Analysis of Groundwater Quality in Dusun Salam and Randuacir, Argomulyo District

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Abstract. Groundwater quality is very much influenced by soil type, soil content, and water flow pattern in the soil. Dusun Salem and Randuacir are hamlets not far from the final garbage dump in Salatiga. This research was conducted to determine the condition of groundwater in Salam and Randuacir hamlets, Randuacir Village, Argomulyo District. The samples were taken as many as 19 wells and the sampling was done randomly by disproportional stratification. To determine water quality, the data from the measurement results of heavy metals [Copper (Cu²⁺), Manganese (Mn²⁺), and Zinc (Zn²⁺), chemical and bacteriological parameters of well water are compared with drinking water quality standards according to Government Regulation No. 82 of 2001 concerning Water Quality Management and Water Pollution Control. Meanwhile, the physical parameters are compared with the Regulation of the Minister of Health of the Republic of Indonesia Number 32 of 2017 concerning Environmental Health Quality Standards and Water Health Requirements for Hygiene, Swimming Pools, Solus Per Aqua, and Public Baths. To determine the level of groundwater pollution, the Pollution Index (IP) is used according to the Decree of the State Minister for the Environment No. 115 of 2003. Based on the results of the study, it can be concluded that: 1) Of the 19 wells in Salam and Randuacir hamlets, there are 3 wells (15.79 %) contaminated with Cu²⁺, Mn²⁺, and Zn²⁺, 2 wells (10.53%) were contaminated with Cu²⁺ and Zn²⁺, 6 wells (31.58%) were contaminated with Mn²⁺ and Zn²⁺, and the remaining 8 wells (42.10%) were contaminated with Zn²⁺; 2) Based on the pollution index (IP) of the 19 wells studied that are within a radius of less than 1 km and more than 1 km, all wells are lightly polluted (100%).

1. Introduction

Groundwater is water that occupies the voids in the soil layer in a sufficient amount of saturation. [5] Groundwater undergoes natural filtering through soil and sediments which causes groundwater to be free of organic impurities. [1] However, the chemical content of groundwater depends on the formation of the lithosphere in which it is passed or due to pollution from the surrounding environment. [2] Randuacir Village is included in the expansion area of the Salatiga area which is within the Argomulyo sub-district with a population of 1476 people / km². [3] Topographically, the Randuacir exit is in the category of sloping areas, this sub-district is located under the foot of Mount Merbabu with an area of ± 387.69 hectares with an altitude of ± 600 - 800 meters above sea level, this altitude causes Randuacir Village to have cool air. Randuacir sub-district has 8 hamlets, including Salam and Randuacir hamlets. [4]
In terms of population density, the population in Salem and Randuacir hamlets is still relatively small, which in turn has an impact on how little land is used. This means that the environmental quality of the two hamlets is still very good, so it is possible that the quality of groundwater, surface water is still very good, which is indicated by almost half of the residents who live in the hamlets of Salem and Randuacir using groundwater as their source of clean water.

Groundwater quality is greatly influenced by soil type, soil content, and water flow patterns in the soil. [15] Dusun Salem and Randuacir are hamlets not far from the final garbage dump in Salatiga. It is not impossible that groundwater in the area adjacent to the TPA will also be contaminated by intruded leachate and move according to the flow pattern of groundwater. This research was conducted to determine the condition of groundwater in Salam and Randuacir hamlets, Ranaduacir Village, Argomulyo District.

2. Methodology

2.1 Materials
The materials used in this study were well water samples taken from Salam and Randuacir hamlets. The chemicals used include KI, HgSO4, MnSO4, K2Cr2O7, H2SO4, Na2S2O3, AgSO4, NaN3, FAS, NaOH, Feroin, Nessler A and B, Mineral Stabilizer, PVA, Spiritus, Cyclohexanone PA, Sulfer, Aquades, Phosver, Sodium Periodate Powder Pillow, Buffer Powder Pillow, Lactose Broth, ZincoVer 5 Reagent Powder Pillow, Ferover, Brilliant Green Lactose Broth, Cuver 1 Copper Reagent Powder Pillow.

2.2 Tools
The tools used are the HACH DR / EL 2000 spectrophotometer, pH meter, dark bottle, test tube, durham, test tube rack, incas, heater, analytical balance (Mettler), reflux device, Biuret, Statif, Autoclave, ice cupboard, oven, Glass tools, buckets, rope, and meter.

