THE STUDY OF WATER QUALITY FOR DEVELOPING TOURISM IN PARANGTRITIS COASTAL AREA, INDONESIA

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Abstract

The quality of groundwater can be affected by natural and human factors condition; such as: litology, climate, time, and the activities of living beings, including humans as waste disposal industry, household waste, agricultural waste and the use of pesticides. The quality of groundwater can be determined by measuring physical, bological and chemical factors. The purposes of this issue are: (1) measuring the distribution of water quality in open aquifer; (2) groundwater potential for tourism purposes. This research took 9 water samples with purposive random sampling methods and geomorphological based analysis. Water analysis standart based on government regulation on Yogyakarta, Indonesia number 214/KPTS/1991. Groundwater in this area is still have huge standarized of clean water with classified as bicarbonate water, because the water flown through the limestone geologic materials. The evaluation of groundwater quality was performed by comparing the physical and chemical elements. Data collected in the field and the measurements in the laboratory. Physical data collected such as: electrical conductivity (EC), pH, color, taste, smell, and turbidity. Chemical data focus on major elements, such as: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2}, HCO_3^{-}, and CO_3^{-}. Groundwater in Parangtritis still has good quality of groundwater, so it can be developed for the purpose of consumption needs and clean water supply. But, people have to aware that using groundwater on coastal area can increase saltwater intrusion.

Keywords : Aquifer, Coastal, Groundwater, Intrusion.

A. Introduction

Groundwater is a natural renewable resource. It is an integral part of the hydrological cycle on Earth . In fact, there are many limiting factors that affect the utilization, in both quantity and quality. In terms of quantity, groundwater will decrease the ability of the provision if the amount taken exceeds the amount of groundwater availability. The quality of groundwater can be affected by factors of lithology, climate, time, and activity of living beings, including human's activity such as industrial waste, household waste, agricultural waste, and the use of pesticides [1]. The quality of groundwater can be determined by physical analysis, including color, smell, taste, turbidity, temperature, and EC. Chemical analysis includes the content of many dissolved ions and its hardness. The dominant and dissolved ions in groundwater are a cation consisting of Ca^{2+}, Mg^{2+}, Na^{+} and an anion consisting of HCO^{3}, Cl^{-}, and SO_4^{2+}. Total cations and anions are generally greater than 90% total dissolved solids, while other ions are in low levels [2]. Groundwater issue which affect the quality of groundwater in Parangtritis, Kretek District, Bantul, Yogyakarta is the intrusion of sea water and groundwater supply supporting the development of tourism in the area [3]. The availability of groundwater in Parangtritis is strongly associated with the genesis and affects on aquifer characteristics of the constituent [4]. Based on interviews with some of the Parangtritis residents, it is obtained information that in dry season, some residents have to deepen their well. Lowering water levels in the wells leads to decreased water supplies to meet the needs of domestic water so that the water use is limited. Therefore, it is important to conduct a study on the potential of groundwater in in connection with efforts to obtain the potential of groundwater resources, in terms of both quantity and quality.

B. Research Problems

This article formulates the following issues:

1. How does the distribution of open groundwater quality in every unit of geomorphology in the area of Parangtritis?
2. How does the availability of groundwater for the purpose of tourism needs in the area of Parangtritis?

C. Methodology

This study used geomorphological approach for the unit of groundwater. The sampling technique used was purposive random sampling, namely the selection of sample locations randomly with the location considerations adequately represent overall region in accordance with the purpose of study, with consideration of geomorphological conditions which are relatively similar. Data collected included physical and chemical properties of groundwater. Data of physical properties collected in the field and the measurements in the laboratory. Data of physical properties collected in the field consisted of electrical conductivity (EC), pH, color, taste, and smell. EC measurements were performed using EC meter. Color, taste, and smell could be directly observed in the field. The physical properties measured in the laboratory were turbidity by using a turbidimeter.

Type elements that were analyzed included the major elements, namely Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2}, HCO_3^{-}, and CO_3^{-}. The results of laboratory tests of chemical elements were expressed in units of parts per million (ppm), namely heavy ion concentration in milligrams per one liter of water (mg/l). Another unit used was equivalent part permillion (epm), ie ppm was divided by its equivalent weight (epm = meq/l).

