Water quality as a base of water treatment with appropriate technology in Girikerto Village, Sine Subdistrict, Ngawi Regency

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Abstract. Girikerto village is located in the upper part of Bengawan Solo sub-watershed and Madiun River sub-watershed. This village has an important role as a recharge zone, while villagers take wood from forest and change land use which will accelerate deforestation on the northern slope of Mount Lawu. This research is needed because it studies the water quality from the spring and river in sub-watershed which includes Girikerto village, to find the alternative water source for drinking water. The objectives of this research are 1) to know the water quality, 2) to compare the water quality with the quality standard, and 3) to know the water pollution status in sub-watershed in which Girikerto village is included. There are several steps in the method, started from collecting water sources data and information; determining points of water sampling by field survey; water sampling; water quality testing in the field for physical properties such as color, odor, and taste; water quality testing in the laboratory for other physical, biological, and chemical properties. The samples are taken at two springs (Sumber Lanang and Sumber Koso) and three rivers (river flow after PLTMh 1-2, after PLTMh 3, and Klenteng). The value of water quality is then compared to the quality standard and calculated into the water pollution status based on TSS, DO, and COD. The results show that the water quality in the sub-watershed which includes Girikerto village vary, depending on place and time though not significant. In general, the water source used by the villagers is still on a safe level nowadays because still meet the quality standard or not polluted. The possible recommended water treatment will be conducted in the river flow after PLTMh 3 as an alternative water source, namely demineralization (deionization) as a preliminary project to create drinking water without cooking fuel (forest wood).
1. Introduction

Girikerto village, Sine subdistrict, Ngawi Regency, East Java Province is located on the northern slope of Mt. Lawu. Sine subdistrict holds an important role as a protected area [1]. Two of the protected areas in Sine subdistrict are the protected forest at Mt. Lawu’s slope and local protected areas such as river riparian and the spring’s surrounding. The cultivation areas in Sine subdistrict is allocated as a plantation with commodities such as tobacco, tea, coffee, ginger, clove, chocolate, and zalacca; rural settlement; and animal husbandry.

Girikerto village plays an important role in succeeding Ngawi Regency Spatial Plan (Rencana Tata Ruang Wilayah, RTRW). Its role can be seen by its function as a strategic area of environmental carrying capacity. This village belongs to recharge zone as it is a part of the upper of Bengawan Solo sub-watershed and Kali Madiun sub-watershed (Figure 1).

![Study Area in Girikerto Village](source: Primary Data, 2018)

There are several water sources in Girikerto village, both spring, and river. The most used springs are Sumber Lanang, Sumber Gunung Gandel, and Sumber Koso. Sumber Lanang’s discharge is 95 liters/second [2] and according to Meinzer spring discharge classification, it is classified as springs underclass IV [3]. The springs are used for domestic use and specifically, Sumber Lanang is used for micro hydro power plant or Pembangkit Listrik Tenaga Mikrohidro (PLM). The most used river for domestic use in Girikerto village is river flow after PLTMh 3.

Former research of water quality in the upper part of Bengawan Solo and Kali Madiun sub-watershed discussed the properness of water quality in Sumber Lanang and drinking water produced by PT Candiloka in Jamus, Girikerto village. The parameters used were coliform, total plate number (to determine the total of aerobic and anaerobic microorganisms), nitrate, and nitrite. The result showed that coliform, total plate number, nitrate, and nitrite of Sumber Lanang spring are lower than drinking water produced by PT Candiloka [4]. The research compared water from the spring and processed water. A continuation from the research, which analyzes the water quality from more than one point and parameters, is needed.

The objectives of this research are 1) to know the water quality, 2) to compare the water quality with the quality standard, and 3) to know the water pollution index in sub-watershed in which Girikerto village is included. This research is expected to be a foundation for water treatment with appropriate technology, as PT Candiloka has no longer produces drinking water for commercial use.
when observed in 2016. This research is important as the spring’s discharge will be efficiently and effectively used if there is another usage of the alternative water source. Besides, deforestation still happens and is considered as a not serious matter by villagers; even though forest conserve the population genetic in nature [5], maintain slope and water cycle [6,7]. Villagers use woods from forest to cook, including cooking water to drink, and fulfill agricultural needs as occurred in Argentina [8]. Continuing deforestation can interfere with recharge zone, which leads to a reduction of spring’s discharge in the future.