2.3 Sampling Locations
The locations where the samples were taken were in the hamlets of Salam and Randuadir. The sample was taken as many as 19 wells and the sampling was done randomly by disproportional stratification (Table 1).

| Sub-district | Hamlets     | Number of samples |
|--------------|-------------|-------------------|
| Randuacir    | Randuacir   | 10                |
| Randuacir    | Salam       | 9                 |
| **Total**    | **19**      |                   |

2.4 Method
2.4.1 Method of Sampling of Water
The bottles to be used in sampling are first washed with a detergent until they are completely clean, then the bottles are washed again with HNO3 3-5 M then rinsed with tap water and distilled water.

From each well, 1 liter of water will be taken and put in a sample bottle and then acidified by adding 1 ml of concentrated HNO3 to pH ≤ 2, this applies to heavy metal samples and other parameters. [7] After it is tightly closed, it is stored in an ice cupboard for further measurement of the concentration of Copper [Cu²⁺], Manganese [Mn²⁺], and Zinc [Zn²⁺]. [8]

2.4.2 Determination of Physical, Chemical, and Biological Parameters
Measurement of physical, chemical, and biological parameters using methods and or tools which can be seen in Table 2.
### Table 2. Supporting Parameters and Tools

| Parameter               | Method / Equipment                          |
|-------------------------|---------------------------------------------|
| **Physical**            |                                             |
| Temperature (ºC)        | Thermometer                                 |
| DHL (ms/m)              | DS meter YK-2001CT                           |
| TDS                     | TDS meter YK-2001CT                          |
| Turbidity (NTU)         | Spectrophotometer                           |
| Color (PTU)             | Spectrophotometer                           |
| **Chemical**            |                                             |
| Cu²⁺ (mg/L)             | Spectrophotometer / HACH DR/EL 2000         |
| Mn²⁺ (mg/L)             | Spectrophotometer / HACH DR/EL 2000         |
| Zn²⁺ (mg/L)             | Spectrophotometer / HACH DR/EL 2000         |
| pH                      | pH meter                                    |
| SO₄²⁻ (mg/L)            | Spectrophotometer / HACH DR/EL 2000         |
| NH₃ (mg/L)              | Spectrophotometer / HACH DR/EL 2000         |
| Fe²⁺ (mg/L)             | Spectrophotometer / HACH DR/EL 2000         |
| PO₄³⁻ (mg/L)            | Spectrophotometer / HACH DR/EL 2000         |
| BOD (mg/L)              | titration [9]                               |
| COD (mg/L)              | titration [9]                               |
| Total hardness (mg CaCO₃/L) | titration [9]                          |
| **Biology**             |                                             |
| Total E. coli feces (/ 100 ml) | MPN analysis [9]                          |

### 2.5 Data Analysis

To determine water quality, data from measurements of heavy metals (Copper (Cu²⁺), Manganese (Mn²⁺), and Zinc (Zn²⁺)), chemical and bacteriological parameters of well water are compared with water quality standards. Drinking according to Government Regulation no. 82 of 2001 concerning Water Quality Management and Water Pollution Control. [10] Meanwhile, the physical parameters are compared with the Regulation of the Minister of Health of the Republic of Indonesia Number 32 of 2017 concerning Environmental Health Quality Standards and Water Health Requirements for Hygiene, Swimming Pools, Solus Per Aqua, and Public Baths. [11]

To determine the level of groundwater pollution, the Pollution Index (IP) is used according to the Decree of the State Minister for the Environment No. 115 of 2003. [12]

### 3. Result and Discussion

Chemical parameters for the value of heavy metal content in well water in Salam hamlet ranged from Cu²⁺ 0.01 - 0.04 mg/l, Mn²⁺ 0.0 - 0.8 mg/l, Zn²⁺ 0.19 - 0.70 mg/l, pH 6.1 - 8.1, COD between 14.16 - 57.58 mgO₂/l, BOD5 between 0.6 - 3.62 mgO₂/l, SO₄²⁻ between 1 - 49 mg/l, Fe²⁺ between 0.02 - 0.26 mg/l, PO₄³⁻ between 0.27 - 2.11 mg/l, NH₃-N between 0.24 - 0.35 mg/l, and hardness ranges from 84.08 - 192.17 mg CaCO₃/l.

