Geological Control To The Salinity Of Groundwater

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Abstract

The saline/brackish water can be found at many places in nature. This phenomena occurs under geological control of the certain place. The origin of the saline water refers to some hydrogeological processes, such as mixing of water (sea water intrusion or flushing), evolution, hydrochemical processes, connate water even man made polution. These origin of salinity should be known in order to build some mitigation ways. The mitigation process include preventive action (reduce groundwater abstraction or polution; control the groundwater flow by any geotechnical building) and remediation by chemical process. However, any saline water sometimes give benefit for society so this phenomena doesn't need remediation.

Key words : saline, groundwater, origin, treatment.

1. Introduction

There are many kind of groundwater in nature, especially in its quality. The quality of groundwater can be determined from its physical, chemical and biological characteristics. Some of the chemical parameters should determine of salinity of groundwater. Groundwater in nature can be found in fresh to saline condition.

There is saline/brackish groundwater that can be found in some places in nature. This phenomena occurs under certain geological control.

Geomorphologically, the saline/brackish water occur both at the high and low elevation. At the low elevation area, this saline water usually occur at the beach and surrounding area. This phenomena usually related with sea water intrusion. At the high elevation, saline groundwater even found at the high valley near peak of mountain.

Saline groundwater is also influenced by stratigraphic condition. Sedimentary rocks, especially which formed in marine environment often produce salinity to the water. This salinity related with salt of paleo sea water as connate water or produce by water-rock interaction between minerals and recent water. The saline water also may be resulted from interaction of minerals in igneous and metamorphic rocks and the meteoric water.

Geological structure can influence the occurence of saline groundwater because the groundwater flow depends on strike/dip of rocks and other structural phenomena likes fault, fold and joint. Sometimes, fault can serve as barrier or way of groundwater flow. Groundwater flows under geological structures control through the aquifers. Geological structures can facilititate the flow of groundwater, but sometimes these structures can block the flows. This condition can be occured in layers of sedimentary rocks which bear the impermeable layer.

Sometimes the saline water give benefit for the people surrounding area. However, saline water sometimes is assumed as polution. Some factors will influence to the occurrence and level of the salinity. Therefore we need to understand the origin of salinity in order to make some ways for mitigation. Determine the geological factors which control salinity of groundwater is a must. Then, some reason of saline water occurrence will be considered to make suggestion of some treatments to mitigate the saline/brackish groundwater.

2. Definition of Salinity

Salinity is a body of water's saltiness or dissolved salt content Salinity is a thermodynamic state variable that governs physical characteristics like density and heat capacity of water, and is an important factor in determining many aspects of the chemistry of natural waters and biological processes within them. It is a thermodynamic state variable that, along with temperature and pressure, governs physical characteristics like density and heat capacity of the water (Wikipedia, 2014).

Salinity in rivers, Lakes and the ocean are conceptually easy, but defining and measuring them correctly is a technological challenge. The salinity of water is defined as the amount of dissolved salt in the water. Salts are substances that dissolve into ions, such as sodium chloride, magnesium sulfate, potassium nitrate, and sodium bicarbonate. In terms of operation, dissolved matter is defined as anything that can pass through a very fine filter (historically, a 0.45 m pore size filter, but currently generally 0.2 m). (Pawlowicz, 2013 in Wikipedia, 2014). A mass fraction, or the mass of the dissolved material in a unit mass of solution, can be used to express salinity.

Salinity level of groundwater is varied, and can be determined based on the element of chloride (Cl), or the total dissolved solid (TDS) of water (Table I).

Table 1: The salinity level of groundwater (PAHIAA, 1986, in Disbang DKI Jakarta - Sapta Daya Karyatama, 1997 [1]; Carroll, 1962, in Todd, 1980 [2])

Water characteristic	TDS (mg/l)[1]	TDS (mg/l)[2]	EC (µmhos/cm)[1]
Fresh	≤ 1,000	0 – 1,000	≤ 1,500
Almost brackish	> 1,000 - ≤ 3,000		> 1,500 - ≤ 5,000
Brackish	> 3,000 - ≤ 10,000	1,000 – 10,000	> 5,000 - ≤ 15,000
Saline	> 10,000 - ≤ 35,000	10,000 – 100,000	> 15,000 - ≤ 50,000
Brine	> 35,000	> 100,000	> 50,000

3. Origin of Saline Groundwater

As long as the water flows below ground level, the different hydrochemical processes can occur. Genesis of saline water is also determined by a variety of hydrochemical processes which occur along the path flow.

