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Research Article

Degradation of groundwater quality due to the occurrence of salty-tasted water in Bayat District, Klaten, Central Java, Indonesia

Doni Prakasa Eka Putra*, Deviana Halim, Sandi Suko Widagdo, Rilo Restu Surya Atmaja

Department of Geological Engineering, Faculty of Engineering, Universitas Gadjah Mada, Jl. Grafika No.2 Bulaksumur, Sleman - Yogyakarta, Indonesia

*corresponding author: putra_dpe@ugm.ac.id

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Abstract: Bayat is located in the south of central Java, Indonesia. In the quaternary deposit area, groundwater on some dug wells taste salty and previous studies discovered salty-tasted water with electrical conductivity (EC) >5000 µS/cm and chloride concentration >1000 mg/l. Local information reported that the number of wells containing salty-tasted water increased after the 6.2 Mw earthquake on May 27th, 2006 in Yogyakarta. This research aims to determine the distribution of salty-tasted groundwater and its relation with the geological condition by conducting a hydrogeological investigation. On the hydrogeological investigation, dug wells were observed for physical-chemical characteristics such as total dissolved solid (TDS) and EC; additionally, groundwater samples were collected for chloride ion analysis. Geology of the study area is mapped based on previous studies. The result showed that the high TDS/EC groundwater correlated with salty-tasted water which found in three different areas, including in the west, middle and east part of the study area. The occurrence of salty-tasted water strongly aligns with faults zone. In conclusion, deep salty-tasted water emerges not only locally near the fault zone but also associated with trapped groundwater and buried anticline. In regard to those sources, it can be predicted that in the near future more dug wells water may turn into salty-tasted water, especially in the area closed to the fault zone.

***Keywords**: Bayat-Indonesia, groundwater quality, salty-tasted groundwater*

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Introduction

Degradation of groundwater quality is one of the challenges to sustain the use the groundwater resources nowadays and in the future. The degradation of groundwater quality is a common problem, especially in the urban and rural area, in which many possible anthropogenic pollution sources can occur (Putra, 2007). A wide variety of materials have been identified as contaminants, such as synthetic organic chemicals, hydrocarbons, inorganic cations, inorganic anions, pathogens, and radionuclides (Fetter et al., 2018). Not all of these contaminants originated from anthropogenic activities, some contaminants may come from natural as well as anthropogenic sources, especially the inorganic cations including heavy metals and anions which occur in nature of groundwater (Fetter et al., 2018). Stefanakis et al. (2015) listed some natural causes of groundwater pollution, i.e., easily dissolved rock, intense evaporation especially in the shallow groundwater which causes elevation of groundwater and salt deposition, degradation of water sources in the geothermal/volcanic field, rock oxidation, sea water intrusion and natural chemical reactions in the water. In other words, the cause of natural contamination is closely related to the geological condition. A widespread of arsenic in the shallow groundwater of Bangladesh is one of harmful example caused by natural geological sources of pollution (Schmoll et al., 2006).

Bayat, Klaten, Central Java, Indonesia is located in the southeast part of the Merapi Volcano. Bayat district has a tropical climate and inhabited by about 53,675 population (Badan Pusat Statistik, 2020). The study area itself covering area approximately 39 km^2 (see Figure 1). Geologically, Bayat area consisted of pre-tertiary metamorphic rocks (one of the oldest rocks assemblages which is exposed in Java Island), diorite intrusion, and tertiary sedimentary rocks such as claystone to limestone of Wungkal Gamping Formation, volcaniclastic rocks of Kebobutak Formation, and limestone of Wonosari Formation, Quarternary Merapi Volcano deposits, and old to young alluvium deposits (Surono et al., 1992). Quarternary Merapi Volcano Deposits is known as a major aquifer in the slope of Merapi Volcano (Hendrayana, 1993; MacDonald and Partners, 1984).

The geological structures in Bayat area are complex and formed by the tectonic activities of the subduction of Australian plate to Eurasian plate (Van Bemmelen, 1949; Smyth et al., 2007; Smyth et al., 2011; Setiawan et al., 2013). The main tectonic force direction was north-south, forming the anticlines extending east-west, and sinistral strike-slip faults extending northeast-southwest. Complex tectonic processes also caused sinistral strike-slip faults extended northwest-southeast, which is opposite to the orientation of the other sinistral strike-slip fault (Van Bemmelen, 1949). On this complexity of the geological condition, most of the area classified as a region without exploitable groundwater (Setiadi et al., 1990).

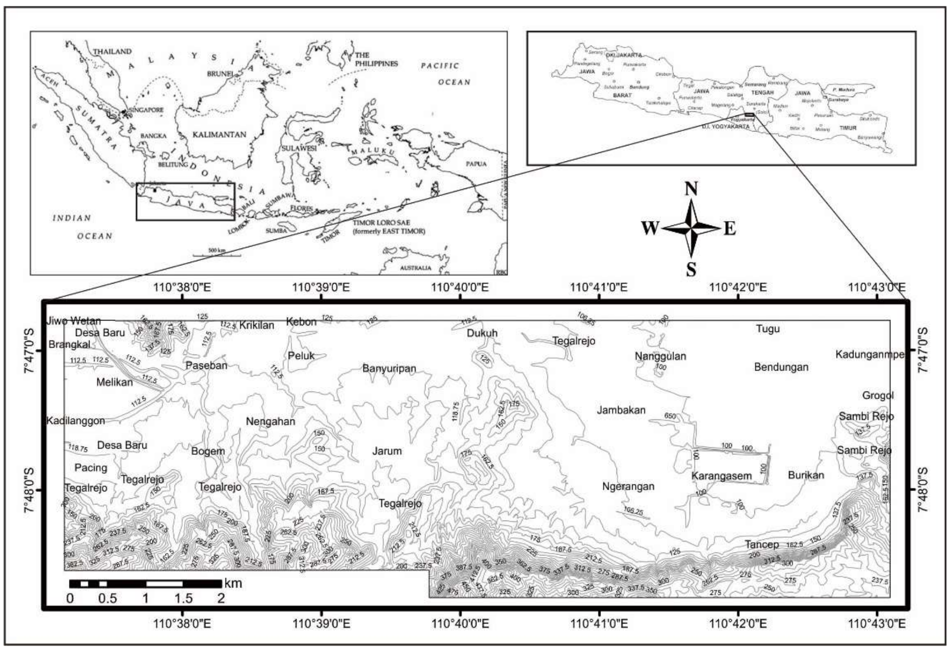

Figure 1. Location of the study area.