The evaluation of the suitability of open aquifer quality in the study area for drinking water was performed by comparing the number of each physical and chemical elements of groundwater analyzed in a laboratory with the number specified in the standards of drinking water or limit of water quality standard of class A and B. The quality standard of class A is the quality standard of water sources which can be directly used as a source of water for daily use.

Table 1. Limit of Water Quality Standard of Class A and B [5]

Indicators	Unit	Class A		Class B	
		Max. suggested	Max. tolerable	Max. suggested	Max. tolerable
Temperatur	˚C	Temp.normal	Temp.normal	Temp.normal	Temp.normal
pH		6.5-8.5	6.5-8.5	5-9	5-9
Turbidity	Ftu		5		
Calsium	mg/l	75	200		
Magnesium	mg/l	30	150		
Amonium	mg/l	-	0.25	0.01	0.5
Fe	mg/l	-	0.3	-	1
Nitrat	mg/l	5	10	-	10
Nitrit	mg/l	-	0.1	-	0.5
Cloride	mg/l	25	250	25	500
Sulfat	mg/l	50	300	50	300

Source : Quality standard of drinking water based on the Decree of Governor of the Special Region of Yogyakarta number 214/KPTS/1991

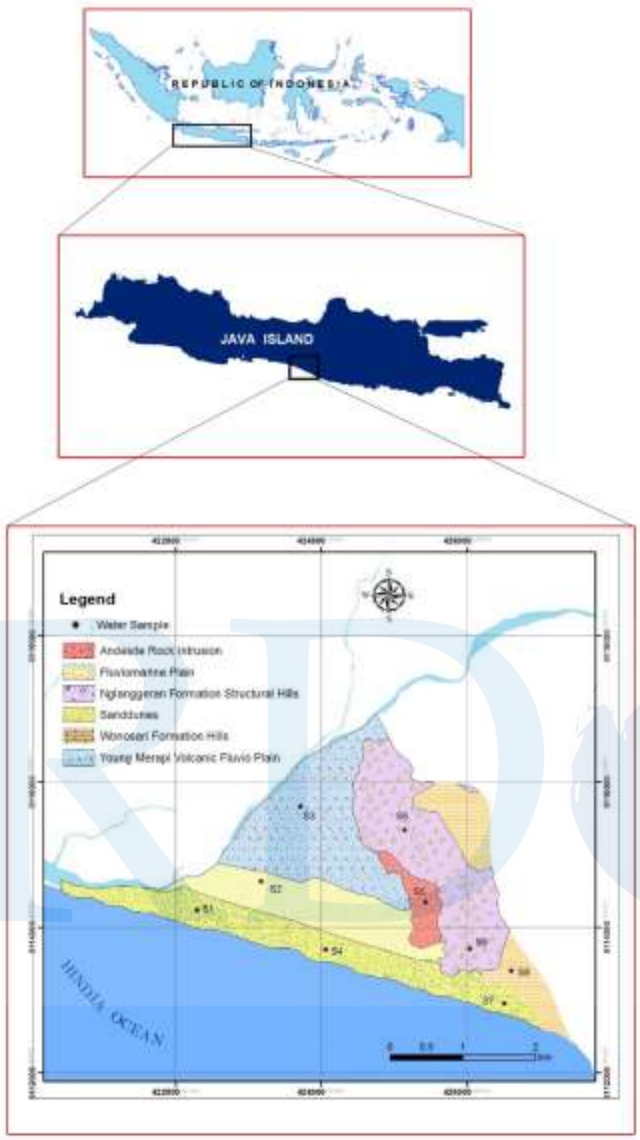

Figure 1. Samples location and study area

The effect of seawater to the groundwater can be determined based on the content of Cl^-, HCO_3^- dan CO_3^-; by performing calculation using the formulation as follows [6]:

$$X = \frac{Cl^-}{(HCO_3^- + CO_3^{2-})} \tag{1}$$

The calculation result is then included to Revelle classification as Table 2 below:

Table 2. The Criteria of Level of Seawater Influence to the Groundwater

No	$Cl^-/(HCO_3^-+CO_3^-)$ (meq)	Level
1	< 0,5	Normal Groundwater in aquifer
2	0,5 – 1,3	Saltwater intrusion (low)
3	1,3 – 2,8	Saltwater intrusion (medium)
4	2,8 – 6,6	Saltwater intrusion (hight)
5	6,6 – 15,5	Saltwater intrusion (very high)
6	15,5 - 20	Seawater