3.1. Mixing of Groundwater

Mixing of groundwater at the area near marine ever occur between freshwater from island and saline water of marine. Mixing occurring in the groundwater at coastal areas could be seawater intrusion or flushing. There are two kind of brackish water chemistry resulted from this mixing because of these processes.

a. Seawater Intrusion

Seawater intrusion generally change the type of water from NaCl into $CaCl_2$ type. When seawater intrudes in a coastal fresh water aquifer, an exchange of cations takes place. Sodium is taken up by the exchanger, and Ca^{2+} is released. The water quality thus changes from NaCl to $CaCl_2$ type water (Freeze and Cherry, 1979).

b. Flushing by Freshwater

The reverse process of sea water intrusin occurs when fresh water from the brine aquifer goes leaching (flushing), where brackish wa will generally has the $NaHCO_3$ type. This process takes place with re-freshening, i.e. when fresh water flushes a salt water aquifer, where Ca^{2+} is taken up from water, in return for Na^+, with a $NaHCO_3$ type as result (Freeze and Cherry, 1979).

3.2. Evolution of Groundwater

In addition to the mixing, the chemical evolution is often a major cause of groundwater salinity. Evolution of groundwater is generally followed by regional changes of anion dominance as indicated by the Chebotarev sequence (1955, in Freeze and Cherry, 1979) as follows:

$HCO_3^- \rightarrow HCO_3^- + SO_4^{2-} \rightarrow SO_2^{2-} + HCO_3^- \rightarrow SO_4^{2-} + Cl^- \rightarrow Cl^- + SO_4^{2-} \rightarrow Cl^-$

To the right sequence is characterized by an increasingly distant flow path of groundwater accompanied by increasing age.

3.3. Hidrocbemical processes

The hydrochemical processes that occur in groundwater systems include dissolution – hydrolysis precipitation, adsorption, ion exchange, reduction - oxidation, mixing, membrane filtration and metabolism microbiology (Todd, 1980). The chemical composition of groundwater depends on the chemical composition of water in the recharge and many reactions that occur in the flow system (Matthess, 1982). The other process that responsible to increase salinity of groundawater evaporation (Hadipurwo, 1996).

3.4. Connate water

Connate water is water that has been out of touch with the atmosphere for at least a significant portion of its geologic history (Todd, 1980); essentially, it comprises of interstitial water from a fossil that has moved from its initial burial site. This water can come from either oceanic or fresh water sources, and it can be used in a variety of ways. typically, is highly mineralized.

3.5. Polution

Groundwater contamination may purposefully induced decline of natural groundwater quality is known as. Pollution can make it difficult to use water and pose a threat to public health. The majority of contamination comes from the disposal of wastewater generated by the use of water for a number of activities. As a result, a variety of sources and causes, ranging from septic tanks to irrigated farmland, can affect groundwater quality (Todd, 1980). Pollution can alter the chemical composition of groundwater, particularly in terms of TDS, The oil and gas is one of the pollution sources that has an impact on salinity.

The production of oil and gas is usually accompanied by substantial discharges of wastewater in the form of brine. Constituents of brine sodium, calcium, ammonia, boron, chloride, sulfate, trace metals, and high total dissolved solids are just a few examples. Previously, oil• field brine was disposed of simply dumping it into streams or evaporation ponds. As infiltrating water reached the underlying groundwater in both cases, brine-polluted aquifers became frequent in oil production zones. (Todd, 1980).

4. Geological Control of Saline Water

There are many kinds of origin of saline water. In nature, this condition is usually controlled by geological factors. These factors include geomorphology, stratigraphy (aquifer properties), geological structure, and hydrogeological characteristics. The hydrogeological characteristics include groundwater

table or piezometric head which responsible to groundwater flow.