However, previous studies from Halim (2016), Putranto et al. (2017) and Widagdo (2016) showed that dug wells can be found on this area with depth to groundwater less than 15 m from ground surface and locally located on the Quarternary Merapi Volcano and alluvium deposits, but also some dug wells are found in the weathered pre-tertiary and tertiary sedimentary rocks. This shallow groundwater is the main source of daily water use in this area and most local people used dug wells to abstract the groundwater. Furthermore, no local water company of Klaten regency provided water supply to this region (Badan Pusat Statistik, 2020). Not all dug wells on this area have a good quality of water, some of the dug wells produce salty-tasted water and these water have electrical conductivity more than 5000 µS/cm (high salinity), chloride concentration of 1275.5 mg/l and classify as Na-Cl water type (Putranto et al., 2017). Putranto et al. (2017) identify five hydrochemical groundwater type in the Bayat area, namely Ca-Mg-HCO3 (the most dominant water type), Ca-Na-HCO_3-Cl, Na-HCO_3, Ca-SO_4 and Na-Cl. According to PAHIAA (1986), such value of electrical conductivity and chloride content in groundwater is classified as slightly brackish to brackish water that explaining why the water taste salty. Moreover, the Na-Cl water facies in groundwater is the common water chemistry facies related or originated from deep geothermal fluids (Mohan et al., 2000), deep groundwater system (Hoelting and Coldeway, 2013), sea water intrusion and brine water (Mazor, 2004; Eby, 2004).

Guo et al. (2019) summarize three sources of salinity in the sedimentary rock aquifer, namely halite dissolution, connate water and geological filtration. In addition, the residence time of water within the groundwater system is suggested to be a factor affecting the groundwater salinity (Guo et al., 2019). As the location of Bayat area is very far from the sea, sea water intrusion may be neglected in this case. Another issue reveals from local communities described that after the 6.2 Mw earthquake on May 27th, 2006, which caused damage on the magnitude of VI-VII MMI scale in Bayat region, the number of wells containing salty-tasted water is increasing. This information gives a question whether the movement of faults due to earthquake induced the opening of the pathway of brackish and saline water from the deeper aquifer to flow upward from depth to the surface through fault plain and causing the spreading of salty-tasted water in the shallow groundwater system. Previous research regarding the movement of deeper brackish and saline water in the groundwater via faults have been reported by Maslia and Prowell (1990), Kindinger et al. (2001), Atmaja and Putra (2016), Atmaja and Putra (2017), and Guo et al. (2019). Moreover, Guo et al.(2019) mentioned that the emergence of saline and salty spring can occur not only due faults but also due to geological anticline, combination of anticlines and faults and contact between different types of lithology strata.

In accordance with the previous description as well as the condition of groundwater quality that have been affected by salt water, hence this study aims to determine the distribution of salty-tasted groundwater in a larger area. Secondly, to investigate the relation between the occurrence of salty-tasted water and geological condition by conducting a hydrogeological investigation.

Methods

Hydrogeological investigation on this research consisted of three main processes which included geological mapping based on secondary data, hydrogeological field observation, and laboratory analysis.

First, to reveal a geology map for the study area, geological data from previous studies of Halim (2016) and Widagdo (2016) were re-analyzed to produce the geological map in the research area. Second, as many as 591 wells were observed during field hydrogeology observation (see Figure 2) in order to obtain data of depth of the groundwater level, physical and chemical properties of groundwater including electrical conductivity (EC) and Total Dissolved Solid (TDS). EC and TDS were measured by portable water test kit HI-98192. The distribution of data was dense to ensure the good result from interpolation and extrapolation of data. From the field observation data, the groundwater level depth map, groundwater level and flow direction map, as well as TDS and EC zonation map were produced. The classification of water, according to PAHIAA (1986) was used to classify the salinity of groundwater (see Table 1).

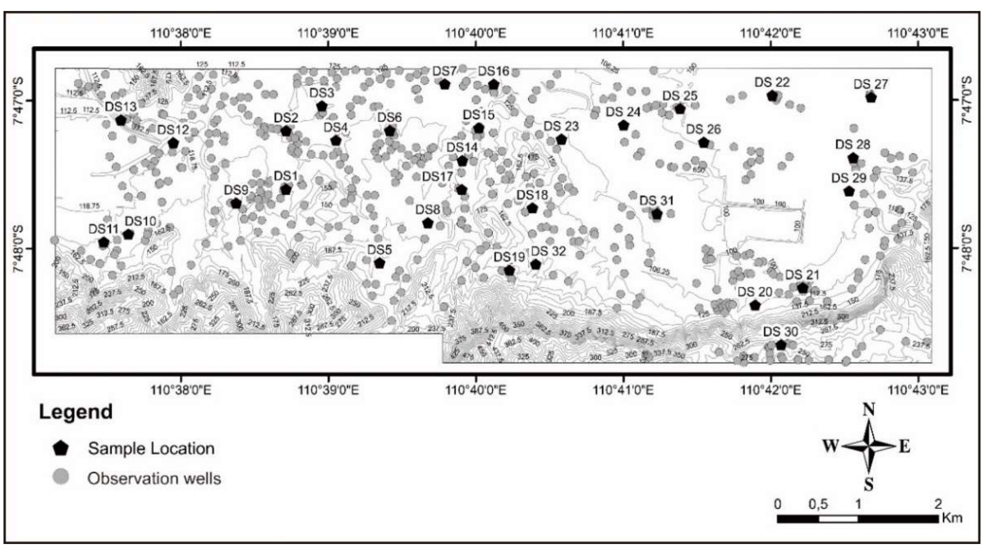

Figure 2. Location of field hydrogeological observation and water sampling locations.

