Ground water quality in natural forest and private forest (a case study in catchment area of lake Rawapening, Semarang District Central Java)

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Abstract. The availability and especially the quality of water are strongly influenced by forests (natural and private forest) and depend on proper forest management. Research location is in the catchment area of Lake Rawapening. The objective of this study was to identify groundwater quality in the area of natural forests (NF) and private forests (PF). Distribution and extent of both natural and private forests can be obtained from Indonesia Topographic Map, scale of 1:25,000 produced in the year of 2001 and updated with SPOT 2 image recorded in July 5th 2006. Groundwater samples were taken from natural and private forest as many as 3 samples. All the samples were taken during the dry and rainy season. Total amount of the samples were 12 and were analyzed in the laboratory of hydrology. The quality of groundwater is determined based on the regulation of the Ministry of Health of Republic of Indonesia No. 492/Menkes/Per/IV/2010. The results indicated that water samples from natural forests (NF1, NF2 and NF3) and private forests (PF1, PF2 and PF3) can be categorized as qualify for drinking water.

1. Introduction

Water is one of the natural resources which is one of the basic needs of the organism. The volume of water (salt water and fresh water) on the earth is equal to 1,385,984,610 km$^3$ [1]. While the volume of fresh groundwater found on earth and can be used for organism is as big as 10,530,000 km$^3$. Groundwater is one of the natural resources that can be used for various purposes such as bathing, washing and cooking. According to the regulation of the Ministry of Public Works of Indonesia No.7 the year of 2004, groundwater is water that is found in layers of soil or rocks below the surface of the soil [2]. Lake Rawapening is extremely important for ecological system. Furthermore, it supports power plant generation for the people, capture fisheries, irrigation, water supply, domestic uses, and more importantly for tourism activities. In brief, with the extent of 25,079 ha area, the lake is a pierce ecosystem to support human welfare in the area [3]. According to Central Java Environmental Agency (Badan Lingkungan Hidup) (2012), water volume maximum of Rawapening Lake is 65 million m$^3$ and minimum 25 million m$^3$ approximately.

Groundwater is found in several types of geological formations, one of which is an aquifer, which is a rock formation that can store or pass water. Aquifers are composed of impermeable rocks called an aquiclade, while aquifuge is an aquifer composed of rocks that cannot store and drain water [4].
Population growth and development has resulted in several of environmental problems related to groundwater, namely the diminishing availability of groundwater sources and increasing groundwater pollution. According to [5] that an increase in population and industrial growth will have an impact on increasing water withdrawal continuously, so that the availability of groundwater will decrease. According to [6] sources of water pollution can come from organic waste, inorganic waste materials, and materials in the form of hazardous chemical substances. Polluted water can be identified physically, chemically and biologically. Therefore, it is necessary to measure and monitor the quality of groundwater.

Forests have a very important role in reducing surface runoff and raising the base flow, so that forests are able to function as flood control and keep the continuity of water supply during the dry season. Forest can improve soil infiltration capacity so as to increase the supply of water into the groundwater reservoir. The objective of this study was to identify groundwater quality in the area of natural forests and private forests. Therefore, the local communities can use the groundwater to meet their needs. Besides that, the local communities are expected to protect the forest and develop private forests so that the quality of the groundwater can be maintained.

2. Methods
2.1. Location
A Catchment area of Rawapening Lake is laid in the coordinate between 110°17’ to 110°30’ East and 7°5’ to 7°25’ South. Administratively, the catchment area is mostly located in Semarang district [7]. There are 9 main rivers that empties into the Rawapening Lake, namely Galeh, Kedung Ringin, Legi, Panjang, Parat, Rengas, Ringin, Sraten and Torong. Based on contour map analysis, slopes of land in the catchment area vary from 0 % to more than 45 %. Land with slope of 0 - 8% are located around the lake. Further, land with slope of 8 - 15% are located at the foot slope of Merbabu Volcano, while that of with slope more than 45 % are located at around Gajah Mungkur Mountain. The Research area is presented in figure.1.

