $\delta^{18}O$ and $\delta^{2}H$ collected from the deep aquifer are displayed at Table 3. Those isotopic values vary in the range of -7.23 ‰ to - 4.46 ‰ for $\delta^{18}O$, and - 41.70 ‰

Table 2. Sampling Location and Secondary Data of Groundwater from A Deep Aquifer in Semarang

No.	Locations	Sample ID	Latitudes-Longitudes	Elevation (m asl.)	Well Depths (m)	Distance from Shore (m)
1	Marina Beach	Seawater	432049.60 mE 9232088.00 mS	0	-	-
2	SMK Texmaco Semarang	S1	421937.00 mE 9229374.00 mS	23	40	5,250
3	PT KIW	S2	426699.00 mE 9228875.00 mS	15	60	2,910
4	Mosque of Baitul Muttaqin	S3	429862.00 mE 9228512.00 mS	5	40	3,220
5	Puri Anjasmoro Blok N	S4	432128.00 mE 9229830.00 mS	7	60	2,260
6	BBPPI	S5	435706.00 mE 9231821.00 mS	5	120	680
7	Mosque of Nurul Falah	S6	438169.00 mE 9230526.00 mS	6	60	1,190
8	CV Sinar Majaputra	S7	442295.93 mE 9231296.68 mS	4	60	950
9	SMA PL Tarcisius	S8	441284.00 mE 9228951.00 mS	7	40	3,630
10	Mosque of Agung-Central of Java	S9	438786.00 m E 9228107.00 mS	5	120	3,660
11	Disnakertrans	S10	436024.33 mE 9226718.61 mS	10	60	5,280
12	STEKOM Majapahit	S11	440396.91 mE 9225456.60 mS	15	60	6,490
13	Aneka Jaya Shop	S12	441878.46 mE 9226757.93 mS	13	40	5,530
14	STIFAR Semarang	S13	443347.00 mE 9223483.98 mS	24	60	9,400

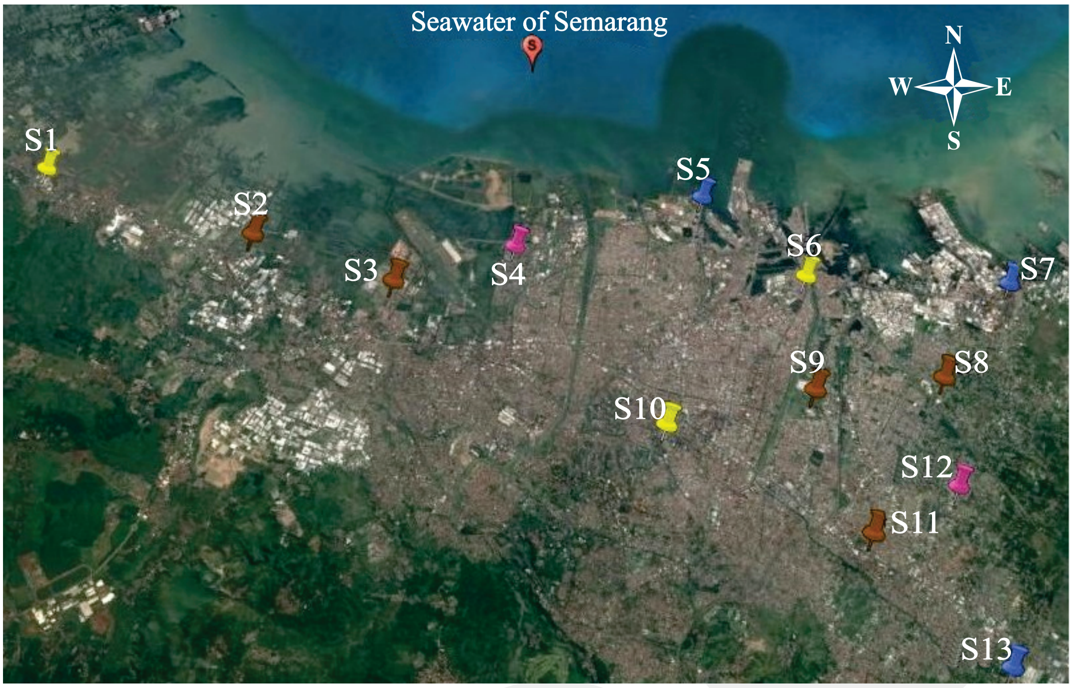

Figure 2. Sampling sites for deep aquifers in the coastal site of Semarang.