This classification was used because ordinary classifications such as from Fetter (2001) do not differentiate the type of brackish water. According to Fetter (2001), brackish water is water with TDS between 1000-10000 mg/L. Third, sampling of groundwater was selected based on stratified random sampling by considering the area coverage, geology condition (faults/not faults area) and the distribution value of electrical conductivity of groundwater.

Table 1. Water classification based on EC and TDS (PAHIAA, 1986).

Type of water	EC (µS/cm)	TDS (mg/l)
Fresh	<1500	<1000
Slightly brackish	1500-5000	1000-3000
Brackish	5000-15,000	3000-10,000
Saline	15,000-50,000	10,000-35,000
Brine	>50,000	>35,000

Thirty-two groundwater samples were collected in the study area. On each sampling location, each water was taken from dug well and filtered by 0.20 µm syringe filter during injecting the water into 100 ml plastic bottle. During transport to the laboratory, samples were kept in the cool-box to preserve the sample condition. Groundwater samples were analyzed in the Department of Geological Engineering, Faculty of Engineering, UGM. The analysis was conducted only for chloride ion. The analysis of water is using Ion Chromatography (IC) MetroOhm 850 in which chloride (Cl-) was analysis by applying Metrosep A Supp 7-250/4.0 IC column.

Results

Based on the secondary data of the geological mapping conducted by Halim (2016) and Widagdo (2016), the geological map of the study area could be revealed, as shown in Figure 3. According to Figure 3, it can be seen that the study area is composed by six units of lithology from the older to the younger (Pre-tertiary to Quaternary age) respectively are metamorphic rocks, tuffaceous siltstone, tuffaceous sandstone, basaltic andesite, calcareous tuffaceous sandstone, and sandy-clay deposits. Metamorphic rocks assemblage is the oldest rocks in the research area with age estimation of Pre-tertiary (Surono et al., 1992). Lithologies found on this unit are phyllite, skarn, marble and minerals calcite crystals. According to Widagdo (2016), phyllite in the study area consisted of muscovite, biotite, quartz, chlorite, and opaque minerals. Tuffaceous siltstone is mainly composed by tuffaceous siltstone with minor intercalation of tuffaceous sandstone and carbonaceous tuffaceous sandstone. According to Halim (2016), this rock unit consisted of lithic fragment of sedimentary rock, lithic fragment of igneous rock, feldspar, tuff, opaque minerals, pyroxene, quartz, and matrix of feldspar and volcanic glass.

Tuffaceous sandstone mainly consists of tuffaceous sandstones and minor intercalation of tuffaceous siltstone and carbonaceous tuffaceous sandstones. Under petrographic observation, tuffaceous sandstone consisted of fragment of sedimentary lithic, tuff, feldspar, igneous lithic, and matrix of igneous lithic, sedimentary lithic, feldspar, quartz, volcanic glass, and opaque minerals (Halim, 2016; Widagdo, 2016). Both sedimentary rocks formed in the Late Oligocene - Early Miocene, similar to the existing of Basaltic Andesite intrusion (Surono et al., 1992). The intrusion of basaltic andesite consisted of andesite fragment and matrix of igneous lithic and hornblende (Halim, 2016; Widagdo, 2016). In the Early Miocene, Calcareous Tuffaceous Sandstone was formed, and this unit consists of carbonaceous tuffaceous sandstones with minor intercalation of carbonaceous tuffaceous siltstone and limestone. According to field observation, the calcareous tuffaceous sandstone consisted of lithic, volcanic glass, feldspar, carbonate materials, quartz, and tuff. Sandy-clay deposit unit is formed during Quaternary Holocene (Surono et al., 1992) and consisted of claystone deposits, clay sediment, black clay deposits, and loose sand. Based on the explanation above, rocks in the research area mainly consisted of silicate minerals, volcanic materials, and fragment of igneous and sedimentary lithic. Moreover, both field and petrographic observation on rocks confirmed the absence of halite. Most of the Tertiary sedimentary rocks on this area have dipping relatively to the south direction.

There are several geological structures found in the research area, which are relatively from west to east, Nengahan sinistral strike-slip fault, Trembono sinistral strike-slip fault, Tegalrejo sinistral strike-slip fault, Karangasem buried anticline, Sambirejo inferred sinistral strike-slip fault and Tancep inferred reverse fault (see Figure 3) (Halim, 2016; Widagdo, 2016). Nengahan sinistral strike-slip fault located at the westernmost of the research area. While Trembono sinistral fault which is the longest strike-slip fault in research area located in the middle. Tegalrejo sinistral strike-slip fault located in the east of Trembono sinistral strike-slip fault. Those three sinistral strike-slip faults have the same NE-SW orientation.

Samiberejo inferred sinistral strike-slip fault located at the easternmost of research area elongated in an NW-SE orientation. Karangasem buried anticline located in the east elongated in a WNW-ESW orientation. In the middle, the anticline cut by Tegalrejo sinistral strike-slip fault. Tancep inferred reverse fault located in the south elongated in an E-W orientation and curved to NE-SW in the east. Trembono sinistral strike-slip fault is the main faults and the most anticipated as the controlling factor of the emergence of salty groundwater.

