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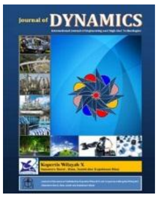

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Groundwater Quality Analysis in the Coastal of Bengkalis City Using Geochemistry Approach

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Abstract

Disproportion between supply and demand of clean water was a complex problem in water management, especially in the coastal of Bengkalis city. Water scarcity occurred in different parts of the region accompanied by bad quality of groundwater. Therefore, it was necessary to study the potential of groundwater as clean water and drinking water using geochemistry approach. Groundwater samples obtained from wells and deep wells in Bantan Tua village, Bengkalis district, Riau. Most groundwater samples did not meet the requirements of clean water and drinking water based on Permenkes 492/Menkes/Per/IV/2010 in terms of physical and chemical parameters with temperatures 26-29ºC, turbidity 5- >100 NTU, TDS 0-30,5 mg/L, pH 4,05–7,40, Cd 0,001-0,011 mg/L, Mn 0,020–1,775 mg/L, Fe 0,291–17,100 mg/L, Cu 0,000–0,095 mg/L, Cr < 0,05 mg/L, hardness 19,669–560,184 mg/L, $SO4^{2-}$ < 25 mg/L, NO_3^- 17,96–220,6 mg/L, NH_4^+ 0,00–3,21 mg/L, F^- < 0,10– 0,13 mg/L and Cl^- 0,2–71,8 mg/L. The groundwater in this study was dominated by non carbonate in form of Na+K indicated that the facies of groundwater aquifers was influenced by seawater with clay lithology and illite mineralogy. The genesis of origin rocks derived from weathering igneous rock which rich in plagioclase and feldspar minerals.

Keywords : Groundwater, drinking water quality, geochemistry analysis

1. Introduction

Water is a natural resource that has an important role in various aspects of social life, including determining the quality and sustainability of human life and the development of the environment. Land-use change has greatly affected the changing hydrological cycle and soil water depths that continue to decline due to reducing the capacity of infiltration and decreasing infiltration rate [1].

The availability of water for various needs tends to decrease both quantitatively and qualitatively, while on the other hand the water demand tends to increase so that problems of water resources management always arise. Theoretically, the amount of water in the earth is relatively fixed, the problems associated with the availability of water appear as a result of the distribution of water resources by space and time are not evenly distributed and less attention of sustainability in its management. One of the potential water resources and a lot of attention in relation to fulfill the necessity of drinking water is ground water [2].

Groundwater is the amount of water beneath the earth's surface that can be collected through wells, tunnels or drainage systems as well as with pumping. Groundwater can also be referred to as a stream that naturally flows into the soil surface through jets or seepage [3]. Ground water is a component of a hydrological cycle involving many aspects of bio-geo-physical, even political and socio-cultural aspects that determine groundwater availability in an area.

The role of groundwater increasingly important because groundwater is the main source of water to fullfil the basic needs of many people, such as drinking water, household, industry, irrigation, urban and others and has become an economic commodity and strategic commodity [4-5]. It is estimated that 70% of the population water needs and 90% of the industrial water needs come from groundwater. In terms of quality, groundwater is one of the best water resources for drinking water because of the advantages compared to other water sources. The advantages of using groundwater include relatively better quality compared to surface water and unaffected seasons, larger and more accessible groundwater reserves and do not require transmission lines to distribute them [6].

Potential groundwater and its quality in a region associated with groundwater use can be identified through the research of the dispersion of aquifer systems and the chemical properties of groundwater [7]. Groundwater quality is very important for life today. Water quality, which includes physical, chemical and biological can affect water availability for human, agricultural, industrial, recreational and other uses [8].

The imbalance between the availability and clean water needs is a complex issue in water management especially in the coastal of Bengkalis City. Optimal pumping of an aquifer is the basis for determining the level of water use from groundwater sources but in reality it is difficult to determine if it does not consider the quantitative and qualitative potential of groundwater that distributed spatially and temporally. The potential distribution of groundwater in the coastal of Bengkalis City is uneven and temporal, which fluctuates based on the seasons in both rainy and dry seasons. This causes the supply of clean water needs are not fulfilled at all. Water scarcity occurs in different parts of the region [9-10]. Based on the problems mentioned above, it is necessary to study the potency of groundwater with geochemistry approach and evaluation the usage of groundwater as drinking water.