Meanwhile, the chemical parameters in Randuacir Cu²⁺ village ranged from 0.01 - 0.03 mg/l, Mn²⁺ 0.0 - 1.1 mg/l, Zn²⁺ 0.26 - 0.57 mg/l, pH ranges from 6 - 7.5, COD between 13.22 - 22.66 mgO₂/l, BOD5 between 0.47 - 2.48 mgO₂/l, Fe²⁺ between 0 - 0.06 mg/l, NH₃-N between 0.24 - 1.28 mg/l, PO₄³⁻ between 0.17 - 0.94 mg/l, SO₄²⁻ between 2 - 30 mg/l, and hardness ranges from 100.9 - 184.17 mg CaCO₃/l. The data are presented in Table 3.
The range of physical parameters is as follows: Temperature (°C) for Salam hamlet ranges from 42 to 43.37°C.

Sunda's research [13] indicated that there was a phosphate compound in the community's wells. This compounding can come from the activities of residents who use well water for household activities such as washing dishes and clothes around the well. Table 3. also shows the values for other chemical parameters such as Fe(II) and Cu(II) in only 1 well in Salam hamlet and 1 well in Randuacir hamlet which has exceeded the NH3-N quality standard.

From Table 3, when viewed based on the existing hamlets, in Salam hamlet there are 2 wells contaminated with Cu(II), Mn(II) and Zn(II), 1 well contaminated with Cu(II) and Zn(II), 3 wells polluted Mn(II) and Zn(II) and the rest (3 wells) were only polluted with Zn(II). In Randuacir hamlet, out of 10 existing wells, 1 well was contaminated with Cu(II), Mn(II), and Zn(II), 1 well contaminated with Cu(II) and Zn(II), 3 wells polluted with Mn(II) and Zn(II) and the remaining 5 wells were contaminated with Zn(II). This data when compared with the quality of drinking water according to WHO is still below the standard (2 mg / l) so that this water can still be consumed. [2]

Based on the quality standard value, the results of water pH measurements measured in situ from the two hamlets were still within the range of quality standards. The same is seen for the SO4^2- parameters, and hardness. Meanwhile, the BOD5 value in well water that has exceeded the quality standard is 2 wells in Salam hamlet and 1 well in Randuacir hamlet. Furthermore, from Table 3. COD content in all well water from the two hamlets is above the quality standard, when compared to Sundra's research [13] the COD content in Salam and Randuacir hamlets is very high, this can be influenced by the presence of organic material and inorganic degraded, which is known to be the two hamlets around the TPA area. The high COD content correlates with a decrease in dissolved oxygen (DO) levels which causes a decrease in groundwater quality.

Meanwhile, the PO4^3- content of the two hamlets is only 1 well in Randuacir hamlet which is within the range of quality standards. The high concentration of phosphate obtained from the two hamlets indicated that there was a phosphate compound in the community's wells. This compounding can come from the activities of residents who use well water for household activities such as washing dishes and clothes around the well. Table 3. also shows the values for other chemical parameters such as Fe(II) in only 1 well in Salam hamlet and 1 well in Randuacir hamlet which has exceeded the NH3-N quality standard.

The supporting parameters for the status of well water quality besides chemical are physical parameters. The range of physical parameters is as follows: Temperature (°C) for Salam hamlet ranges