Source : Revelle, 1941

D. Results

1. Physical Properties of Groundwater

The physical properties of groundwater observed and analyzed to determine the quality of groundwater are pH, turbidity, and electrical conductivity (EC) [7], [8]. Electrical conductivity demonstrates the ability of water to be able to deliver the electric current. EC value shows the total ion concentration in the groundwater. The higher the value of EC, the higher the total dissolved ions in the groundwater, and the worse the quality of groundwater in relative terms. The results of measurements in the field show that the value of electrical conductivity varies. The lowest electrical conductivity value is in the sample 6 originating from the sandbanks. The highest EC is in sample 9, i.e 18750 µmhos/cm. All water samples except sample 7 and 9 have a low EC value so that it is still included in the group of fresh groundwater. The results of measurements of physical properties of groundwater are shown in the table below.

Table 3. The results of measurements of physical properties of groundwater

Samples	1	2	3	4	5	6	7	8	9
DHL	760	929	949	529	899	929	589	830	18750
Turbidity	0.43	0.05	0.29	0.20	0.17	0.30	0.82	0.56	0.48
pH	7.57	6.73	6.66	7.40	6.87	6.83	7.37	6.88	7.01

The turbidity of groundwater is caused by the presence of substances such as fine mud or the like which floates as a colloid or suspension in water [9]. Based on the Decree of the Governor of the Special Region of Yogyakarta number 214/KPTS/1991, maximum standard of allowable turbidity value is 5 FTU. The results of field measurements of turbidity samples show that the sample values ranging from 0.05 to– 0.82 FTU. This value is far below the maximum standard for drinking water turbidity.

PH is a term used to express the intensity of the acid or base of a solution. Pure water has a pH = 7 at a temperature of 25˚C. Water with a pH greater than 7 is expressed base in which the number of H^+ ions < number of OH^- ions. While a pH less than 7 is declared acid in which the number of H^+ ions > number of OH^- ions. The expected standard pH is neutral, that groundwater is not too acidic or too base. Quality standards of pH show values between 6.5 – 8.5. The results of laboratory analysis show that good pH values range from 6.66 – 7.57.

2. Chemical Properties of Groundwater

2.1.1 Calcium (Ca^{2+})

Fresh water in the coastal area is influenced by elements of Ca^{2+} and HCO_3^-, as a result of the dissolution of calcite. Calcium contained in the groundwater in the study area ranges from 16.8 mg/l – 2842 mg/l. The highest calcium element is in sample 9 and the lowest is in sample 1. There is a very noticeable difference between sample 9 with another sample as Ca content in the sample is very high. The requirement of the allowable maximum limit according to the Decree of the Governor of the Special Region of Yogyakarta of 1991 is 200 mg/l. Under these provisions, the calcium content in sample 9 exceeds the quality standard of class A and so that it cannot be used for drinking water.

2.1.2 Magnesium (Mg^{2+})

Magnesium is derived from the mineral olivine, pyroxene, amphibole and dark mica. In sedimentary rocks, the magnesium is in the form of compounds with the carbonate. The content of magnesium in the freshwater is less than 50 mg/l and in seawater is as much as 1350 mg/l. Laboratory test results show that the content of magnesium in the study area ranges from 12.7 mg/l – 126 mg/l. The concentration of magnesium is still below the allowable limit for water quality standard of class A namely 150 mg/l but exceeds the recommended limit for water quality standard of class namely 30 mg/l. The average value of the highest magnesium content is found in sample 9 taken from the foot of the slopes with material of andesite breccia, andesite lava, sandstone (Nglanggran Formation) ie 126 mg/l.

2.1.3 Sodium (Na^{+})

Sodium is a member of alkali metal group. Sodium is found in igneous or sedimentary rocks. Elements of sodium can also be derived from the intrusion of sea water, in which this element in seawater is derived from the weathering of igneous rocks dissolve then carried to the ocean and accumulated. The main source of sodium element is seawater. The allowable concentration of sodium in water is less than 200 mg/l. The content of sodium in the study area ranges from 10.5 mg/l – 1100 mg/l. The highest sodium content is found in sample 9. The study area is close to the ocean waters so that it requires monitoring of excessive sodium concentration. Na^{+} and Cl^{-} is dominant ions contained in seawater and sediment experiencing contact with sea water will absorb Na^{+} in large numbers.