2. Methodology
This research started with collecting water sources data and information. Water samples were determined by field survey and then taken from five points (Figure 2), as follows: 1) Sumber Lanang spring, 2) the river flow after PLTMh 1-2, 3) the river flow after PLTMh 3, 4) Sumber Koso spring, and 5) Klenteng river (located in the border of Nglegok-Girikerto sub-village). Samples were taken twice, the first in the morning and the second in the afternoon on the same day. Sumber Gunung Gandel spring was not taken because it is not easily accessible, far from the village settlement and street.

The water samples are observed in the field for physical parameters such as color, odor, and taste. The water samples are then examined in the laboratory for other physical, biological, and chemical parameters. The physical parameters which are examined in the laboratory are turbidity, total dissolved solids (TDS), and total suspended solids (TSS). The biological parameter includes coliform (E. coli bacteria). Chemical parameters include pH, dissolved oxygen (DO), chemical oxygen demand (COD), sodium (Na⁺), potassium (K⁺), calcium (Ca²⁺), magnesium (Mg²⁺), total iron (Fe), chloride (Cl), bicarbonate (HCO₃⁻), total hardness (CaCO₃), sulfate (SO₄²⁻), and nitrate (NO₃⁻). All cations and anions are illustrated by a stiff diagram.

The water quality results are analyzed by comparing the values to the standard. The parameters used in water pollution status calculation are TSS, DO, and COD [9]. The values are processed and analyzed based on a calculation of water quality status by [10]. Water pollution status is represented by water pollution index (PIj), calculated with formula (i-iv) followed by Table 1 and in general, refers to the standard for drinking water or class I [9].

\[
\frac{C_i}{L_{ij}} = \frac{\text{water quality concentration}}{\text{standthe ard value of water quality concentration}}
\]

\[
\text{PIj} = \sqrt{\left(\frac{C_i}{L_{ij}}\right)^{2/k} + \left(\frac{C_i}{L_{ij}}\right)^{2/M}}
\]

where:
PIj = water pollution index
Ci = water quality concentration in parameter i—TSS, DO, or COD— (mg/l)
Lij = water quality concentration in parameter i—TSS, DO, or COD— at standard j (mg/l)
\((C_i/L_{ij})_M = \text{maximum value of } C_i/L_{ij}\)
\((C_i/L_{ij})_R = \text{average value of } C_i/L_{ij}\)
(Ci/Lij) that has value more than 1.0 from (i), needs to be recalculated with (Ci/Lij)_new as follow [10]:

$$ (Ci/Lij)_{new} = 1.0 + 5x \log (Ci/Lij)_{measurement \ result} $$

\( (3) \)
DO parameter has antagonistic characteristics with other parameters. The higher the DO, the quality of water is better (pollution indication is lower). Therefore, the value of \( \frac{C_i}{L_{ij}} \) for DO should be adjusted to a formula below [10]:

\[
\frac{C_i}{L_{ij}} = \frac{C_{im} - C_{i \text{ measurement}}}{C_{im} - L_{ij}}
\]

where:

\( C_{im} \) = maximum DO, 8.26 mg/l for saturated DO values at room temperature (25°C) (Cole, 1983 in [12]).

3. Discussion

Water from Sumber Lanang spring flows to the river after PLTMh 1-2 then continue to the river after PLTMh 3, to the north. Water from Sumber Lanang spring also flows to Klenteng river at the northwestern part. Sumber Kosos spring is separated from the system which connects point 1, 2, 3, and 5, but is also taken as a comparing material to Sumber Lanang spring as it is widely used by villagers of Girikerto.