The purpose of this research are to find out whether the quality of groundwater under study has fulfilled the water quality requirements that may be consumed by the population according to Permenkes No.492/MENKES/PER/IV/2010 in terms of physical and chemical parameters and to know the condition of facies (Genetic state) groundwater in the coastal of Bengkalis City.

2. Material and Methods

A. Place and Time

This research was conducted at Basic Geology Laboratory of Islamic University of Riau and Physics-Chemical Laboratory of Kopertis Region X, Padang. The groundwater samples were obtained from wells and deep wells in Bantan Tua village, Bantan district, Bengkalis. This research was conducted for three months, from May to July 2015.

B. Materials and Tools

The materials used in this research were groundwater samples and aluminum foil. The tools used in this study consist of: 1). Equipment for measuring the physical properties of groundwater and field conditions, such as : meter, hammer, geological compass, GPS and sample bottle, 2). Groundwater chemical analysis devices such as glassware, oven, desiccator, Whatman No.1 filter paper, Atomic Absorption Spectrophotometer (AAS), Spectroquant Nova 400, 934-AHTM circle 90 mm filter paper, turbidimeter, autoclap, analytical scales, water bath, magnetic stirer, filter tool, vacuum pump, bunsen burner, pH meter, thermometer and nikrom wire.

C. Research Methods

The method used in this research : 1) Survey method with flexible grid approach. This result was used to determine the groundwater observation points; 2) Purposive sampling method to collect the location data of wells and deep wells in the study area. This result was used to determine the observation points (pumping test) and water sampling.

The data collected in this research : 1) Groundwater observation data consist of wells and deep wells. 2) Groundwater quality data, consist of temperature, turbidity, total dissolved solids (TDS), pH, hardness, and concentration of chemical elements / groundwater compounds (Fe, Mn, Cd, Cu, Cr, Na, Mg, Ca, Cl^-, F^-, SO_4^{2-}, NO^{3-} and NH_4^+) [11].

D. Research Procedures

The groundwater samples were obtained from wells and deep wells in Bantan Tua village, Bantan district, Bengkalis with purposive sampling technique.

Physical parameter analysis in form of temperature was measured using thermometer, turbidity was measured using turbidimeter and total dissolved solids (TDS) were measured using gravimetric method.

Analysis of chemical parameters in form of pH was measured using thermometer. The heavy metals of cadmium (Cd), manganese (Mn), iron (Fe) and copper (Cu) were analyzed using Atomic Absorption Spectrophotometer (AAS). Chromium (Cr) metal was analyzed using Spectroquant Nova 400. Total hardness, chloride (Cl^-), flour (F^-), sulfate (SO_4^{2-}), nitrate (NO_3^-) and ammonia (NH_4^+) were analyzed using Spectroquant Nova 400 .

The result of groundwater physical-chemical analysis was shown in the form of Trillinier Piper Diagram. This diagram was useful to know the name of groundwater type. The Trillinier Piper diagram was also used to maps area that has same groundwater type.

The data from the quantitative analysis presented in table form and discussed descriptively. The data that obtained will compared with the standard of drinking water based on Permenkes No.492/MENKES/PER/ IV/2010 [12].

3. Results and Discussion

A. Preparation and Sampling

The groundwater samples were obtained from wells and depp wells in Bantan Tua village, Bantan district, Bengkalis. Groundwater samples were taken from several locations that were residential areas, areas adjacent to rivers and areas adjacent to landfills Groundwater sample sources can be seen in Table 1.

Table 1. Groundwater Sample Sources

Sample	Type of Well	
	Well	Deep Well
1	√	
2	√	
3	√	
4	√	
5	√	
6	√	
7	√	
8	√	
9	√	
10	√	
11	√	
12		√

B. Physical Parameter Analysis

1) Temperature

The temperature of groundwater samples was measured using thermometer. The temperature measurement of groundwater samples can be seen in Table 2.

