Water quality analysis of bribin underground river as the source of raw water for a government-owned water company (pdam) in the bribin management unit, Gunungkidul regency-Indonesia

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Abstract. Bribin Underground River supplies raw water for a government-owned water company, PDAM, and has more potential than the other three of its sources, namely Baron, Seropan, and Ngobaran. In addition to sufficient quantity, raw water has to meet a set of water quality standards. This research was intended to describe the quality of raw water from the source to the service areas spatially. The water quality was measured directly in the field and then in the laboratory using the water samples collected by the purposive sampling technique. The test analyzed physical, biological, and chemical parameters. According to Governor Regulation No. 20 of 2008, some water quality parameters of Bribin Underground River exceed the standards for Class I raw water i.e. TSS, pH and NO₃. Besides, according to the Decree of Health Minister No 492/MENKES/PER/IV/2010, pH and total coliform number exceed the standard. A spatial variation in water quality was detected from Bribin Underground River to customer taps, especially in parameters that have significant changes, such as pH, EC, TDS, TSS, nitrate, and total coliform. Spatially, the content of TDS and EC that correlates each other show a fluctuating result according to water flow treatment in water treatment plant (WTP) and the reservoir. pH and total coliform show increasing trends of number from the source to customer taps, whereas TSS and nitrate show decline trends.

1. Introduction
Karst aquifer has potential groundwater resources [1]. In European countries such as Slovenia and Austria, it contributes to 50% of the total drinking water supply [2]. This essential role that the karst groundwater has in supplying drinking water is also true for Gunungkidul Regency. Due to scarce surface water in karst systems, Gunungkidul is widely known as a barren area with lack of water. Whereas hydrologically, the subsurface system is more developed and has abundant groundwater resource potential. The problem is that this system is located at varying depths between 50 – 100 m [3]
and, thereby, requires pumping to create accessibility. Many karst groundwater resources have the potential for raw water whose amount depends on the development of the hydrogeological system.

The Regional Government of Gunungkidul Regency through its water company PDAM Tirta Handayani fulfills the local demand for clean water by pumping raw water from four sources, namely Bribin, Seropan, Baron, and Ngobaran underground rivers (Bribin-Baron system), and constructing networks for its distribution. The Bribin-Baron underground system is the central river system in Gunungsewu Karst Area with a large flow discharge throughout the year. PDAM potentially provides 2,945 l/s of raw water, consisting of 950 l/s from Seropan, 1,000 l/s from Baron, 120 l/s from Ngobaran, and 875 l/s from Bribin [4]. These figures, however, have not covered the optimum extractable capacity. Currently, PDAM Tirta Handayani has served 50.32% of the total population of Gunungkidul and 69.51% of the total population in the service area. The number of houses connected to the pipeline has increased from year to year, from 34,890 in 2013 and 47,325 in 2018 [4].

In addition to large quantity, the quality of the raw water sources needs to meet a particular set of requirements. Gunungkidul is a karst region with an aquifer system that is highly susceptible to pollution. Its thin soil layers concentrate the flow in epikarst—forming intensive fractures and a karst layer with carbonate aquifers—and allow water to enter through ponor; hence, contaminants can rapidly reach underground and spread to great distances in karst conduits. For this reason, the quality of raw water fluctuates temporally depending on the loads of pollutants entering the subsurface system [5].

This research has comprehensively described the raw water quality of PDAM Tirta Handayani, particularly that of Bribin Underground River. It was designed to 1) assess the raw water quality of Bribin Underground River, the piping system, and the customer taps and 2) analyze any changes in the quality from the source to the customer taps. It provides a spatial picture of the raw water quality from the source through the service areas.

2. Study area

The management unit of PDAM Tirta Handayani Gunungkidul in Bribin Subsystem, or referred to as Bribin Management Unit, has service areas in Semanu, Tanjungsari, Rongkop, Girisubo, and Tepus Districts, as seen in Figure 1. The raw water is withdrawn from karst aquifers in the Bribin Underground River system and distributed to customers through pipelines. Previous research found that in 1982, Bribin discharged 1,500 l/s of water, making it the most substantial single flow in the Gunungsewu plateau [3]. Currently, Bribin produced 1,000 L of water per second with potential raw water of 875 l/s, an optimal capacity of 350 l/s, and extractable water of 126 l/s [4].