4.1. Geomorphology

Morphology of certain area has strong influence to surface water, but it also should influence to groundwater. This fact can be understood because groundwater table sometimes follow the topography of ground surface. Then, the groundwater table will detemine any groundwater flow pattern

Geomorphology can support the formation of salinity. For example, saline water in Kurulu Spring (1900 m) at Baliem Valley, is supported by groundwater flow from Habema Lake at high elevation of 4400 m asl (Hutasoit and Ashari, 1998, in Kossay, 2008). Baliem Valley is located at Jayawijaya mountain (350 -400 m asl), especialy at Jikiwa Village, Kurulu Subdistrict, near Wamena (the capital city of Papua Province). The people surrounding area are protected from mumps because of this saline water.

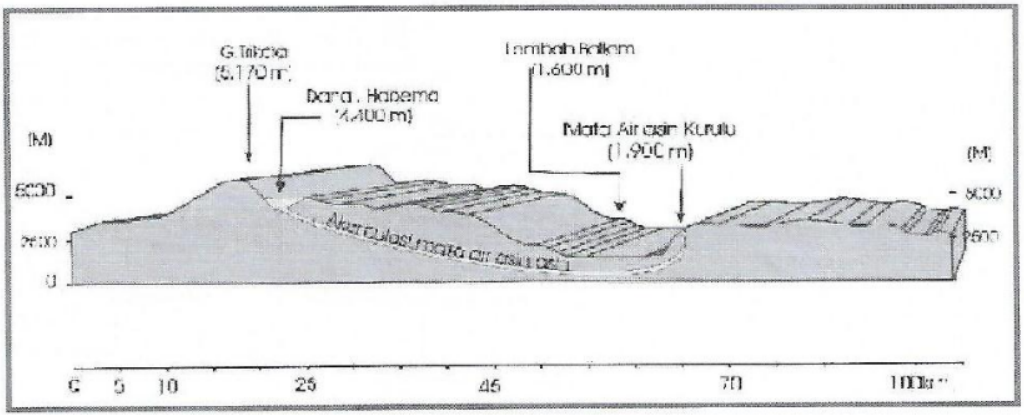

Figure 1. Geomorphology control groundwaterflow of Baliem Valley (Kossay, 2008).

4.2. Stratigraphy

The layers of aquifer zone determine the potential of groundwater. Saline water should be able to flow to the aquifer from sea water or move from aquifer to the others. It depends on the condition of local or regional stratigraphy. This stratigraphy includes many kind of litology. Saline water in Baliem Valley is also supported by the occurrence of limestone of karst landform. The interaction between minerals in limestone and water may increase the salinity.

The other example is saline groundwater in Jakarta Groundwater Basin (JGB). In this basin, there are saline groundwater can be found at both shallow and deep aquifer zones. Hadipurwo (1996) show there were some origin of saline/brackish groundwater in JGB as below

a. Aquifer I zone (< 40 m depth) : seawater intrusion, leaching, evaporation, flushing.
b. Aquifer II (40 - 140 m depth) and Ill zones (>140 m depth): leaching, flushing.

Those saline/brackish groundwater is influenced by stratigraphy of JGB which consist of quaternary sediments (Figure 2).

4.3. Geological Structure

Many kinds of geological structures, like fault, fold and joint can influence the groundwater flow. Consequently, saline water formation will be supported or decreased by these structures.

Saline water at Parangwedang is originated from mixing of meteoric water and old groundwater, influenced by magmatic activity or the intrusion of seawater in past time through the aquifers (Listyani, 2008). This saline water is supported by fault in the boundary of Nglanggran Formation (Figure 3).

4.4. Hydrogeology

The properties of aquifer and condition of groundwater table/piezometric level will determine groundwater flow as well as salinity. The origin of salinity is strong influenced by hydraulic parameters of aquifer especially on its porosity and permeability.

The connate water (Hutasoit and Ashari, 1998, in Kossay, 2008) of saline water in Baliem Valley is also formed by hydrogeologic condition of paleo marine sediments. This saline water may be trapped in the rocks when deposition process at the past time. The origin of connate water here is supported by isotope (0 & H) analysis.

The salinity of groundwater at Parangtritis caused by infiltration of tidal seawater and controlled by the flushing of seawater by fresh water (Listyani, 2009).

This flushing process is influenced by loose litology of aluvial deposites. This sediments act as good aquifer because of their high porosity and permeability. The brackish water here is usualy formed when high tides.

5. Saline Water Treatment

Because of many kind of origin of saline water, there are many kind of treatment to mitigate this water (if the water assumed as polutant). In brief, the proposed ways of treatment can be noticed in Table 2.