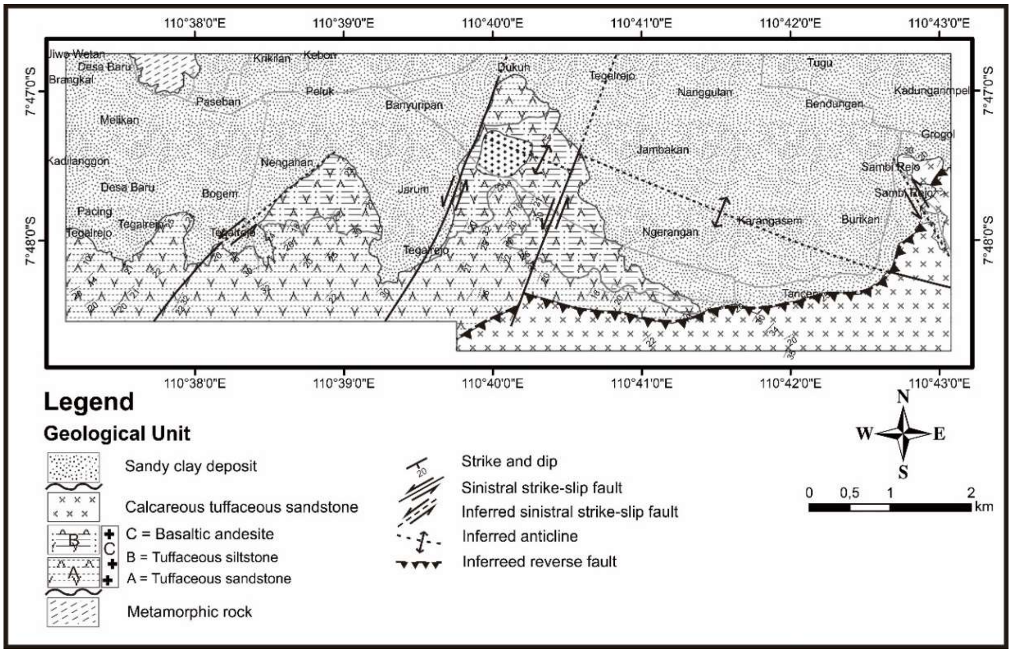

Figure 3. Geological map of the study area.

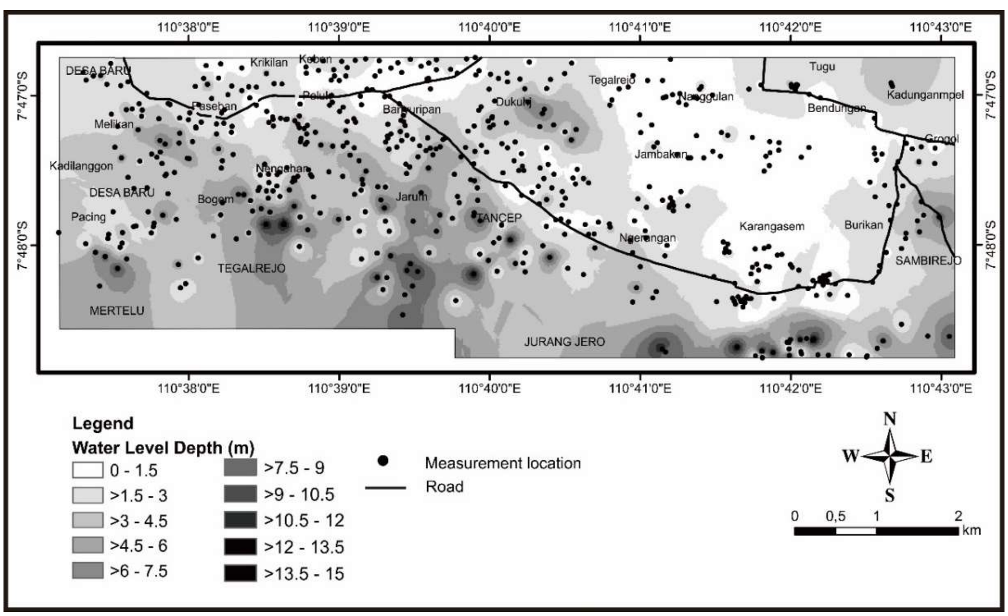

Figure 4. Groundwater level depth in the study area.

In the study area, shallow groundwater mainly found in dug wells but no wells located in metamorphic rocks area. Based on the measurement in the field, groundwater depth ranging of 0.2-14.8 m below surface. The depth of groundwater varies depending on the landscape and elevation of the location of wells. The depth of groundwater level in high elevation area is deeper than groundwater depth to surface in the low land area (see Figure 4). Plain and low land areas in the east have very shallow groundwater level. This location related to sandy-clay alluvial deposit. The groundwater level in research area ranging from 99 to 279 masl and the groundwater flow mainly from south to north which mainly controlled by topography.

Nonetheless, in the north in alluvial plain area, close to the edge of impermeable metamorphic rocks outcrop, the groundwater flow changes its direction to west or east or at some area concentrate to build a closed contour of groundwater flow (see Figure 5).