### Table 3. Chemical Parameters of Well Water in Salam and Randuacir Hamlets

| Hamlets | Well | Chemical Parameters |
|---------|------|---------------------|
|         | Cu(II) (mg/l) | Mn(II) (mg/l) | Zn(II) (mg/l) | pH | BOD5 (mg/l) | COD (mg/l) | SO4^2- (mg/l) | NH3-N (mg/l) | Fe(II) (mg/l) | PO4^3- (mg/l) | Total hardness (mg/l) |
| Salam   | 1    | 0.01 | 0.2 | 0.24 | 6.6 | 0.94 | 17 | 36 | 0.35 | 0.03 | 0.44 | 140.13 |
|         | 2    | 0.02 | 0.1 | 0.28 | 6.8 | 1.07 | 14.16 | 13 | 0.29 | 0.03 | 0.31 | 172.15 |
|         | 3    | 0.02 | 0.1 | 0.26 | 6.2 | 1 | 22.66 | 49 | 0.31 | 0.35 | 0.34 | 192.17 |
|         | 4    | 0.02 | 0.2 | 0.19 | 6.7 | 0.6 | 19.82 | 8 | 0.24 | 0.02 | 0.54 | 84.08 |
|         | 5    | 0.04 | 0.0 | 0.29 | 6.4 | 0.74 | 20.71 | 10 | 0.26 | 0.07 | 0.9 | 124.11 |
|         | 6    | 0.02 | 0.2 | 0.35 | 6.1 | 3.55 | 57.58 | 44 | 0.26 | 0.24 | 2.11 | 152.14 |
|         | 7    | 0.02 | 0.2 | 0.29 | 6.4 | 0.67 | 21.71 | 36 | 0.27 | 0.26 | 0.4 | 188.17 |
|         | 8    | 0.01 | 0.0 | 0.35 | 7.1 | 3.62 | 53.81 | 21 | 0.25 | 0.04 | 0.42 | 132.12 |
|         | 9    | 0.03 | 0.8 | 0.70 | 8.1 | 1.38 | 35.86 | 1 | 0.28 | 0.04 | 0.27 | 116.1 |
| Randuacir | 1    | 0.02 | 0.1 | 0.43 | 6.3 | 0.47 | 15.1 | 6 | 0.24 | 0.02 | 0.43 | 104.09 |
|         | 2    | 0.03 | 0.1 | 0.45 | 6.3 | 1.07 | 13.22 | 3 | 0.32 | 0.02 | 0.48 | 148.13 |
|         | 3    | 0.02 | 0.2 | 0.39 | 6.1 | 0.8 | 15.1 | 19 | 0.33 | 0.03 | 0.44 | 100.9 |
|         | 4    | 0.02 | 0.3 | 0.46 | 6.1 | 1 | 16.05 | 8 | 0.3 | 0.05 | 0.42 | 172.15 |
|         | 5    | 0.01 | 0.1 | 0.31 | 6.7 | 2.48 | 13.22 | 30 | 0.28 | 0.04 | 0.94 | 172.15 |
|         | 6    | 0.02 | 0.1 | 0.41 | 6.4 | 0.6 | 16.05 | 4 | 0.31 | 0 | 0.37 | 180.16 |
|         | 7    | 0.01 | 0.3 | 0.26 | 6.1 | 0.8 | 16.99 | 4 | 0.29 | 0.03 | 0.72 | 184.17 |
|         | 8    | 0.02 | 0.0 | 0.37 | 7 | 1.21 | 22.66 | 2 | 1.28 | 0.01 | 0.77 | 136.12 |
|         | 9    | 0.03 | 1.1 | 0.57 | 7.5 | 1.77 | 20.68 | 5 | 0.32 | 0.03 | 0.17 | 100.9 |
| Randuacir | 10   | 0.02 | 0.1 | 0.33 | 6 | 0.54 | 16.99 | 2 | 0.3 | 0.06 | 0.45 | 108.1 |

Description: BM (Quality Standards) Government Regulation No. 82 Year 2001 Regarding Water Quality Management and Water Pollution Control.

The numbers in bold indicate that they exceed the quality standard.
from 22 - 24°C and Randuacir between 22 - 25°C, DHL (mS / m) for Salam and Randuacir hamlets ranges from 0.17 - 0.47 mS / m and 0.13 - 0.31, TDS (mg / l) in Salam hamlet ranges from 80 - 240 mg / l and in Randuacir hamlet 40 - 150 mg / l, color (PTU) ranges from 0 - 175 PTU for Salem hamlet and 0 - 32 NTU for Randuacir hamlet. The quality standard used for physical parameters is the Decree of the Minister of Health of the Republic of Indonesia No. 907 / MENKES / VII / 2002. A comparison of physical parameters and quality standards is presented in Table 4.

Table 4. Physical Parameters in Well Water in Salam and Randuacir Hamlets

| Hamlets | Sm | Physical Parameters |
|---------|----|---------------------|
|         |    | DHL (mS/m) | TDS (mg/l) | Color (PTU) | Turbidity (NTU) | Temperature (°C) |
| Salam   | 1  | 0.47        | 230        | 2           | 2              | 23               |
|         | 2  | 0.4         | 200        | 6           | 1              | 24               |
|         | 3  | 0.49        | 240        | 4           | 1              | 22               |
|         | 4  | 0.17        | 80         | 7           | 1              | 22               |
|         | 5  | 0.29        | 200        | 6           | 1              | 24               |
|         | 6  | 0.35        | 170        | 2           | 0              | 23               |
|         | 7  | 0.45        | 220        | 12          | 3              | 23,5             |
|         | 8  | 0.36        | 180        | 2           | 1              | 23               |
|         | 9  | 0.17        | 113        | 4           | 1              | 23,5             |
| Randuacir| 1  | 0.19        | 90         | 0           | 0              | 24               |
|         | 2  | 0.16        | 60         | 4           | 1              | 23               |
|         | 3  | 0.15        | 70         | 0           | 1              | 24               |
|         | 4  | 0.16        | 80         | 0           | 0              | 23               |
|         | 5  | 0.16        | 80         | 0           | 0              | 22               |
|         | 6  | 0.12        | 60         | 175         | 32             | 23               |
|         | 7  | 0.31        | 150        | 0           | 0              | 24               |
|         | 8  | 0.09        | 40         | 1           | 0              | 24               |
|         | 9  | 0.19        | 129        | 2           | 1              | 24               |
|         | 10 | 0.23        | 110        | 8           | 2              | 25               |

BM

|        | 1000 | 50 | 25 |

Description: Sm: A resident well
BM (Quality Standards) PermenKes RI No. 32 of 2017
The numbers in bold indicate that they exceed the quality standard.