3.1. Physical Properties of Water

Physical properties of water are represented in Table 2 and Table 3. The parameters of odor, taste, and color in the morning and in the afternoon from every point have the same results, where the parameters are analyzed qualitatively. The turbidity in the morning samples is the same as the afternoon. The highest turbidity is on sample 5. This is caused by the condition of the location, which contains suspended solids such as mud and colloid substances from extracted vegetation or transported sediment. TDS parameter on sample 1 to 2 and 3 generally increases, so does sample 1 to 4. The parameter increases on sample 1 to 2 and 3 or 1 to 5 is affected by sample points contaminated by liquid waste. Point 1 is the spring that flows to point 2 and 3. This point is yet to be contaminated by domestic liquid waste, while point 2 and 3 have been contaminated by domestic liquid waste from the villagers. Besides, point 1 has not been contaminated by liquid waste from Candiloka tea industry, yet point 2 and 3 has been contaminated with liquid waste from Candiloka tea industry. TDS concentration on point 4 is higher than point 1. This is because Sumber Kosos as a spring is not well protected as Sumber Lanang spring. TDS on point 5 is higher than its source as there is suspension sediment. No recent data about the relationship between a health effect and TDS consumption in drinking water. When the amount exceeds the safe limit, TDS specific components such as chloride, sulfate, magnesium, calcium, and carbonate can affect health. The highest TSS is on point 2 in the morning and 3 in the afternoon. TDS and TSS in the afternoon samples are generally higher than morning samples. Human activity during the day increases the dissolved and suspended solid, especially in the opened water sources such as river after PLTMh 3, Klenteng river, and Sumber Kosos spring.

| No | Parameter | Unit | Standard | 1.1 | 2.1 | 3.1 | 4.1 | 5.1 |
|----|-----------|------|----------|-----|-----|-----|-----|-----|
| 1. | color     | TCU  | colorless[13,14] | colorless | colorless | colorless | colorless | colorless | colorless | colorless |
| 2. | odor       | -    | odorless[15,16,13,14] | odorless | odorless | odorless | odorless | odorless | odorless | odorless |
| 3. | taste      | -    | tasteless[15,16,13,14] | tasteless | tasteless | tasteless | tasteless | tasteless | tasteless | tasteless |
| 4. | turbidity  | NTU  | 5[16,14,17] | 0.00 | 0.00 | 0.00 | 0.00 | 0.31 |
| 5. | TDS        | mg/l | 500[16,14] | 37.6 | 37.5 | 37.7 | 45.6 | 38.2 |
| 6. | TSS        | mg/l | 25a | 4.2 | 13.8 | 8.4 | 0.4 | 4.8 |

Source: Primary Data, 2018

an Alabaster and Lyold, 1982 in [12]
### Table 3. Physical Properties of Water in Afternoon Sampling in Girikerto Village, Sine Subdistrict

| No | Parameter | Unit | Standard 1.2 | Standard 2.2 | Standard 3.2 | Standard 4.2 | Standard 5.2 |
|----|-----------|------|--------------|--------------|--------------|--------------|--------------|
| 1. | color     | TCU, colorless | colorless | colorless | colorless | colorless | colorless |
| 2. | odor       | odorless | odorless | odorless | odorless | odorless | odorless |
| 3. | taste      | tasteless | tasteless | tasteless | tasteless | tasteless | tasteless |
| 4. | turbidity  | NTU | 5[16,14,17] | 0.00 | 0.00 | 0.00 | 0.00 | 0.31 |
| 5. | TDS        | mg/l | 500[16,14] | 37.5 | 37.8 | 37.9 | 46.1 | 38.2 |
| 6. | TSS        | mg/l | 25a | 8 | 1.2 | 12.2 | 10 | 8.6 |

source: Primary Data, 2018

3.2. **Biological Properties of Water**

Biological properties or biotic aspects of water quality that are generally tested are coliforms, benthos, and plankton [18]. This study reviewed only total coliform (Table 4 and Table 5), which is calculated as the most probable number of *Escherichia coli* bacteria in 100 ml. *E. coli* which will be consumed as drinking water must be zero or 0 MPN/100 ml [16]. The water body on the earth surface is possibly containing coliform because surface water is closely related to the sunlight penetration. The physical properties of water in Girikerto village which are not turbid and still relatively low in suspension support sunlight penetrates underwater so it supports the growth and development of aquatic organisms, including *E. coli*. Therefore, a longer standard of quality is used. Tolerance of *E. coli* bacteria up to 100 MPN/100 ml and total coliform of 1,000 MPN/100 ml in class I which is raw water to be processed for drinking water [14]. Tolerance of *E. coli* up to 10 MPN/100 ml for drinking water [17].