Bribin has a catchment area comprised of Sodong, Jomblang, and Gilap Caves [3]. Another study by Adji and Nurjani (1999, as cited in [6]) has identified Pentung River as the upstream of Bribin and a catchment area of 55 km² that includes 39 vertical and horizontal caves; most of which are hydrologically connected to the Bribin system. This catchment area is determined based on the assumption that rain falling within the topographic boundaries (ridges) is transferred into Bribin regardless of the typical hydrological features in the karst system.

This research took place in the Bribin Management Unit because Bribin Underground River is the main river that is prone to contamination and its catchment area has diverse landuse, such as dry fields, paddy fields, and settlements with its karst typical morphology [7]. Based on these conditions, Bribin is highly susceptible to contamination. Therefore, water quality identification becomes necessary in an attempt to describe the spatial dynamics of water quality and observe the optimization of water treatment installation completed by PDAM Tirta Handayani.
3. Materials and methods

3.1. Data Type
This research used both primary and secondary data. The former consisted of raw water quality from the source through the service areas, while the latter included maps of PDAM pipelines. Some of the water quality parameters were measured directly in the field, namely temperature, pH, Total Dissolved Solids (TDS), and electrical conductivity. Some others were determined by water sample testing in the laboratory, including turbidity, Total Suspended Solids (TSS), phosphate (PO₄), nitrate (NO₃), sulfate (SO₄), ammonia (NH₃), cadmium (Cd), copper (Cu), lead (Pb), iron (total Fe), fecal coliform, and total coliform.

3.2. Data Collection and Analysis
The research population was the raw water in the Bribin Management Unit, while the sampling areas were determined by purposive sampling technique based on distance from the source of raw water and the coverage of the service area. The areas included the source of raw water, i.e., Bribin Underground River, the water in pipelines on the main distribution networks, and the water in the service areas (customer taps). The data was collected by direct field measurements (primary data) and institutional survey (secondary data). The primary data in question were the water quality profiles from the source through the service areas, while the secondary data was a relevant thematic map.

In principle, data processing and analysis in this study aimed to describe the spatial raw water quality in the Bribin Management Unit. The analyzed raw water quality data from the sources through the service areas were compared with the standards for Class I water quality according to the Governor Regulation of the Special Region of Yogyakarta No. 20 of 2008 and the Regulation of the Minister of
Health No. 492/MENKES/PER/IV/2010. From this process, the raw water quality was classified as exceeding or meeting the specified requirements. The spatial analysis compared and observed spatial variation in raw water quality from the sources to the service areas. The parameters with significant changes are shown in graphical form to determine the spatial tendency from the source to the reservoir and from the reservoir to the customer. According to the laboratory instrument limit of detection, few parameters, i.e. phosphate, ammonia, cadmium, copper, iron, and lead are not able to be compared with the used regulation so that the result is not able to show the spatial variation among the source, reservoirs, and customer taps. Furthermore, the influencing factors of water quality were also analyzed by considering the catchment area of Bribin Underground River, the source of pollutants or landuse, and the optimization of existing water treatment system comprehensively.

4. Results and Discussion

4.1. The Water Quality of Bribin Underground River and the Reservoir and Customer Taps of PDAM Tirta Handayani

The water quality of underground rivers and Bribin Management Unit was measured at 11 points, including Bribin Underground River as the source, one reservoir with the water treatment process, two reservoirs, and seven customer taps. The 11 sampling points were distributed in three districts, namely Semanu, Rongkop, and Girisubo, creating a nearly straight line to determine spatial variation in water quality from the source to reservoirs and then the furthest customers. The water quality analysis results are presented in Table 1, and the red cells mark parameters with values beyond the thresholds set in the Governor Regulation No. 20 of 2008 on Water Quality Standards in the Special Region of Yogyakarta [7].