Figure 1. Research location map
Based on Indonesian Topographic Map (RBI) scale of 1:25,000 and SPOT-2 image analysis, the catchment area has a total area of approximately 26,575.85 ha while natural forest occupies an area as large as 1,490.38 ha and private forest occupies 8,032.58 ha. Distribution of sample points location are presented in figure 2.

![Figure 2. Sample points location](image)

2.2. Material and Tools

The materials used in this research are Indonesian Topographic Map (RBI) scale of 1:25,000 produced in 2001 was obtained from the Geospatial Information Agency (BIG), SPOT-2 image recorded in July 5th, 2006 was obtained from the Indonesian National Institute of Aeronautics and Space (LAPAN) and thematic map such as soil type map scale 1:100,000 and geological map scale 1:100,000. The thematic maps were obtained from the Forest Protection and Watershed Management Agency (BPDASHL) Ministry of Environment and Forestry. Land cover / land use survey was carried out in 2017. Tools can be divided into three i.e. digital image processing and GIS analysis, such as hardware and software (Erdas Imagine version 9.1 and ArcGIS 10.2). Field survey equipment consists of compass, Global Positioning System (GPS), balpoint, and clipboard. Printing equipment consists of cartridges and papers. The SPOT-2 satellite imagery used for the classification of natural forests and private forests must be corrected geometrically and radiometrically.

The SPOT-2 image obtained through sensor recording mechanism cannot be separated from errors that can be caused by the mechanism of recording, satellite movement, topography of the earth's surface and atmospheric conditions at the time of recording. The error needs to be corrected so that the image can be used for resource mapping and environmental assessment [8]. In case of satellite imageries which experience topographically induced illumination effects, one measure that can be done to improve the land cover classification results is by conducting topographic correction [9].
2.3. Research Procedures
The research method used was a survey with purposive sampling of groundwater samples in natural forests and private forests. Groundwater samples are carried out on springs that occur in natural forests and private forests as much as 3 samples. All the samples were taken during the dry and rainy season. Total amount the samples were 12 and then analyzed in the laboratory of hydrology. The quality of groundwater is determined based on [10]. Research procedure is presented in figure 3.

Figure 3. Chart of research procedures
3. Results and Discussions

Analysis of ground water quality consists of 3 types, namely: (1). The chemical quality of groundwater consists of elements: acidity (pH), nitrite (NO$_2$), nitrate (NO$_3$), cyanide (CN), selenium (Se), aluminum (Al), iron (Fe), arsenic (US), Fluoride (F), Chromium (Cr), Hardness, Zinc (Zn), Sulfate (SO$_4$), Copper or Copper (Cu), and Ammonia (NH$_3$); (2). The physical quality of ground water consist of elements: Smell, Color, TDS, Turbidity, Taste, and Temperature. Samples of groundwater were taken during rainy season (March 2016) and during dry season (September 2016). Based on the result study of [11], dig wells in Daraulin village are polluted with domestic waste.

3.1. Chemical Quality of Groundwater

The chemical quality of ground water consists of elements: acidity (pH), nitrite (NO$_2$), nitrate (NO$_3$), cyanide (CN), selenium (Se), aluminum (Al), iron (Fe), arsenic (US), Fluoride (F), Chromium (Cr), Hardness, Zinc (Zn), Sulfate (SO$_4$), Copper (Cu), and Ammonia (NH$_3$). Results of laboratory analysis of the chemical quality of groundwater during the rainy season were presented in Table 1 and Table 2.