Biological properties (*E. coli*) of water samples in the study area vary from less than 3, 3, 7, and 28 MPN/100 ml. The samples still meet drinking water quality standards based on [14] though based on [17], sample 1.1 exceeds the quality standards. Sample 1.1 or Sumber Lanang spring in the morning has an outlier value compared to other data. *E. coli* must be analyzed as soon as possible after taking water samples, before 30 hours in drinking water samples and before 6 hours on water source samples, with storage at temperatures below 10 °C [19]. If all samples are tested beyond the sample preservation time limit, the measured *E. coli* bacteria can be excessive because it develops within the period of time during storage. Data shows that the development of *E. coli* bacteria in sample 1.1 is very fast. Conventional water treatment based on [14] shows that *E. coli* 100 MPN/100 ml bacteria can be tolerated so that conventional or more sophisticated water treatment technology can reduce or destroy *E. coli* for drinking purposes.

### Table 4. Biological Properties of Water in Morning Sampling in Girikerto Village, Sine Subdistrict

| No | Parameter | Unit | Standard 1.1 | Standard 2.1 | Standard 3.1 | Standard 4.1 | Standard 5.1 |
|----|-----------|------|--------------|--------------|--------------|--------------|--------------|
| 1. | *E. coli* | MPN/100 ml | 10[17] | 28 | <3 | 7 | <3 |

source: Primary Data, 2018

### Table 5. Biological Properties of Water in Afternoon Sampling in Girikerto Village, Sine Subdistrict

| No | Parameter | Unit | Standard 1.2 | Standard 2.2 | Standard 3.2 | Standard 4.2 | Standard 5.2 |
|----|-----------|------|--------------|--------------|--------------|--------------|--------------|
| 1. | *E. coli* | MPN/100 ml | 10[17] | <3 | <3 | <3 | <3 |

source: Primary Data, 2018
3.3. Chemical Properties of Water

Table 6 and Table 7 show the chemical properties of water in the study area. pH value of water samples in Girikerto village ranges from 6.14-7.03. The water pH range Girikerto village still meets the standards for drinking water (6-9) [14], but not at all points meet the standard [15, 16, 17]. Both Sumber Lanang and Sumber Koso spring have pH value under 6.5, in morning and afternoon samples. It can be caused by the number of stagnant litter and fairly calm water forming a pool, especially in Sumber Koso. This stagnant litter can rot and cause a lower pH than other sample water. Besides, water in quite a calm environment will not make the litter drift and gather at the location of the spring. Note that water pH is an indicator of the level of water quality and pollution [20].

Water with pH lower than 6.5 or higher than 8.5 causes some chemical compounds to become highly toxic in the human body [21]. According to data from the World Health Organization (WHO), pH causes health problem if the level is above 10 or below 4. Water with pH >11 causes irritation on eyes and skin exacerbation. pH on level 10-12.5 causes swelling on hair fibers and gastrointestinal irritation for sensitive individual. pH with a level below 4 causes redness and eye irritation, which increases as the pH decreases [22]. According to the pH measurement result on all samples, water is still safe to be used in general.

DO measurement in the study area is in between 6.48-8.1. The DO meet the standard, which should be minimum 6 [14]. The highest DO from five points is from PLTMh and Klenteng river. The highest level is caused by heavy water flow. A heavy water flow helps diffusion process between oxygen and water [23]. Klenteng River canal is located on the upper part of sub-watershed, which features many rocks and high water turbulence. These features increase oxygen diffusion in water. The lowest DO of five points is acquired by Sumber Koso with DO value 6.93 in the morning and 6.48 in the afternoon. The lowest DO is caused by still water, so diffusion is not massive. Besides, the amount of aquatic biota and microorganisms in Sumber Koso reduces DO level. The existence of aquatic biota, such as fish and tadpole, reduce DO level as the biota consume oxygen. The high amount of litters become the place for aerobic microorganisms, which consume oxygen for its metabolisms to grow. The high amount of organic matters cause most oxygen consumed by microorganisms [23].