Table 2. Temperature Measurement of Groundwater Samples

Sample	Temperature (°C)
1	28
2	28
3	27
4	27
5	27
6	26
7	27
8	28
9	27
10	27
11	29
12	26

From Table 2, it can be seen that the temperature of groundwater samples was 26-29°C. The maximum temperature standard permitted based on Permenkes 492/ Menkes/ Per/IV/2010 was air temperature ± 3°C. Water temperatures that exceed the normal limits indicated that there were large amounts of dissolved chemicals (phenol or sulfur) or there was the decomposition process of organic matter by microorganisms. So, the water was said to be polluted and unfit to drink.

2) Turbidity

The turbidity of groundwater samples was measured using turbidimeter. The turbidity measurement of groundwater samples can be seen in Table 3.

Table 3. Turbidity Measurement of Groundwater Samples

Sample	Turbidity (NTU)
1	10
2	61
3	8
4	9
5	>100
6	5
7	5
8	9
9	37
10	27
11	29
12	5

From Table 3, it can be seen that turbidity of groundwater samples was 5 - >100 NTU. The maximum turbidity standard permitted based on Permenkes 492/Menkes/Per/IV/2010 was 5 NTU. Nine groundwater samples were below the maximum limit. The high level of turbidity indicated a runoff of mud particles and organic waste infiltrated into the soil entering the water. Turbidity would inhibit the penetration of sunlight and affected the process of photosynthesis in the well.

3) Total Dissolved Solids (TDS)

Total dissolved solids (TDS) of groundwater samples were measured using the gravimetric method. From the result of this research, it was found that the amount of TDS in groundwater samples was 0-30,5 mg/L. The amount of TDS presented in all groundwater samples was still in normal limits (maximum standard based on Permenkes 492/Menkes/Per/IV/2010 was 500 mg/L). Dissolved salts such as sodium, chloride, magnesium and sulfate contributed to the amount of total dissolved solids. In addition, high concentration of dissolved solids in water can affected clarity, color and taste. TDS usually consist of organic substances, organic salts and dissolved gases. TDS measurements of groundwater samples can be seen in Table 4.

Table 4. Total Dissolved Solids (TDS) Measurement of Groundwater Samples

Sample	TDS (mg/L)
1	30,5
2	12,7
3	5,3
4	30,1
5	0
6	6,4
7	7,1
8	8,8
9	1,5
10	0,6
11	8,4
12	17,4

C. Chemical Parameter Analysis

1) pH

pH of groundwater samples was measured using pH meter. pH measurement of groundwater samples can be seen in Table 5.

Table 5. pH Measurement of Groundwater Samples

Sample	pH
1	7,40
2	5,00
3	6,62
4	7,29
5	7,05
6	6,93
7	6,85
8	7,00
9	4,30
10	4,05
11	7,38
12	7,06

Table 5 showed that pH of groundwater samples were 4,05-7,40. There were three groundwater samples that did not meet the requirements as clean water and drinking water (maximum standard based on Permenkes 492/Menkes/Per/IV/2010 was 6,5-8,5). The pH indicated the high low hydrogen ions in water. Water pH below 6,5 or above 8,5 caused some chemical compounds in the human body turn into a toxin. The low pH value was thought to be due to geological factors of the location.

2) Heavy Metal

Cadmium (Cd), manganese (Mn), iron (Fe) and copper (Cu) were measured using Atomic Absorption Spectrophotometer (AAS). Chromium (Cr) metal was measured using Spectroquant Nova 400. Heavy metals measurement of groundwater samples can be seen in Table 6.