Table 3. Isotope Analysis Results of ^{2}H And ^{18}O from A Deep Aquifer in the Coastal Site of Semarang

No.	Sites	Sample ID	δ^{2}H (‰)	δ^{18}O (‰)
1	Seawater in Semarang Beach	Seawater	-1.20	-0.36
2	SMK Texmaco	S1	-36.69	-5.42
3	PT KIW	S2	-38.71	-6.29
4	Mosque of Baitul Muttaqin	S3	-31.36	-4.46
5	Puri Anjasmoro Blok N	S4	-33.55	-4.52
6	BBPPI	S5	-41.70	-6.89
7	Mosque of Nurul Falah	S6	-36.59	-5.78
8	CV Sinar Majaputra	S7	-41.37	-6.62
9	SMA PL Tarcisius	S8	-37.00	-6.71
10	Mosque of Agung Jawa Tengah	S9	-38.09	-6.83
11	Disnakertrans	S10	-35.94	-5.02
12	STEKOM Majapahit	S11	-35.41	-5.09
13	Aneka Jaya Shop	S12	-34.40	-4.61
14	STIFAR Semarang	S13	-40.93	-7.23

to - 31.36‰ for δ^{2}H. These variations are strongly related to some processes taking place in the environment of groundwater samples, such as interaction with rocks and surface water (sea and river) or the groundwater samples that probably still preserve their isotopic contents as when they were recharged from meteoric water (Yang *et al.*, 2012; Bhandary, 2013).

The isotope data of groundwater were plotted in a scatter diagram as depicted in Figure 3 that formed a linear relationship between δ^{18}O and δ^{2}H values. In this diagram, the δ^{18}O and δ^{2}H values

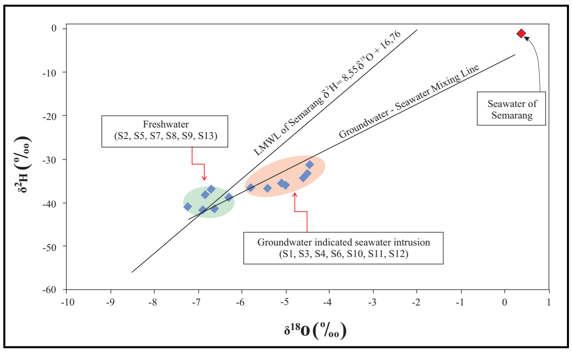

Figure 3. Relationship between $\delta^{18}O$ and $\delta^{2}H$ values for a deep aquifer in Semarang.

from Semarang meteoric water samples which were previously investigated were also plotted. This local meteoric water line provides a baseline for groundwater. Local meteoric water line (LMWL) for Semarang has a linear regression of $\delta^{2}H = 8{,}55\delta^{18}O + 16{,}76$ as previously investigated by The Centre for Groundwater Resources and Environmental Geology, Bandung (Mamlucky and Harnadi, 2007; Prasetio, 2015; Satrio *et al.*, 2017). Based on the relationship of both isotopes, the groundwater samples collected from a deep aquifer in Semarang are classified into two main groups. They were:

Group I: Fresh Groundwater

This group consists of sample points of S2, S5, S7, S8, S9, and S13 distributed close to the local meteoric water line, and generally they has more depleted isotope values. Hence, those samples are supposed as starting points for deep aquifers in Semarang and classified into uncontaminated groundwater by seawater. Sampling sites of S5 and S9 with the depth of 120 m and the distance from the shoreline around 680 m and 3.6 km respectively, do not indicate seawater intrusion. S2, S7, and S8 wells also underwent the similar evidence located about 950 m to 3.6 km from the shoreline and the depths around 40 - 60 m. Those characteristics of fresh groundwater shows that hydrostatic pressure balance between freshwater and seawater systems are still well maintained. Another possibility can be explained that there is an impermeable layer stretching out under unconfined aquifer, such that the seawater does not easily pass through this layer and it give an excellent protection for the confined aquifer. While the well of S13 located at a hilly land in southern part with the distance of 9.4 km from the shoreline still represents freshwater composition.

Group II: Groundwater with an Indication of Seawater Intrusion

The groundwater samples in this cluster show more enriched values of stable isotopes than those in Group 1. This group consists of S1, S3, S4, S6, S10, S11, and S12 wells. The sampling sites of S1, S3, S4, and S6, located around 1 km to 5 km distance from the shoreline, has an isotopic variation in the range of -5.78 ‰ to -4.46 ‰ and -36.69 ‰ to -31.36 ‰ for $\delta^{18}O$ and $\delta^{2}H$, respectively. While, the other sampling sites such as S10, S11, and S12 situated approximately 5 km to 6 km distance from the shoreline are found in the range of -5.09 ‰ to -4.61 ‰ and $\delta^{2}H$ -35.94 ‰ to -34.40 ‰ for $\delta^{18}O$ and $\delta^{2}H$ isotope values, respectively. As seen at Figure 2, the cluster of S3, S4, and S12 wells are in the right side; the cluster has most enriched value, distributed along the freshwater-seawater mixing line reflecting as most encroached groundwater by seawater. The indication of seawater intrusion that is estimated from $\delta^{18}O$ and $\delta\ ^{2}H$ approaches is confirmed further by utilizing hydrochemical data and the relationship $\delta^{18}O$ versus salinity.