As the spring is covered by canopy trees, leads to lower light intensity and reduces photosynthesis of water vegetation and photosynthetic microorganisms. In general, DO level decreases in the afternoon. This is caused by a decrease in water discharge and low light intensity. However, the DO level in Sumber Lanang increases in the afternoon. This is caused by swift water flow, terraced water flow building, high light intensity, and water flow ground are covered by moss. These characteristics increase oxygen diffusion. The high amount of light increases photosynthesis in moss.

| No | Parameter | Unit | Standard | 1.1 | 2.1 | 3.1 | 4.1 | 5.1 |
|----|-----------|------|----------|-----|-----|-----|-----|-----|
| 1. | pH | - | 6.5-8.5[15,16,17] | 6.38 | 6.54 | 6.79 | 6.15 | 7.03 |
| 2. | DO | mg/l | 6[14,17] | 7.38 | 8.10 | 7.92 | 6.93 | 7.83 |
| 3. | COD | mg/l | 20[17] | 9.05 | 10.00 | 10.00 | 15.09 | 10.32 |
| 4. | Na⁺ | mg/l | 200[13,17] | 33.44 | 6.49 | 129.7 | 47.18 | 34.95 |
| 5. | K⁺ | mg/l | 10[17] | 2.95 | 2.87 | 2.84 | 2.93 | 2.21 |
| 6. | Ca²⁺ | mg/l | 15 | 8.484 | 8.888 | 7.676 | 10.1 | 7.676 |
| 7. | Mg²⁺ | mg/l | 50[17] | 1.9634 | 1.7180 | 2.6997 | 2.6997 | 2.673 |
| 8. | Fe | mg/l | 0.3[16,14,17] | 0.00 | 0.01 | 0.01 | 0.01 | 0.03 |
| 9. | Cl⁻ | mg/l | 100 | 16.2945 | 19.7 | 17.253 | 17.253 | 18.2115 |
| 10. | HCO₃⁻ | mg/l | * | 65.0016 | 76.8722 | 65.0016 | 88.7428 | 65.0016 |
| 11. | CaCO₃ | mg/l | 50 | 29.29 | 29.29 | 30.30 | 36.36 | 30.30 |
| 12. | SO₄²⁻ | mg/l | 250[15,16] | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 |
| 13. | NO₃⁻ | mg/l | 10 | 0.245 | 0.00 | 0.00 | 0.867 | 0.00 |

source: Primary Data, 2018

* in combination with calcium and magnesium forms carbonate hardness
b Peavy et al., 1985 in [12]  d Davis & Cornwell, 1991; Sawyer & McCarty, 1978 in [12]
c McNeely et al., 1979 in [12]  e Davis & Cornwell, 1991 in [12]
COD represents the amount of oxygen needed to chemically oxidize organic matter to CO$_2$ and H$_2$O. COD will be more precisely analyzed in water which contains resistant organic materials to biological degradation such as cellulose, tannin, lignin, phenol, polysaccharides, and benzene [12]. The COD analysis is important in the study area because it is relatively faster tested than Biological Oxygen Demand (BOD), and COD become indicators for water pollution [18]. COD in the study area varies between 9.05 mg/l - 15.09 mg/l in morning samples and 8.42 mg/l - 14.45 mg/l in afternoon samples. The lowest COD is point 1, followed by the three points (river), and the highest is point 4. Water samples in COD value are still meet the standard because lower than 20 mg/l [17].