| No | Elements         | Standard quality | Unit | Land Use |
|----|------------------|------------------|------|----------|
|    |                  |                  |      | NF1      | NF2      | NF3      | PF1      | PF2      | PF3      |
| 1  | pH               | 6.5-8.5          | mg/l | 5.0      | 6.7      | 6.2      | 5.4      | 6.2      | 6.0      |
| 2  | Nitrite (NO$_2$) | 3 mg/l           | <0.0013 | <0.0013 | <0.0013 | 0.002    | 0.0136   | <0.0013 |
| 3  | Nitrate (NO$_3$) | 50 mg/l          | 0.12 | 2.03     | 1.15     | 10.48    | 13.59    | 3.30     |
| 4  | Alumunium (Al)   | 0.2 mg/l         | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| 5  | Iron (Fe)        | 0.3 mg/l         | 0.2265 | 0.0407 | <0.0162 | <0.0162 | <0.0162 | <0.0162 |
| 6  | Arsen (As)       | 0.01 mg/l        | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| 7  | Fluoride (F)     | 1.5 mg/l         | 0.0921 | <0.0921 | <0.0921 | <0.0921 | <0.0921 | 0.1151 |
| 8  | Chromium (Cr)    | 0.05 mg/l        | <0.0213 | <0.0213 | <0.0213 | <0.0213 | <0.0213 | <0.0213 |
| 9  | Hardness         | 500 mg/l         | 45.45 | 47.52     | 52      | 57      | 120.790 | 130, 69 |
| 10 | Zinc (Zn)        | 3 mg/l           | 0.0093 | <0.0083 | <0.0083 | <0.0083 | <0.0083 | <0.0083 |
| 11 | Sulfate (SO$_4$) | 250 mg/l         | 7     | 9         | 8       | 8       | 6       | 9       |
| 12 | Copper (Cu)      | 2 mg/l           | <0.0069 | <0.0069 | <0.0069 | <0.0069 | <0.0069 | <0.0069 |
| 13 | Ammonia          | 1.5 mg/l         | <0.0003 | <0.0003 | <0.0003 | <0.0003 | <0.0003 | <0.0003 |

Remark: NF: Natural Forest, PF: Private Forest
Table 2. The results of chemical analysis of groundwater in during dry season (September) were compared with the regulation of the Ministry of Health of Republic of Indonesia No. 492/Menkes/Per/IV/2010

| No | Elements       | Standard quality | Unit | Land use | Land use | Land use | Land use | Land use |
|----|----------------|------------------|------|----------|----------|----------|----------|----------|
|    |                |                  |      | NF1      | NF2      | NF3      | PF1      | PF2      |
| 1  | pH             | 6.5-8.5          |      | 5.2      | 4.7      | 4.8      | 5.7      | 5.8      |
| 2  | Nitrite (NO2)  | 3                | mg/lt| < 0.0013 | < 0.0013 | 0.0013   | 0.006    | 0.0093   |
| 3  | Nitrate (NO3)  | 50               | mg/lt| 0.84     | < 0.04   | < 0.004  | 0.3      | 2.69     |
| 4  | Alumunium (AL)| 0.2              | mg/lt| R        | R        | R        | R        | R        |
| 5  | Iron (Fe)      | 0.3              | mg/lt| 0.2049   | 0.9377   | 0.5043   | 0.1245   | 0.0619   |
| 6  | Arsen (As)     | 0.01             | mg/lt| < 0.005  | < 0.005  | < 0.005  | < 0.005  | < 0.005  |
| 7  | Flouride (F)   | 1.5              | mg/lt| 0.5038   | 0.5871   | 0.3287   | 0.3568   | 0.4600   |
| 8  | Chromium (Cr)  | 0.05             | mg/lt| < 0.0213 | < 0.0213 | < 0.0213 | < 0.0213 | < 0.0213 |
| 9  | Hardness       | 500              | mg/lt| 98.99    | 48.48    | 42.42    | 62.63    | 118.18   |
| 10 | Zinc (Zn)      | 3                | mg/lt| < 0.0083 | < 0.0083 | 0.04259  | < 0.0083 | < 0.0083 |
| 11 | Sulfate (SO4)  | 250              | mg/lt| 8        | 2        | 9        | 6        | 49       |
| 12 | Copper (Cu)    | 2                | mg/lt| < 0.0069 | < 0.0069 | < 0.0069 | < 0.0069 | < 0.0069 |
| 13 | Ammonia        | 1.5              | mg/lt| 1.5      | < 0.0003 | < 0.0003 | < 0.0003 | < 0.0003 |