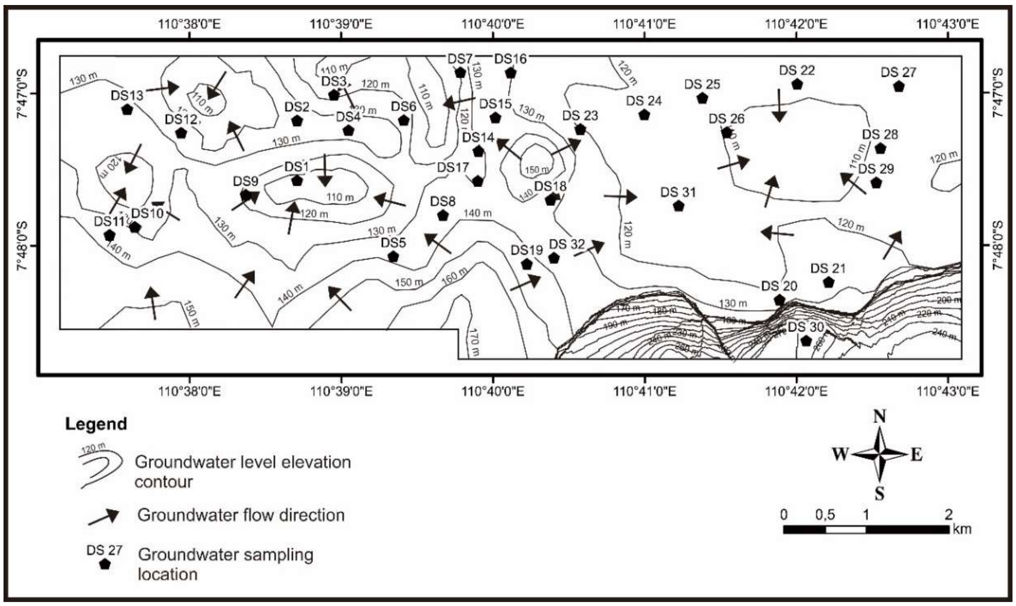

Figure 5. Groundwater level, flow direction and sampling location in the study area.

The physical-chemical characteristics of groundwater represented by electrical conductivity (EC) and total dissolved solid (TDS) from the observed dug wells showing a range of value between 207-6426 µS/cm and 90-3390 mg/l, respectively. Based on PAHIAA (1986) classification, those value representing three types of water in the study area fresh, slightly brackish and brackish groundwater. Result of chloride analysis for 32 samples of groundwater is provided in Table 2. From this table, the concentration of chloride in the groundwater in the study area found to be range between 14.2 to 973.9 mg/l or 0.40 to 27.3 meq/l.

Discussion

Relation of water properties, groundwater flow and geological condition

In order to answer the first objective of the research to determine the distribution of salty tasted water, the distribution map of groundwater EC from 591 observation points is provided and shown in Figure 6. Based on this figure, most of the groundwater in the study area is categorized as freshwater type, and the occurrence of slightly brackish groundwater is found in the west-part (Melikan and Pacing Village), middle-part (Dukuh and Tancep Village) and northeast-part (Nanggulan and Tugu Village) of the study area. Moreover, brackish water is local to be found in the middle part of the study area. Brackish water in the middle part was reported by Putranto et al. (2017), and a similar result is also found in this study.

According to Figure 6, a question rise, why the occurrence of slightly brackish to brackish water is only local on spotted location? Sea water intrusion is already neglected as the study area is very far from the sea. Another cause of geothermal activities is also discarded because no hot water springs relate to the geothermal system found in the area. The hypothesis mentioned in the background is the source of salty-tasted water comes from deeper groundwater system due to opening of groundwater flow pathway caused by faults. To prove this, an attempt was made by overlaying the distribution value of groundwater EC with the geological map, as shown in Figure 7. From the overlaying map, it can be seen that slightly brackish water and brackish water emerge locally and correlated only with Trembono fault zones (see Figure 7).

Report from the local villagers about the increasing number of dug wells with salty-tasted water actually comes from this area, especially after the Yogyakarta earthquake 2006. Moreover, brackish water is also found dominantly in this area. Nevertheless, it is agreed that the other fault zones do not have an occurrence of slightly brackish to brackish water. This phenomenon is proven that not all faults can act as a conduit for water flow. Faults may facilitate storage and flow of groundwater depends on its aperture, roughness, material filling, orientation and its forming stress (Singhal, 2008). Trembono sinistral strike-slip fault and Nengahan sinistral strike-slip fault may be formed by same stress orientation. Nonetheless, two of which have a different impact on groundwater flow. Trembono sinistral strike-slip fault may be an open fault zone which acts as a conduit. Whereas Nengahan sinistral strike-slip fault may be a sealed one. Therefore, further observation of fracture density and orientation, aperture, roughness and filling need to be conducted in order to fully understand the hydraulic conductivity of faults. Other locations with slightly brackish and brackish water in the study area are not correlated with geological fault, the cause may relate to the groundwater flow pattern and others may be controlled by the existing of buried anticline of Karangasem. Hoelting and Coldeway (2013) mentioned with regard to the anions, long flow paths and sufficient reaction time to chemical and physical adjustment equilibrium states following sequence (equation 1):

$$HCO_3^- \rightarrow (+\ CO_3^{2-}) \rightarrow HCO_3^- + SO_4^{2-} \rightarrow SO_4^{2-} \rightarrow SO_4^{2-} + Cl^- \rightarrow Cl^- + SO_4^{2-} \rightarrow Cl^- \quad \ldots\ldots\ldots\ldots \quad (1)$$

Table 2. Chloride concentration in the groundwater from the study area.

Sample No	EC (µS/cm)	Cl^- (mg/l)	Water Type	Sample No	EC (µS/cm)	Cl^- (mg/l)	Water Type
DS 1	2290	128.0	Slightly brackish	DS 17	6790	11.12	Brackish
DS 2	1430	83.8	Fresh	DS 18	2620	85.9	Slightly brackish
DS 3	2070	236.4	Slightly brackish	DS 19	1090	41.1	Fresh
DS 4	1780	94.8	Slightly brackish	DS 20	1070	71.1	Fresh
DS 5	380	14.2	Fresh	DS 21	2660	444.3	Slightly brackish
DS 6	2970	89.6	Slightly brackish	DS 22	5530	847.0	Brackish
DS 7	860	55.0	Fresh	DS 23	2700	137.0	Slightly brackish
DS 8	910	41.7	Fresh	DS 24	870	47.9	Fresh
DS 9	720	17.4	Fresh	DS 25	3230	530.9	Slightly brackish
DS 10	4870	331.1	Slightly brackish	DS 26	3370	639.5	Slightly brackish
DS 11	2460	409.1	Slightly brackish	DS 27	2250	239.9	Slightly brackish
DS 12	2110	319.9	Slightly brackish	DS 28	1850	74.6	Slightly brackish
DS 13	2580	612.7	Slightly brackish	DS 39	1910	136.6	Slightly brackish
DS 14	3450	944.8	Slightly brackish	DS 30	1230	77.0	Fresh
DS 15	6120	973.9	Brackish	DS 31	2300	238.5	Slightly brackish
DS 16	2320	98.5	Slightly brackish	DS 32	2680	395.4	Slightly brackish