| No | Parameter | Unit | Standard | 1.2 | 2.2 | 3.2 | 4.2 | 5.2 |
|----|-----------|------|----------|-----|-----|-----|-----|-----|
| 1  | pH        | -    | 6.5-8.5[^15,16,17] | 6.46 | 6.77 | 6.88 | 6.35 | 6.98 |
| 2  | DO        | mg/l | 6[^14,17] | 7.47 | 7.56 | 7.65 | 6.48 | 7.56 |
| 3  | COD       | mg/l | 20[^17] | 8.42 | 9.37 | 8.73 | 14.45 | 12.86 |
| 4  | Na$^+$    | mg/l | 200[^13,17] | 43.05 | 53.64 | 53.41 | 53.31 | 75.16 |
| 5  | K$^+$     | mg/l | 10[^17] | 2.81 | 2.9 | 2.96 | 2.7 | 1.88 |
| 6  | Ca$^{2+}$ | mg/l | 15[^17] | 8.08 | 8.08 | 8.484 | 10.504 | 8.08 |
| 7  | Mg$^{2+}$ | mg/l | 50[^17] | 1.9634 | 2.2089 | 1.9634 | 2.2089 | 2.4543 |
| 8  | Fe        | mg/l | 0.3[^16,14,17] | 0.01 | 0.01 | 0.01 | 0.01 | 0.04 |
| 9  | Cl$^-$    | mg/l | 100[^d] | 16.2945 | 18.2115 | 18.2115 | 19.17 | 18.2115 |
| 10 | HCO$_3^-$ | mg/l | 88.7428-76.8722 | 88.7428 | 76.8722 | 76.8722 | 65.0016 |
| 11 | CaCO$_3$  | mg/l | 50[^b] | 28.28 | 29.29 | 29.29 | 35.35 | 30.30 |
| 12 | SO$_4^{2-}$ | mg/l | 250[^15,16] | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 |
| 13 | NO$_3^{-}$ | mg/l | 10[^e] | 0.00 | 0.00 | 0.00 | 1.08 | 0.00 |

source: Primary Data, 2018

Figure 3 and Figure 4 illustrated stiff diagram, to show the dominant ion in water. The dominant cation in the stiff diagram is Na$^+$+K$^+$ or sodium and potassium, while the dominant anion is HCO$_3^-$ or bicarbonate. Sodium and potassium are cations which are analyzed together. Sodium ion in water samples varies between 6.49 mg/l - 129.7 mg/l in morning samples and 43.05 mg/l - 75.16 in afternoon samples. Potassium ion in water samples vary between 2.21 mg/l - 2.95 mg/l in morning samples and 1.88 mg/l - 2.96 mg/l in the afternoon. Sodium is under the standard, 200 mg/l [17].
Figure 3. Stiff Diagram of Cations and Anions in Morning Water Sampling in Girikerto Village
(source: Primary Data, 2018)

Hard water contains a lot of metal ions Ca$^{2+}$ and Mg$^{2+}$. The highest amount of Ca$^{2+}$ is acquired by Sumber Koso, which is 10.1 mg/l in morning samples and 10.504 mg/l in afternoon samples. A constituent mineral of rock will be dissolved in water, making dissolved ions [24]. Positive ions that are commonly found in almost every water are Na$^+$, K$^+$, and Ca$^{2+}$ [25]. Compared to water in Sumber Lanang, Ca$^{2+}$ in Sumber Koso is higher. The highest amount of Mg$^{2+}$ is acquired by PLTMh 3 and Sumber Koso in the morning, about 2.6997 mg/l, and K lenteng River in the afternoon, about 2.4543 mg/l. The amount of Mg$^{2+}$ is lower than PLTMh 3, Sumber Koso, and Sumber Lanang, both in the morning and in the afternoon. High level of hardness gives a negative effect on health. WHO states that hard water causes tartar, the cardiovascular problem (heart blood blockage) and urolithiasis (kidney stone) [26]. Ca$^{2+}$ and Mg$^{2+}$ in the study area still meet the standard.

Klenteng river contains the highest amount of Fe, which is 0.03 mg/l in the morning and 0.04 mg/l in the afternoon as the river is relatively far from the upstream. It results in the accumulation of physical contact with its surrounding. Fe in groundwater is caused by contact between water and rocks containing Fe, such as a weathering result from pyrite minerals, microcline, and clay minerals [27]. Klenteng River is not groundwater, but Fe constituent minerals are found in river sediments. Iron (Fe) is a basic element in human’s nutrition. Excessive iron causes poisoning, which leads someone to vomit, suffer diarrhea, and suffer intestinal damage [28].