Table 6. Heavy Metals Measurement of Groundwater Samples

Sample	Heavy Metals Concentration (mg/L)				
	Cd	Mn	Fe	Cu	Cr
1	0,005	1,775	0,845	0,029	<0,05
2	0,011	1,475	17,100	0,095	<0,05
3	0,007	0,931	2,301	0,007	<0,05
4	0,008	0,405	0,294	0,021	<0,05
5	0,009	0,321	4,917	0,009	<0,05
6	0,002	0,300	0,291	0,004	<0,05
7	0,004	0,822	2,324	0,005	<0,05
8	0,001	0,490	0,871	0,000	<0,05
9	0,003	0,040	0,848	0,000	<0,05
10	0,001	0,027	0,320	0,000	<0,05
11	0,001	0,020	0,322	0,042	<0,05
12	0,003	0,300	0,518	0,000	<0,05

From Table 6, it can be seen that the concentrations of heavy metals found in all samples were varieted. Cr concentrations in all groundwater samples were still below the maximum permitted limit. However, some groundwater samples contained heavy metals above the maximum permitted limit. According to Permenkes 492/Menkes/Per/IV/2010, standart concentration of each heavy metals were Cr 0,05 mg/L, Cd 0,003 mg/L, Mn 0,4 mg/L, Fe 0,3 mg/L and Cu 2 mg/L.

Natural water contained heavy metals in trace amounts. The concentrations of heavy metals found naturally in drinking water can varieted depend on the nature of the soil and the rocks passed by water. The presence of heavy metals can also be caused by environmental pollution.

Heavy metals were toxic and can not be destroyed if absorbed into the body. In humans, heavy metals caused health effects depend on which part of the heavy metals bound in the body. Toxicity will worked as a barrier to enzyme work and caused the metabolism of body was cut off. Heavy metals can also caused allergies, carcinogens for humans and death in high doses.

The absorption of Cd from food or drink can caused stomach cramps, dizziness, diarrhea and shock. Absorption of Cd in the long term can caused kidney and bone damage, anemia, and hypertension. Manganese poisoning (Mn) was often chronic with symptoms that arise in the form of imsomnia, weak in the legs and muscles.

Iron levels (Fe) that exceed above maximum limit can caused lung function reduction, deposition on the pipe wall and the growth of Fe bacteria. Water containing a lot of Fe will be yellowish and caused corrosion of metal objects.

Basically, copper (Cu) was necessary for the development of the human body. However, in high concentrations the presence of copper can damaged the respiratory organs and caused cancer in humans.

3) *Total Hardness, Sulfate, Ammonia, Nitrate, Flouride and Chloride*

Total hardness was determined by measured the concentration of calcium ions (Ca^{2+}) and magnesium ions (Mg^{2+}) using Atomic Absorption Spectrophotometer (AAS). The sulfate content (SO_4^{2-}), nitrate (NO_3^-), ammonia (NH_4^+), fluoride (F^-) and chloride (Cl^-) were measured using Spectroquant Nova 400.

From the result of this research, it was found that the hardness of groundwater samples was 19,669-560,184 mg/L. The result showed that most of the groundwater samples have a normal hardness (maximum standart based on Permenkes 492/Menkes/Per/IV/2010 was 500 mg/L) and only one groundwater sample has hardness value above the maximum limit that permitted. Hardness was influenced by calcium and magnesium ions contained in water. High levels of hardness in groundwater will cause crust on kitchen appliances.

The content of organic matter in form of sulfate (SO_4^{2-}) in groundwater samples was < 25 - 62 mg/L. All groundwater samples were still below the maximum permitted limit (maximum limit that permitted was 400 mg/L for clean water and 250 mg/L for drinking water).

The content of organic matter in form of nitrate (NO_3^-) in groundwater samples was 179,6 – 220,6 mg/L. All groundwater samples were still below maximum permitted limit (50 mg/L). The high content of nitrate in water illustrated there was biological process of organic materials decomposition with very low dissolved oxygen levels.

The content of organic materials in form of ammonia (NH_4^+) in groundwater samples was 0,00-3,21 mg/L. Seven groundwater samples were still below the maximum limit that permitted (1,5 mg/L) and five groundwater samples contained ammonia in amount that exceeded the maximum limit.

In certain amount, the body needs water containing organic chemicals. But if the amount of organic chemicals contained over the limit, it can cause interference in the body. The result of the total hardness measurements, SO_4^{2-}, NO_3^-, NH_4^+, F^- and Cl^- on groundwater samples can be seen in Table 7.