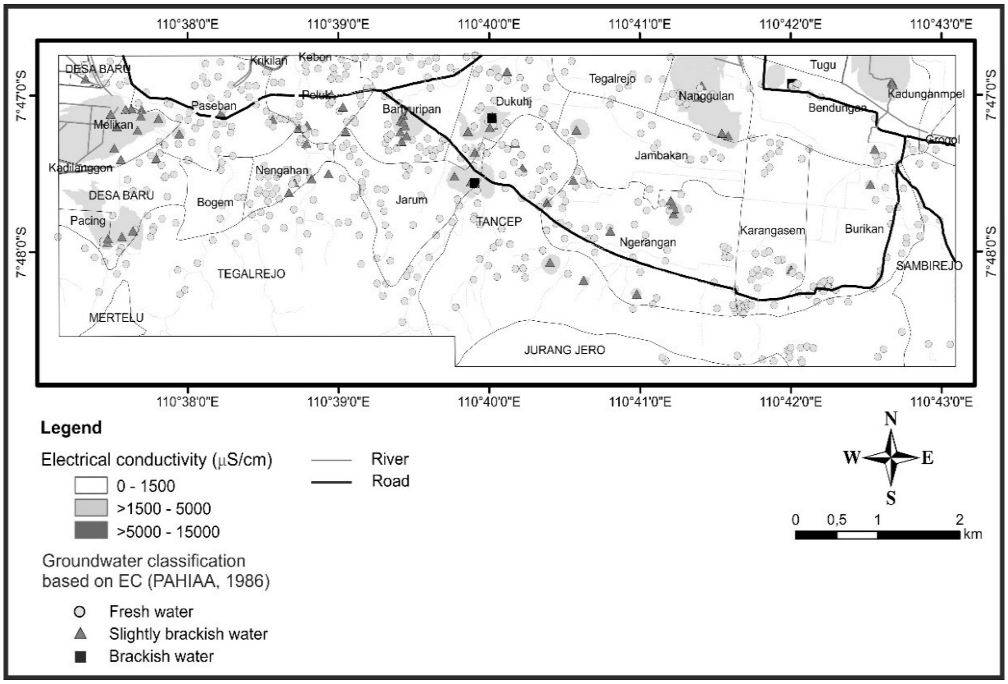

Figure 6. Electrical conductivity of groundwater in the study area.

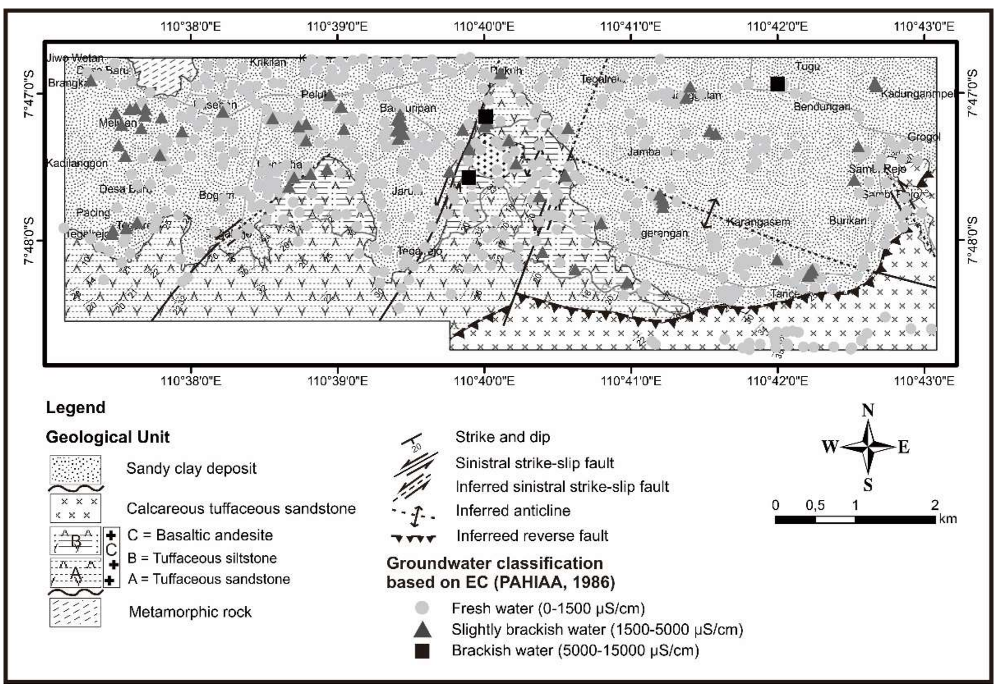

Figure 7. Geology versus electrical conductivity of groundwater in the study area.

Hoelting and Coldeway (2013) also stated regarding the above sequence that if in the aquifer materials due to the petrographic nature contain less Cl, the sequence can end beforehand. It means the final dominance anion maybe not the only chloride. In other words, the older the groundwater age, and the higher the sulphate and chloride content will be. These hydrochemical characteristics in which sulphate also become the dominant ion in the Bayat area is reported as Ca-SO_4 groundwater facies by Putranto et al. (2017).