2.1.4 Potassium (K^{+})

The concentration of potassium in the water is always smaller than sodium. This is because the element of potassium is not easily dissolved in water. Laboratory test results show that the content of potassium in the study area ranges from 1.2 mg/l – 20 mg/l. The highest content of potassium is found in sample 9.

2.1.5 Chloride (Cl^{-})

Chloride is an essential element and is widespread in groundwater. Chloride in water can originate from a variety of sources, including precipitation, seawater intrusion, pollution of water and rock. Chloride levels in natural water such as groundwater, artesian water, lake or river water is usually relatively fixed. The high levels of Cl^{-} lead to salty water, so that the content of chloride dissolved in water can be used as an index of determining the quality and taste of the water. Laboratory test results show that chloride content ranges from 20.4 mg/l – 6018 mg/l. Sample 9 with material andesite breccia, andesite lava, sandstone (Formation Nglanggran) has the highest chloride content namely 6018 mg/l. This value exceeds the water quality standard of class A so that it is not suitable for drinking water and clean water sources.

2.1.6 Sulfate (SO_4^{2-})

Sulfate is found in sedimentary rocks and igneous rocks as the sulfide metal. In weathering by water, the sulphur is oxidized to produce sulfate ions which then carried away by the water. In this oxidation proces forms H ion, crystalline pyrite, and groundwater. Sulfate is found in igneous rocks, especially as feldspatoid, also abundant in sedimentary rocks evaporates as gypsum, anhydrite, and barite. The concentration of sulfate in groundwater in the study area ranges from 0.29 mg/l – 33.42 mg/l. The value is below the limit of allowable water quality standard of 300 mg/l. Based on the concentration of sulfate in groundwater samples then all samples are eligible to be used as drinking water and clean water sources.

Table 4. The Analysis Results of Groundwater Quality in Parangtritis village in ppm (mg/l)
3.

Sample	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	$S0_4^{2-}$	HCO_3^{-}	CO_3^{2-}
1	25.3	63.9	23.9	6.9	105	3.05	205	0
2	116	34.3	15.6	10.1	50	9.13	210	0
3	126	25.8	15.6	1.2	38.9	0.29	245	0
4	69.5	12.7	10.5	3	37	0.29	180	0
5	92.6	39.8	15.3	2.9	37	0.29	220	0
6	124	24.3	18.3	2.2	55.5	0.29	235	0
7	75.8	12.8	11	1.5	25.9	0.29	170	0
8	124	14.1	14.3	10	38.9	4.43	325	0
9	2842	126	1100	20	6018	33.42	1250	0

2.1.7 Alkalinity (Bicarbonate (HCO_3^-) and carbonate (CO_3^-))

Alkalinity in the water is caused by the dissolved bicarbonate and carbonate element. The main source of carbon dioxide to produce alkalinity in surface water or groundwater is the fraction of CO_2 from the atmosphere or atmospheric gases contained in the unsaturated zone between the soil surface and the groundwater surface. The process of dissolution of carbon dioxide in the water can be seen in the following reaction :

$$CO_2 + H_2O \longrightarrow H_2CO_3$$
$$H_2CO_3 \longrightarrow H^+ + HCO_3^-$$

The analysis results of water samples show that carbonate concentration is 0 mg/l. It occurs because the groundwater pH does not exceed 7 or is still in neutral pH range. The content of bicarbonate ranges from 70 mg/l – 1250 mg/l. The highest concentration is found in sample 9. The quality of groundwater in Parangtritis mostly includes in the category of GOOD, except in three samples that have quality MEDIUM.

3. The Level of Seawater Influence to Groundwater

The analysis of the influence level of sea water to the groundwater in Parangtritis village, Kretek District is made based on the classification of Revelle. The classification results of influence level of sea water in the study area are listed in Table 5. These results indicate that in general the groundwater in the study area has not been affected by the sea water. Of the nine samples taken, sample 7 and 9 which is slightly affected by seawater, namely the influence of connate water in the tourism area of Parangwedang. Sample 9 also has the highest EC value compared to another sample, namely 18.750 µmhos/cm. According to the classification of Kloosterman, EC value is classified as salty groundwater.