Hydrochemicals

Salinity

Salinity is an important component in the determination of the extent of seawater- freshwater mixing portion in most coastal regions. Salinity increases proportionally to chloride content as expressed through the following equation: salinity (ppt) = 0.0018066 x Cl^{-} (mg/l). Salinity level for seawater is about 35 ppt (35.000 mg/l), whereas brackish water in the coast is in the range of 1 - 10 ppt (Vernier Software and Technology, 2014). In this investigation, some groundwater samples such as S3, S4, S11, and S12 have the salinity that are higher than 1. The characteristic of groundwater can also be observed through the relationship between $\delta^{18}O$ value and Salinity (Gaye, 2001) as illustrated in Figure 4 for deep groundwater samples from Semarang. The status of the deep aquifer in Semarang according to the figure could be classified into three groups. Those are:

1. Group-I: fresh groundwater, consisting of S2, S5, S7, S8, S9, and S13
2. Group-II: groundwater under slight seawater intrusion, comprising of S1, S6, and S10
3. Group-III: groundwater under moderate to high seawater intrusion, composed of S3, S4, S11, and S12.

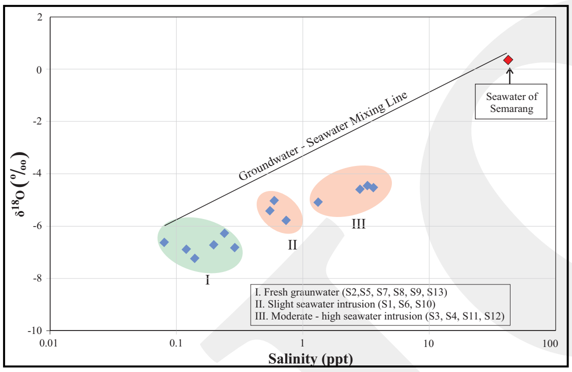

Figure 4. Relationship between $\delta^{18}O$ value and salinity for a deep aquifer in Semarang coast.

Chloride-Bicarbonate Ratio (R)

As mentioned above, the ratio (R) of chloride and bicarbonate can be used to characterize the extent of the salinization process in groundwater. Hydrochemical results and calculated R-value for deep groundwater and seawater from Semarang are shown in Table 4. Concentrations of CO_3^{2-} component for all samples are neglected in this calculation due to their values of 0 ppm.

Chloride and bicarbonate ratio (R) contained in groundwater from a deep aquifer in the Semarang coast is classified into five groups as revealed in Table 5. R-value of S2, S5, S7, S8, S9, and S13 wells seem to be less than 0.5 indicating a characteristic of freshwater. Well sites of S5 and S7 at a distance of about 600 m and 950 m from the shoreline, respectively, seemingly do not undergo seawater intrusion referred to their lower ratio of chloride-bicarbonate. This evidence is confirmed by their more depleted isotope values of δ^2H and $\delta^{18}O$ spreading along Semarang meteoric water line, as characterized by the fresh groundwater. The other sites have experienced seawater intrusion from slight to a high level. Sampling sites of S3 and S4 with the distance of 2 - 3 km from the shoreline have a high level of seawater intrusion. Sampling sites in the downtown of Semarang such as S10, S11, and S12 also indicates a slight to moderate level of seawater intrusion.

The Fraction of Seawater Associated With Deep Groundwater

Based on either the isotope values ($\delta^{18}O$ and δ^2H) or the molar ratio between chloride and bicarbonate (Table 5), it can be concluded that seawater intrusion has occurred in wells of S1, S3, S4, S6, S10, S11, and S12. Thus, it needs to determine the portion of seawater into the groundwater system for those sites. Determining seawater fraction associated with freshwater can be approached by using Equation (2) above (p.4). Data of $\delta^{18}O$ stable isotope in both rainwater and seawater representing each end member of freshwater and contamination source respectively are needed to calculate seawater mixture into groundwater. As seen in Figure 2, the intersection between a local meteoric water line and groundwater-seawater mixing line are on the $\delta^{18}O$ value of -6.9 ‰. The results for seawater fraction into deep aquifer are listed in Table 6.

The site of S6 located at 1,190 m distance from the shoreline are characterized as the lowest fraction of seawater around 0.15. The highest fraction of seawater as much as 0.34 occurs at S3 located at a distance of 3,220 m from the shoreline. The other sites such as S10, S11, and S12 within 5-6 km from the shoreline representing the centre part of Semarang City has between 0.25 to 0.32 of seawater fraction.