From Table 4, it can be seen that the value of the permissible TDS content quality is 1000 mg / l, the color is 15 PTU, and the turbidity is 5 NTU. The TDS and DHL content of the two hamlets were still below the quality standard, while for color and turbidity there was 1 well in Randuacir hamlet where the color and turbidity values were still above the quality standard.

One of the indicators of well water in these two hamlets is suitable for drinking is Coliform measurement. The results of the measurement of coliform per 100 ml in the well water of Salam and Randuacir hamlets ranged from 9-110 and 17-350. The measurement results were compared with Class I Quality Standards from the Decree of the Minister of Health of the Republic of Indonesia No. 907 / MENKES / VII / 2002 which is presented in Table 5.

Table 5. Coliform Bacteria in Well Water in Salam and Randuacir Hamlets

| Hamlets | Well | E. coli |
|---------|------|---------|
| Sal     | 1    | 17      |
|         | 2    | 12      |
|         | 3    | 14      |
Table 5. shows that the wells of the 2 existing hamlets have been polluted by E. coli, with the highest E. coli content was in Randuacir hamlet. Groundwater research conducted by [14] showed a total coliform per 100 ml in water samples around TPA Ngronggo in Ngronggo hamlet ranged from 26 - 1600 per 100 ml. From this comparison, it can be said that the E. coli content of the two hamlets has different values. The E. coli found in Table 5. above is high enough so that pathogenic bacteria such as Giardia and Cryptosporidium can survive. [17] Some of the factors that affect the quantity of E. coli in well water samples are contamination by human feces. [9] Septic tank, which is a fecal storage place, has a major effect on the content of E. coli in water, especially the septic tank model used by residents in Salam and Randuacir hamlets. The distance of the septic tank from the well also needs attention [14]. The increase in pH also has an impact on the growth of E. coli, because E. coli grows in an optimum pH (6 - 9). [14]

The quality of well water in Salem and Randuacir hamlets is calculated based on the Decree of the State Minister for the Environment No. 115 of 2003. The results of the analysis of well water from the two hamlets are presented in Table 6.

| Table 6. Well Water Pollution Index in Salam and Randuacir Hamlet |
|---------------------------------------------------------------|
| **Hamlets** | **Well** | **IP Value** | **Category** |
| Salam | 1 | 3.22 | Lightly polluted |
| | 2 | 3.38 | Lightly polluted |
| | 3 | 3.22 | Lightly polluted |
| | 4 | 2.85 | Lightly polluted |
| | 5 | 3.5 | Lightly polluted |
| | 6 | 4.48 | Lightly polluted |
| | 7 | 3.51 | Lightly polluted |
| | 8 | 3.8 | Lightly polluted |
| | 9 | 4.87 | Lightly polluted |
| Randuacir | 1 | 4.06 | Lightly polluted |
| | 2 | 4.15 | Lightly polluted |
| | 3 | 3.93 | Lightly polluted |
| | 4 | 4.19 | Lightly polluted |
| | 5 | 3.58 | Lightly polluted |
From Table 6, it can be seen that the 19 wells studied were mildly polluted, so it can be said that the conditions of well water in Salam and Randuacir hamlets were mildly polluted (100%). If these results are compared with Arumawati's research [14], the quality of well water in the Ngronggo RW IV hamlet is still in quite a good condition, because of the 28 wells studied there are still 8 wells that are in good condition.

4. Conclusion
Based on the research results, it can be concluded as follows:

1. Of the 19 wells in Salam and Randuacir hamlets, 3 wells (15.79%) were contaminated with Cu$^{2+}$, Mn$^{2+}$, and Zn$^{2+}$, 2 wells (10.53%) were contaminated with Cu$^{2+}$ and Zn$^{2+}$, 6 wells (31.58%) were contaminated with Mn$^{2+}$ and Zn$^{2+}$, and the remaining 8 wells (42.10%) were contaminated with Zn$^{2+}$.

2. Based on the pollution index (IP) of 19 wells in Salam and Randuacir hamlets, all wells were mildly polluted (100%).

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