Table 5. The level of seawater influence to groundwater by Revelle

Sample	$Cl^-/ (HCO_3^- + CO_3^{2-})$ (epm)	Class
1	0.13	Normal Groundwater
2	0.06	Normal Groundwater
3	0.04	Normal Groundwater
4	0.05	Normal Groundwater
5	0.04	Normal Groundwater
6	0.06	Normal Groundwater
7	0.53	Saltwater intrusion (low)
8	0.03	Normal Groundwater
9	1.27	Saltwater intrusion (low)

E. Discussion

The development of Parangtritis area refers to the three-dimensional of tourism area development, namely: (1) development of a gentle and defenseless people; (2) uniqueness of the sacred dimension; and (3) preservation of natural sandbanks. Based on the vision of the development of the tourism area, the spatial of Parangtritis is the divided into core zone and region zone.

1. Core zone

   The Core zone is an area of parangtritis which is recognizable by the public and tourists including Parangkusomo, Parangwedang, Parangtritis. The administration of the core zone name is to further emphasize that this area is an area that has become the tourism area and to distinguish other areas that may be developed to support this zone.

2. Buffer zone

   This zone covers other areas outside the core zone. To see the potential distribution of groundwater in each area of the zone, then the following will describe the function of each regional zone along with its potential distribution of groundwater. This zone includes: Bazar, accommodation, special interest tourism, conservation of nature and culture, marine (fisheries and marine), agrobusiness and agrotourism, conservation of Japanese cave and ecotourism, settlement.

F. Conclusion

The quality of groundwater in the study area mostly meet the quality standards of drinking water issued by the Governor of Special Region of Yogyakarta number 214/KPTS/1991 on Standard Local Environmental for the Region of Special Region of Yogyakarta and most of the groundwater in the study area has a type of bicarbonate water due the effect of structural denudasional hills of Wonosari Formation which has a limestone material. There is no influence of seawater on the groundwater in the study area, there is only the effect of connate water in the tourism area of Parangwedang. The upconing has not occurred in the study area, and it is because the amout of groundwater taken has not exceeded the allowable maximum discharge of groundwater pumping. Groundwater in the tourism area of Parangtritis meets the requirements of water quality, so that it can be developed for the purpose of meeting the needs of clean water in Parangtritis with the proportion of groundwater taken does not exceed the discharge and supply of groundwater in the region for several tourist activities in the core zone and the tourist area zone.

Acknowledgments: The authors gratefully acknowledge the research supported in part by Department of Natural Resources and Environmental Study, National Dong Hwa University, Taiwan R.O.C.

Author Contributions: Hendro Murtianto conducted the field samplings, data collection, and other works under the supervision of Shyang Woei Lin. Hendro Murtianto formulated the research topic as part of his Ph.D. dissertation.

References:

[1] FAO, 1997, *Seawater Intrusion In Coastal Aquifers*, Food And Agriculture Organization Of The United Nations, Rome.
[2] Rachmawati, R.S., 1998, *The Study of Groundwater in Parangtritis Area, Surrounding of Bantul Regency*, Thesis, Geography Faculty, Universitas Gadjah Mada, Yogyakarta.
[3] Fidhiana, WP 2008, *Potency of Groundwater in Parangtritis village, Kretek, Bantul Regency*, Tesis, Geography Faculty, Universitas Gadjah Mada, Yogyakarta.

[4] Todd, D.K., 1980, *Groundwater Hydrology*, 2nd edition, John Wiley & Sons, New York.
[5] Bappeda Bantul, 2000, *The Preparation of RIPOW Parangtritis*, Tourism Development and Research Center UGM, Yogyakarta.

[6] Revelle, R., 1941, *Criteria for Recognition of Sea Water in Ground Water*, America Geophysical Union, V.22.

[7] Sutikno, 1990, The Study of Landform for Suplying Clean Water System in Serang Catchment Area, Kulon Progo Regency, Geography Faculty UGM, Yogyakarta.

[8] Sutikno, 1989, *Coastal Geomorphology of Parangtritis Yogyakarta*, Gadjah Mada University, Yogyakarta.

[9] Purnama, Setyawan.,Suyono., Simoen, Soenarso., 1993, Distribution of Saltwater Intrusion in Groundwater in Coastal Area Jawa Tengah and Yogyakarta. Research Report, Geography Faculty, UGM, Yogyakarta.