Water samples from PLTMh 1-2 and Sumber Koso contain the highest amount of Cl$^-$, which is 19.7 mg/l in the morning (PLM 1-2) and 19.17 mg/l in the afternoon (Sumber Koso). The existence of chloride in water is caused by industrial activities and domestic waste. Cl$^-$ in PLTMh 1-2 is higher than PLTMh 3 as there is a high amount of salt decomposed in PLTMh 1-2. Chloride in Sumber Koso is higher than in Sumber Lanang as Sumber Koso is near to the settlement area. The high amount of chloride in water is caused by waste decomposition that seeps into the water [29]. High level of chloride is corrosive to skin and equipment, and potentially damage human and animal respiration system [26]. There is no report from a villager who affected by the level of chloride.
The highest amount of HCO$_3^-$ is possessed by Sumber Koso in the morning and Sumber Lanang and PLTMh 3 in the afternoon, which is 88.7428 mg/l. HCO$_3^-$ in water is called Alkalinity. Alkalinity is caused by ionization of carbonic acid, particularly in water with the high amount of saturated CO$_2$. The existence of alkali neutralizes the groundwater. HCO$_3^-$ in Sumber Koso is higher than Sumber Lanang as water in Sumber Koso is stagnate so that CO$_2$ in the water becomes saturated. HCO$_3^-$ in PLTMh 1-2 is lower than PLTMh 3 as the dissolved ion concentration increases when the distance traveled by water is longer [30].

The highest amount of CaCO$_3$ is acquired by Sumber Koso, which is 36.36 mg/l in the morning and 35.35 mg/l in the afternoon. The presence of CaCO$_3$ is caused by physical contact between water and rocks. CaCO$_3$ in Sumber Koso is higher than in Sumber Lanang as Sumber Koso is located far from sub-watershed and the duration of physical contact between water and rocks in Sumber Koso is longer than in Sumber Lanang. CaCO$_3$ in water is called hardness. The compound can disrupt the pipe wall. High hardness is mainly caused by calcium, magnesium, strontium, and forum. Water with high hardness is very detrimental as it leads to corrosion on equipment made by iron, higher consumption for soap as the soap become less foaming, and it causes crust in processing container [31].

The highest amount of SO$_4^{2-}$ is possessed by Sumber Koso in the morning and PLTMh 1-2 in the afternoon. The existence of SO$_4^{2-}$ is caused by domestic waste, such as detergent usage and industrial waste. SO$_4^{2-}$ in Sumber Lanang is lower than Sumber Koso in the morning as Sumber Koso is located near the settlement area, resulting in an easier chance of being contaminated by detergent waste. SO$_4^{2-}$ in PLTMh 3 and Klenteng River is lower than PLTMh 1-2 in the afternoon. SO$_4^{2-}$ in water samples is still lower than the standard (250 mg/l). Sulfate causes irritation on the digestive tract (gastrointestinal tract) [32]. Note that the presence of sulfate and chloride in water can make corrosion on metal heater [33]. Water in the study area is safe to be used because of the low level of SO$_4^{2-}$.

The highest amount of NO$_3^-$ is in Sumber Koso, both in the morning and in the afternoon. The presence of NO$_3^-$ in Sumber Koso is caused by the microbial activity of nitrate. Water in Sumber Koso is stagnate, making the nitrate content is higher than Sumber Lanang. Nitrate is an important anion. In a higher concentration, this compound indicates the pollution source in the water [30]. Nitrate becomes a specific concern as a high level of nitrate causes blue baby syndrome or methemoglobinemia, a blood disease that attacks babies below six months old [28]. There is no report from villagers who suffer from the syndrome.
3.4. Water Pollution Status and Water Treatment

Water quality in Table 2, Table 3, Table 6, and Table 7 are processed to be Table 8. The standard used follows the combination of class I [14][17], and Alabaster and Lyold, 1982 in [12] to accommodate the chance of transforming water in Girikerto village as drinking water. The result shows that pollution index from the highest to the lowest are as follow: Sumber Koso spring, Klenteng river, river flow after PLTMh 3, river flow after PLTMh 1-2, and Sumber Lanang spring. The five points have the water which is not polluted or still meet the quality standard in TSS, DO, and COD.

The cause of the pollution in the points may not come from TSS, DO, and COD since the pH in the 2 springs are below the minimum standard. The contamination status should be considered when the water from potential and actual sources is planned to be used as a material for drinking water. The treatment should consider conditioning, so the pH level will be 6.5 to 8.5.