6. Conclusion

This can be summarized about the geological control of saline groundwater.

1. The saline groundwater can be found at many locations under geological control.
2. There are geological characteristics influence in the occurrence of saline water, include geomorphology, stratigraphy (litology), geological structure and hydrogeology of certain area.
3. Some treatment to mitigate the saline water which can be proposed are reduce the abstraction, control groundwater flow with geotechnical building, or remediation by chemical process.

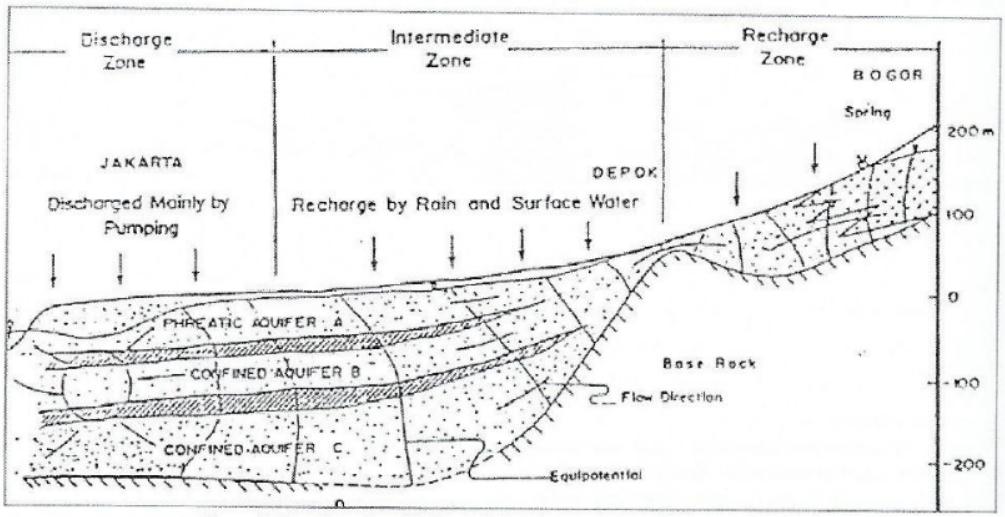

Figure 2. Stratigraphy of Jakarta Groundwater Basin (Naryanto, I 996).

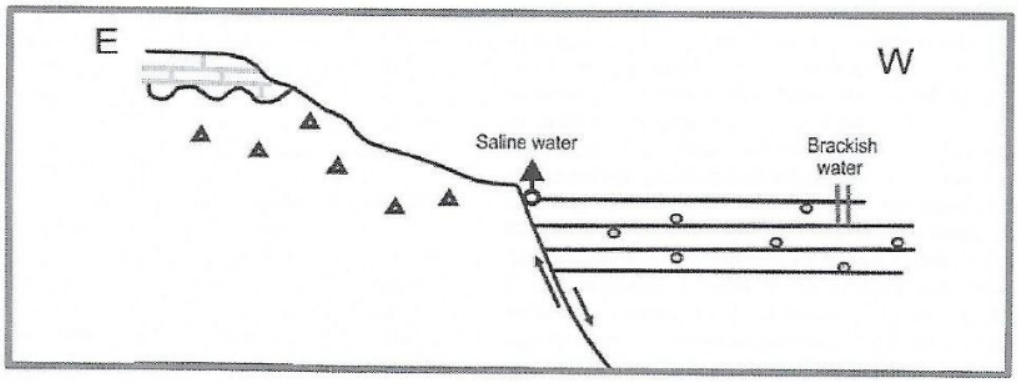

Figure 3. Fault should be supported the occurrence of saline water in Parangwedang Spring (Listyani, 2008).

Table 2: Some examples of the treatments proposed to mitigate saline water.

Example of Location	Origin/Geological Factor	Treatment
Jakarta Groundwater Basin	Seawater intrusion; leaching	-Reduce groundwater abstraction -Build the geotechnical building to prevent or divert groundwater flow -Remediation by chemical process
Baliem Valley, Papua	Water-rock interaction; connate water	No treatment because this water gives benefit (provide iodine) for people at surrounding area.
Parangwedang, Yogyakarta	Meteoric water mixed by heat of past volcanic activity	- No treatment (good for tourism & skin pain therapy)

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