Table 4. Hydrochemical Analysis Results in the Deep Aquifer

No.	Sample ID	Salinity (ppt)	Cl^- (ppm)	Na^+ (ppm)	HCO_3^- (ppm)	R
1	Seawater	41.12	22,763.9	103.77	148	153.81
2	S1	0.55	305.89	65.98	252	1.21
3	S2	0.24	133.74	34.6	232	0.58
4	S3	3.25	1,802.14	270.69	188	9.59
5	S4	3.64	2,015.55	445.58	328	6.14
6	S5	0.12	68.29	42.77	216	0.32
7	S6	0.74	407.85	148.68	356	1.15
8	S7	0.08	45.53	106.35	240	0.19
9	S8	0.20	123.82	51.2	472	0.26
10	S9	0.29	161.24	105.45	224	0.72
11	S10	0.60	331.97	83.9	344	0.97
12	S11	1.33	735.08	136.85	472	1.56
13	S12	2.83	1,565.02	199.9	680	2.30
14	S13	0.14	76.83	163.5	464	0.17

Table 5. Molar Ratio between Chloride and Bicarbonate in the Deep Aquifer of Semarang Coast

	Sample ID	Level of Seawater Intrusion
< 0.5	S2, S5, S7, S8, S9, S13	Fresh groundwater
0.5 - 1.30	S1, S6, S10	Slightly encroached
1.30 - 2.80	S11, S12	Moderately encroached
2.80 - 6.60	S4	Injuriously encroached
6.60 - 15.50	S3	Highly encroached

Table 6. Fraction of Seawater into Deep Groundwater in Semarang Coast

No.	Location	Sample ID	Fraction of Seawater
1	SMK Texmaco Semarang	S1	0.20
2	Mosque of Baitul Muttaqin	S3	0.34
3	Puri Anjasmoro Blok N	S4	0.33
4	Mosque Nurul Falah	S6	0.15
5	Disnakertrans	S10	0.26
6	STEKOM Majapahit	S11	0.25
7	Aneka Jaya Shop	S12	0.32

Conclusion

Based on the isotope data of δ^2H and $\delta^{18}O$ in the groundwater samples collected from a deep aquifer in Semarang, the groundwater is classified into three groups. The first group consists of S2, S5, S7, S8, S9, and S13 sites. The sampling sites of S5 and S9 with the depth of 120 m are located at the distance about 680 m to 3.6 km from the shoreline. Meanwhile, the sampling sites of S2, S7, S8, and S13 with the depth about 40 m to 60 m occur at the distance about 950 m to 3.6 km from the shoreline. All of the δ^2H and $\delta^{18}O$ values in the first group are characterized by their more depleted isotope values, *i.e.* between -7.23‰ and -6.29‰ for $\delta^{18}O$, and between -41.70‰ and -37.00‰ for δ^2H. In comparison with the local meteoric line, these values are distributed close to the local meteoric water line indicating its meteoric origin. Figure 4 also shows that the salinity value of the first group consisting of S2, S5, S7, S8, S9, and S13 sites is smaller than 1. Thus, it can be concluded that groundwater in the first group is freshwater, where there are no seawater intrusion indicated.

The second group comprising of S1, S6, and S10 sites has a salinity value which is almost one. The δ^2H and $\delta^{18}O$ values in the second group are characterized by their isotope values which are richer than the first group isotope values, *i.e.* between -5.78‰ and -5.02‰ for ^{18}O, and between -36.69‰ and -35.94‰ for δ^2H. It indicates the groundwater in the second group is slightly under seawater intrusion.

The third group composed of S3, S4, S11, and S12 sites has the salinity higher than one which indicates a seawater intrusion. Seawater mixture associated with the occurrence of groundwater salinization process is characterized by their enriched isotope values. Those points have shifted away from the local meteoric water line and are laid at seawater-freshwater mixing line.

Hydrochemical data show that seven deep groundwater sites, those are S1, S3, S4, S6, S10, S11, and S12, are supposed to be mixed with seawater. While the others are still predominated by freshwater, such type is also indicated through δ^2H and $\delta^{18}O$ data. Groundwater under slight seawater encroachment is S1, S6, and S10 with the range of seawater fraction are 0.15 to 0.26. While moderate to high ones occur in S3, S4, S11, and S12 with the fractions of seawater are in the range of 0.25 to 0.34. Nevertheless, there is an interesting point that the portion of seawater into the deep aquifer system in Semarang is independent either to the distance from the shoreline or the depth of bore well. It is confirmed by the evidence in sites S5 and S7 located from the shoreline around 680 m and 950 m, respectively, which are still characterized as a freshwater type. On the contrary, the further sites of deep groundwater around 5-6 km long from the shoreline clearly indicate seawater intrusion that has taken place in S10, S11, and S12 sites.

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