Table 7. Hardness, Sulfate (SO_4^{2-}), Nitrate (NO_3^-), Ammonia (NH_4^+), Flouride (F^-) and Chloride (Cl^-) Measurement on Groundwater Samples

Sample	Concentration (mg/L)					
	Hardness	SO_4^{2-}	NO_3^-	NH_4^+	F^-	Cl^-
1	560,184	< 25	220,6	1,05	<0,10	71,6
2	366,001	62	185,8	0,06	<0,10	69,2
3	144,482	< 25	191,8	1,07	<0,10	50,5
4	426,404	< 25	179,6	2,75	<0,10	71,8
5	95,502	< 25	194,1	0,72	0,13	29,3
6	109,838	< 25	187,7	2,19	<0,10	49,1
7	194,217	< 25	188,7	0,04	<0,10	56,7
8	95,378	< 25	191,4	1,26	<0,10	26,5
9	19,669	< 25	193,6	3,21	<0,10	0,2
10	33,269	< 25	198,0	1,76	<0,10	8,4
11	142,541	< 25	198,0	2,76	<0,10	64,9
12	385,010	< 25	198,0	0,00	<0,10	70,2

Inorganic substances in form of fluoride (F^-) and chloride (Cl^-) in groundwater samples was <0,10-0,13 mg/L for fluoride (F^-) and 0,2-71,8 mg/L for chloride (Cl^-). All groundwater samples weres still below maximum limit that permitted (1,5 mg/L for F^- and 250 mg/L for Cl^-). The source of chloride in water came from minerals present in the soil. In addition, other sources of chloride can be derived from domestic wastewater and seawater carried by rainwater.

D. Groundwater Facies Analysis

Analytical method with Trillinier Piper Diagram was important for groundwater genetic studies. This study was to find out the source of the constituent elements dissolved in groundwater, changes or modifications of water properties that pass through a particular region and its relation to the geochemical problem. The Trillinier Piper Diagram was performed by plotting all ions on the diamond-shaped-field diagram so that the groundwater facies will be known.

In groundwater samples (1-12) there were groundwater with elements composition dominated by alkaline earth such as Sodium+ Potassium (Na+K), Calcium (Ca) and Magnesium (Mg). From the analysis results, it can be seen that the groundwater samples (1-8 and 11-12) were dominated by non-carbonate elements of Na+K with average concentration 73,4%, followed by Ca element with average concentration 14,7% and Mg element with average concentration 11,8%. However, the groundwater sample (9) was dominated by carbonate in form of Ca with average concentration 58,8%, followed by Na+K element with average concentration 32,4% and Mg element with average concentration 8,7%. In groundwater samples (10) was dominated by carbonate elements of Mg with average concentration of 45%, followed by Ca element with average concentration 30% and Na+K salt with average concentration 25%.

The groundwater in this study was dominated by non carbonate elements (Na+K) indicated that the facies of groundwater aquifers was influenced by seawater with clay lithology and illite mineralogy. The genesis of origin rocks derived from weathering igneous rock which rich in plagioclase and feldspar minerals.

4. Conclusion

The groundwater samples were obtained from wells and deep wells in Bantan Tua village, Bantan district, Bengkalis. Groundwater samples were taken from several locations that were residential areas, areas adjacent to rivers and areas adjacent to landfills. Most groundwater samples did not meet the requirements of clean water and drinking water based on Permenkes 492/Menkes/Per/IV/2010 in terms of physical and chemical parameters with temperatures 26°C-29°C, turbidity 5 - >100 NTU, TDS 0-30,5 mg/L, pH 4,05-7,40, Cd 0,001-0,011 mg/L, Mn 0,020-1,775 mg/L, Fe 0,291-17,100 mg/L, Cu 0,000-0,095 mg/L, Cr < 0,05 mg/L, hardness 19,669-560,184 mg/L, SO_4^{2-} < 25 mg/L, NO_3^- 17,96-220,6 mg/L, NH_4^+ 0,00-3,21 mg/L, F^- <0,10-0,13 mg/L and Cl^- 0,2-71,8 mg/L.

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