Once again to prove the hypothesis, the groundwater flow pattern was overlaid by groundwater's EC value indicating a correlation between the closed contour of groundwater flow pattern with the local emergence of slightly brackish to brackish water. Closed groundwater flow system means a slow movement of groundwater and longer residence time which causing increase of interaction between water and the rock material of the aquifer become old trapped groundwater system, and the older the age of water, the higher the chloride content will be (Mazor, 2004). There are five closed groundwater flows forming annular groundwater flow pattern where groundwater from all direction flow centrally into one area (see Figure 5). Most of the closed groundwater flow system is located in the west part of the study area (Banyuripan, Peluk, Paseban, and Melikan), while only one closed groundwater flow system located in the east part of the study area. It can be identified that slightly brackish water also emerges in those areas. All of these groundwater closed systems are located in sandy-clay alluvial deposits. The phenomena of closed groundwater contour in the alluvial plain of Bayat prove that this area is the groundwater accumulation area, as also described by Putranto et al. (2017). Some minor slightly brackish water also found near the axis of buried anticline of Karangasem (see Figure 6 and 7). Guo et al. (2019) mentioned that the emergence of salty water in the anticline relate to the well developed vertical fractures between stratigraphic layers of anticline structure.

Based on the above facts, there shall be different characteristics between salty-tasted groundwater due to upwelling of deep groundwater system via fault or fractures in the buried anticline and due to the closed/trapped groundwater flow system. Figure 8 shows a compositional diagram between chloride versus EC in order to understand the differences. A compositional diagram is a useful tool to understand the grouping of groundwater type (Mazor, 2004).

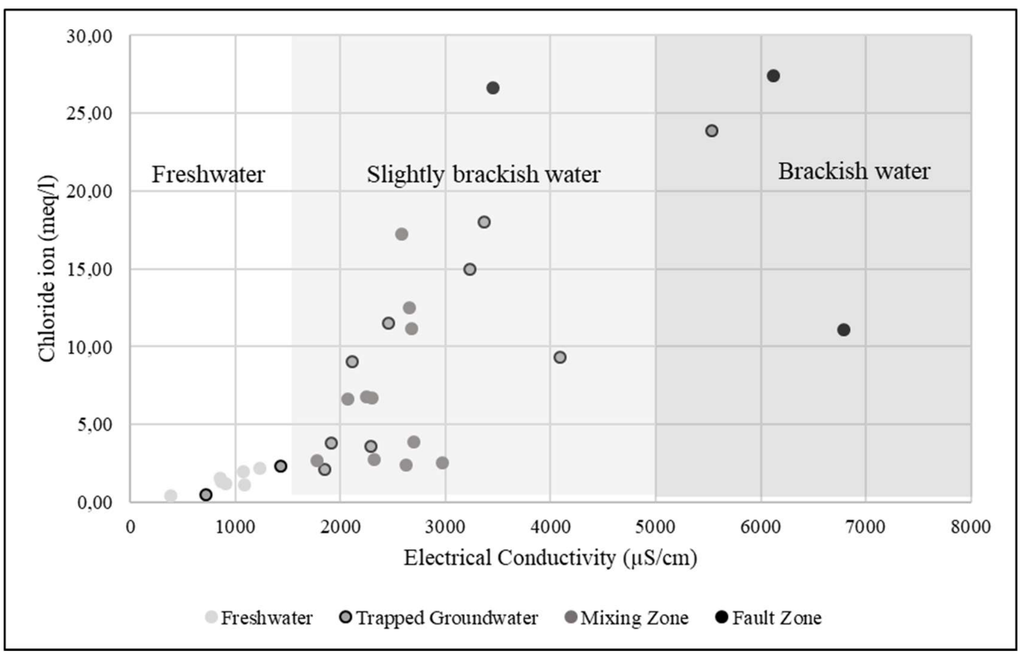

Figure 8. Composition diagram of Cl-EC in groundwater of the study area.

All 32 groundwater samples plotted in this diagram and classified into 3 clusters showing a group of freshwater, slightly brackish water and brackish water in a linear pattern. Mazor (2004) stated a linear pattern in the compositional diagram indicates a mixing between water type. There are two important things revealed from Figure 8, (1) all two samples taken in dug wells of the Trembono fault zone area categorized as only the brackish water type, (2) samples taken in the closed/trapped groundwater flow system and near the axis of the buried anticline classify only as slightly brackish water. Regarding mixing probability, in the fault zone and buried anticline area, slightly brackish water can be occurred due to mixing processed of upwelling brackish water with freshwater type also. This process may also disperse and dilute the salty-tasted water to the surrounding and causing more dug wells to contain salty-tasted water and it is probable that the groundwater facies due to this mixing process represent by Ca-Na-HCO_3-Cl water type as reported by Putranto et al. (2017). According to the finding on this research, it can be predicted along the time, more dug wells will be naturally contaminated by this process.

Conceptual model of the occurrence of salty water

The following three conceptual models are proposed for the formation and occurrence of the brackish and slightly brackish water which caused groundwater in wells of the study area have become salty. The conceptual models are presented in Figure 9.