Remark:
NF : Natural Forest
PF : Private Forest
R : Not Recorded

3.2. Physical Quality of Groundwater

Physical analysis of groundwater is determined qualitatively and quantitatively. Some parameters of the physical properties of groundwater, which is qualitatively determined such as smell and taste, while those determined quantitatively are color, turbidity, Total Dissolved Solids (TDS) and temperature. The physical quality of groundwater is determined based on [10]. The results of physical analysis of groundwater from natural forests and private forests were presented in table 3 and table 4. Based on table 3 and table 4, the results of physical quality analysis of groundwater have value below the standard quality value for drinking water. Based on [10] concerning Drinking Water Quality Requirements, physical quality of groundwater at the study location can be categorized as qualify for drinking water. Cohesion and adhesion as well as hydrophobicity are part of many important natural occurrences, such as water retention and movement in the soil, as well as solubility and mobility of pollutants in the groundwater [13].
Table 3. The results of physical analysis of groundwater in during rainy season (March) were compared with the regulation of the Ministry of Health of Republic of Indonesia No. 492/Menkes/Per/IV/2010

| No | Elements   | Standard Quality | Unit | Land use |
|----|------------|------------------|------|----------|
|    |            |                  |      | NF1 | NF2 | NF3 | PF1 | PF2 | PF3 |
| 1  | Smell      | NS               | NS   | NS  | NS  | NS  | NS  | NS  | NS  |
| 2  | Color      | 15 TCU           | < 1  | 3   | 3   | 9   | < 1 | 1   |     |
| 3  | TDS        | 500 mg/lt        | 57   | 68  | 69  | 85  | 159 | 208 |
| 4  | Turbidity  | 5 NTU            | 2    | 3   | 1   | 4   | 1   | 2   |     |
| 5  | Taste      | T                | T    | T   | T   | T   | T   | T   |     |
| 6  | Temperature| Dev 3            | 28.1 | 28.1 | 25.2 | 29.1 | 29.1 | 28.1 |     |

Remark:
NS : Not Smell
T : Tasteless
NTU : Nephelometric Turbidity Units
TCU : True Color Unit

Table 4. The results of physical analysis of groundwater in during dry season (September) were compared with the regulation of the Ministry of Health of Republic of Indonesia No. 492/Menkes/Per/IV/2010

| No | Elements   | Standard Quality | Unit | Land Use |
|----|------------|------------------|------|----------|
|    |            |                  |      | NF1 | NF2 | NF3 | PF1 | PF2 |
| 1  | Smell      | NS               | NS   | NS  | NS  | NS  | NS  | NS  |
| 2  | Color      | 15 TCU           | < 1  | < 1 | < 1 | < 1 | < 1 |     |
| 3  | TDS        | 500 mg/lt        | 60   | 47  | 48  | 80  | 116 |
| 4  | Turbidity  | 5 NTU            | 1    | 4   | 5   | 5   | 2   |     |
| 5  | Taste      | T                | T    | T   | T   | T   | T   |     |
| 6  | Temperature| Dev 3            | 25.2 | 26.1 | 26.1 | 26.1 | 26.1 |     |

Remark:
NS : Not Smell
T : Tasteless
NTU : Nephelometric Turbidity Units
TCU : True Color Unit

4. Conclusion
Based on [10] concerning Drinking Water Quality Requirements, the quality of ground water (both physical and chemical) at the study location qualifies as drinking water. However, almost all groundwater samples have a pH <6.5 (below the drinking water quality standard) except for samples in natural forest number 2 (NF 2) taken during the rainy season (March) which has a pH that is in accordance with the drinking water quality standards. To maintain groundwater quality and to avoid groundwater pollution hence the used of fertilizers from hazardous chemicals in the agricultural land, moor and vegetable fields must be reduced and replaced with the used of organic fertilizers and biological pesticides.
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