Table 8. Water Standard Status (Average of Morning and Afternoon Sampling) in Girikerto Village

| Parameter | Unit | Standard (Lij) | 1 | 2 | 3 | 4 | 5 |
|-----------|------|---------------|---|---|---|---|---|
|           |      | (Ci/Lij)      | (Ci/Lij) | (Ci/Lij) | (Ci/Lij) | (Ci/Lij) | (Ci/Lij) | (Ci/Lij) |
| TSS       | mg/l | 25            | 6.1 | 0.244 | 7.5 | 0.3 | 10.3 | 0.412 | 5.2 | 0.208 | 6.7 | 0.268 |
| DO        | mg/l | 6             | 7.425 | 0.0616 | 7.83 | 0.0317 | 7.785 | 0.0350 | 6.705 | 0.1147 | 7.695 | 0.0417 |
| COD       | mg/l | 20            | 8.735 | 0.4368 | 9.685 | 0.4843 | 9.365 | 0.4683 | 14.77 | 0.7385 | 11.59 | 0.5795 |

Water Pollution Index meet the quality standard (<1.0) 

source: Primary Data, 2018 (analyzed)

Villagers in Girikerto village, especially those who reside in Banjaran hamlet, use the river flow after PLTMh 3 for daily needs. This means that the water is safely used as it meets the standard. Villagers who reside in Jamus hamlet use water from Sumber Lanang spring. However, no health
problem is reported. Villagers who reside in Girikerto hamlet, specifically those who live in Bugar (RT 2) and Girikerto (RT 3), use water from Sumber Kosos and there is no health problem reported. This evidence shows that Sumber Lanang and Sumber Kosos spring are still safe to be used. The criteria for safe water contaminant are relative, depending on the standard used. For example, according to class I, the standard pH is between 6 to 9 [14], not 6.5 to 8.5.

There are five points of water sampling which will be selected to cultivate with a treatment. Point 1 and 4 are spring, not recommended as an alternative water source. Point 2 cannot be cultivated because it is input for micro hydropower plant (PLTMh 3), while point 3 is the output of PLTMh 3. Point 5 is not recommended now because it is located on a deep valley, low accessibility. Point 3 is the most possible to cultivate water with treatment, as it has been utilized as daily needs.

There are physical method, chemical method, and energy-intensive technologies to cultivate water to be drinking water. The recommended method of water cultivation in Girikerto village is demineralization, especially deionization or ion exchange [34]. It is relatively easy to do, easy to install, need simple space, and not cause corrosion since the water is not hard or contain low sodium, potassium, and bicarbonate. But deionization will give less mineral in water, so people can support mineral to their body by vegetables. Sine subdistrict is projected to be an agropolitan area [1], so vegetables stock in Girikerto village can be supported. The demineralization/deionization technology also needs experts then human resources who manage the deionization project is village-owned business entity or Badan Usaha Milik Desa (BUMDes), which can be supported by expert mentoring. The deionization needs high cost but the village has two sources of income budget, they are general village fund and tourist village fund.

Using water from the river as an alternative is a need in the future, especially to create drinking water without cooking fuel from forest wood. The forest area in Indonesia continues to decrease as tree cutting continues (Figure 5). One of its contributors is Mt. Lawu’s slope. Upcoming deforestation disrupts the recharge zone, leading to minimizing water discharge or water volume that can be directly used from springs. Deionization technology is expected to keep the forest area, which reaches 493.44 ha or 53.80 % of sub-watershed which includes Girikerto village.

![Forest Area in Indonesia, Continues to Decrease](source: [35, 36, 37] (analyzed))

**Figure 5.** Forest Area in Indonesia, Continues to Decrease

4. **Conclusion**

The water quality in sub-watershed in which Girikerto village is included varies, depending on place and time. However, the difference is not significant at the same location. In general, water quality in the study area meets the standard. The water sources used by the villagers are still on a safe level nowadays because still meet the quality standard or not polluted. The possible recommended water treatment will be conducted on point 3 (river flow after PLTMh 3) as an alternative water source, namely demineralization (deionization) as a preliminary project to create drinking water without
cooking fuel, especially from forest wood. Then villagers are restrained to cut down trees to maintain the forest area or recharge zone.

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