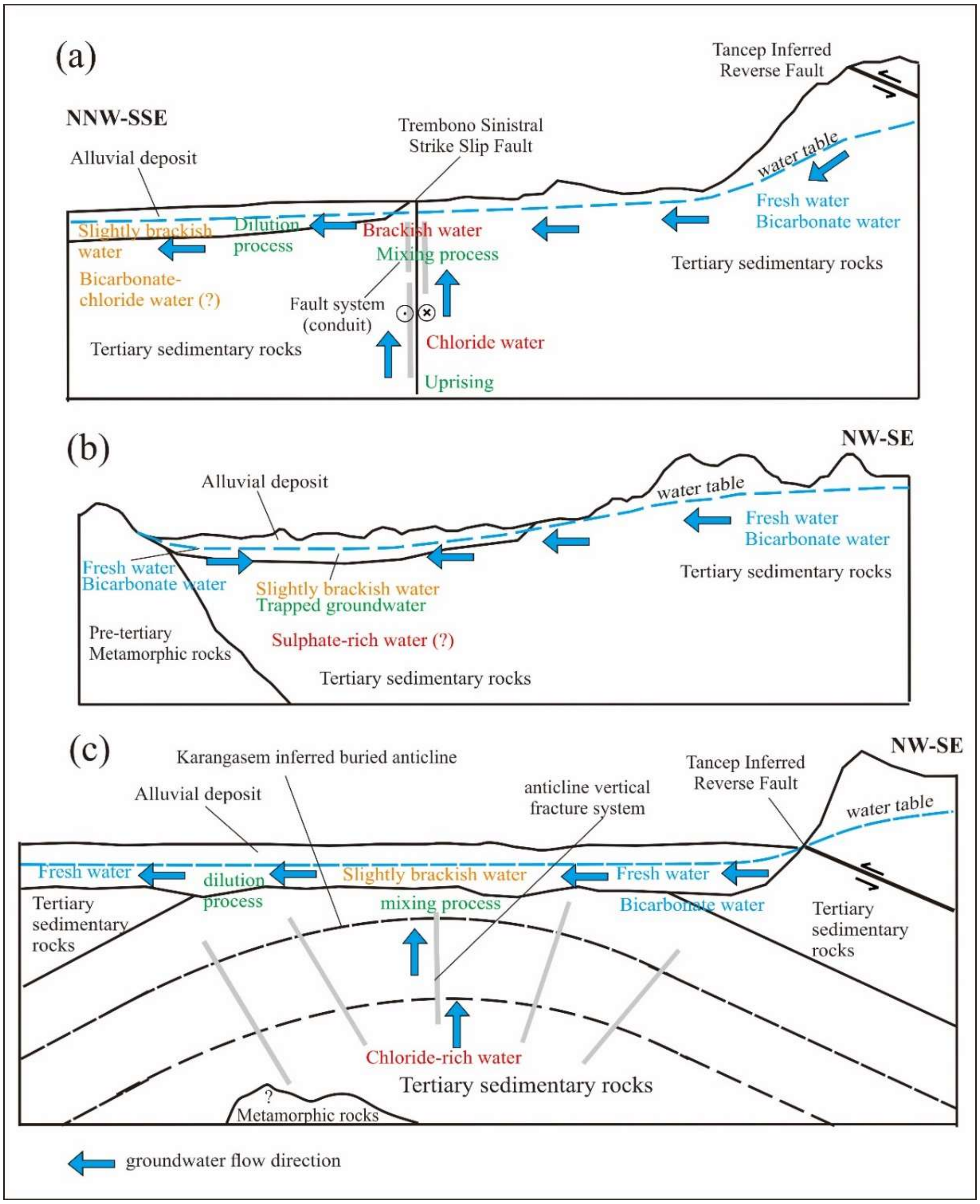

Figure 9. Conceptual models of the occurrence of salty-tasted water in Bayat (the figures are not to scale). (a) uprising flow of deep brackish water through Trembono fault zone. (b) trapped old groundwater due to closed groundwater system. (c) uprising flow of brackish water through fractures on the crest of Karangasem buried anticline.

The first conceptual model is the control of Trembono sinistral strike-slip fault. This conceptual model explains the occurrence of brackish and slightly brackish water along and near the fault zone. Deep brackish water which contains a high concentration of chloride flow upward to the surface through Trembono sinistral strike-slip fault zone. The fault zone act as a conduit which able to facilitate the uprising flow. The chloride water coming from the deep undergo the mixing process with freshwater (bicarbonate type water) resulting in brackish water emergence near the surface. Due to groundwater flow combined with the dilution process by freshwater, the brackish water changed into slightly brackish water. The slightly brackish water discovered in the west and northwest of Trembono sinistral strike-slip fault can probably be classified as bicarbonate-chloride type water.

The second conceptual model illustrates the effect of closed groundwater flow system on salty water emergence. As explained before, there are five closed groundwater flow systems related to the emergence of slightly brackish water. Most of them located on sandy clay deposit (alluvial deposit) in the west part of the study area. Old groundwater (fresh and bicarbonate type water) which trapped in the closed groundwater flow system along the time transformed into sulphate dominated groundwater type which increases the electrical conductivity and resulting salty taste. This conceptual model explains the occurrence of slightly brackish water in Banyuripan, Peluk, Paseban, and Melikan.

The third conceptual model is proposed to illustrate the impact of possible well developed vertical fractures on the crest of Karangasem buried anticline. This conceptual model explains the emergence of slightly brackish water along and near the axis of Karangasem inferred anticline. The well developed vertical fractures on the crest of Karangasem buried anticline allows deep chloride-rich water to flow upward. Near the surface, chloride-rich water undergone mixing process with freshwater (bicarbonate water type) resulting in slightly brackish water on shallow wells. Due to groundwater flow combined with the dilution process by freshwater, the slightly brackish water changed into freshwater. Consequently, all wells located further away from the axis of Karangasem inferred anticline are freshwater.

Conclusion

The main objective of this research is to understand the distribution and origin of salty-taste groundwater in the study area, which causing the degradation of groundwater quality. The salty-tasted groundwater in the study area found locally in all region of study area as slightly brackish and brackish groundwater type with a high concentration of chloride ion. The emergence of the salty-tasted groundwater also limited only in the sandy clay alluvial deposit. The occurrence of the salty-tasted water are in the west part (Melikan and Pacing Village), middle-part (Dukuh and Tancep Village) and northeast part (Nanggulan and Tugu Village) of the study area. Results of comprehensive evaluation include geological and hydrogeological shows that the origin of salty tasted water may come from three natural phenomena. First, the up-rising of deep brackish water flow through Trembono fault zone. Second, the trapped old groundwater in the closed groundwater flow system in which chloride and sulphate ions along the time will become the dominant ions. Lastly, the uprising of brackish water through fractures on the crest of Karangasem inferred buried anticline. In regard to those sources, it can be predicted that in the future more dug wells water in the study area may turn into salty-tasted water due to dilution and dispersion process between brackish water with fresh groundwater, especially in the area closed to the Trembono fault zone.

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