Based on this regulation, the selected physical parameters were color, odor, taste, temperature, TDS, TSS, and turbidity. The measurement and laboratory test results showed that most parameters did not exceed the standards for Class I water quality, except for TSS. The analyzed temperatures ranged from 19.7°C to 23.7°C, which is within the allowable thresholds (10-23°C, cold) and is considered safe for domestic use. At this range, the raw water will not cause chemical dissolution in pipelines, which can endanger health (Slamet, 2007, as cited in [8]).

The lowest and highest TDS were 198 mg/l and 394 mg/l, respectively. The results mean that the TDS at the eleven sampling points do not exceed the standards for Class I water quality. The TSS at all points were above 0.1 mg/l, exceeding the water quality standard issued in the Governor Regulation No. 20 of 2008. However, according to the Government Regulation No. 82 of 2001 on Water Quality Management and Water Pollution Control [9], these TSS levels have met the standards for Class I water quality because they are not higher than 50 mg/l. The latter regulation also states that as long as the TSS is <5000 mg/l, the water still meets the requirements for conventional drinking water treatment. TSS positively correlates with turbidity; the higher the TSS, the higher the turbidity. The turbidity at all observation points ranged from 0 to 1.22 NTU, which still affirms the designation of Bribin Management Unit as the source of raw water for drinking.
The Bribin Service Unit of PDAM Tirta Handayani in Gunungkidul has a water treatment plant (WTP) (Figure 2). This WTP allows mud in the water extracted from Bribin Underground River to settle while reducing the turbidity level. Then, this water has to pass through several filters in the WTP and is stored in a reservoir next to the PDAM Bribin Office. The reservoir contains clear water that is readily distributed to customers, and this condition is evident from the laboratory test results of TSS. The TSS of the water extracted from Bribin Underground River was 36.4 mg/l, while that of the treated water in the reservoir was considerably low, i.e., 12.2 mg/l (Table 1).

The microbiological parameters, consisting of fecal coliform and total coliform, did not exceed their respective benchmarks for a Class I water. The identified fecal coliform ranged from <3 MPN/100ml to 4 MPN/100 ml, and the total coliform varied between <3 MPN/100 ml and 64 MPN/100 ml. The Governor Regulation No. 20 of 2008 states that raw water for drinking must not have fecal coliform of more than 100 MPN/100 ml and the content of total coliform must not exceed 1000 MPN/100 ml. However, when the water samples were compared with the Regulation of Minister of Health No. 492/MENKES/PER/IV/2010 [10], the value of total coliform content of all sample have exceeded the standard i.e. 0 MPN/100 ml. Therefore when considered from the health aspect, total coliform aspect has contaminated the water at all observation points.

The chemical parameters consisted of non-metallic indicators and nutrients (i.e., pH, sulfate, phosphate, nitrate, and ammonia) and heavy metals (i.e., cadmium, copper, iron, lead). The reference of water quality standard says that the lower and upper benchmarks of pH for a Class I water are 6 and 8.5, and the pH of five customer taps exceeded them. With a pH higher than 8.5, the water has high alkalinity due to the high carbonate content in the water. This finding is somewhat typical of the research area because it is a karst region. Moreover, indications of pollution, namely high pH and nitrate content, were detected in customer tap No. 1, which is located relatively close to reservoir I. Meanwhile, sulfate, phosphate, and ammonia levels are all within the specified water quality standards.

Previous research has identified several heavy metals polluting the Bribin-Baron Underground River System [11]. As a source of raw water for PDAM, the water from this system was sampled and tested in the laboratory. The results showed that all heavy metal parameters were within their allowable presence in Class I water according to the Regulation of the Minister of Health No. 492 of 2010. The lead content was the highest among the other heavy metals because it was readable with a sensitivity of up to 0.1 mg/l. At 0.01 mg/l (absolute number), lead is believed to have originated in its use as adhesives.
for iron pipes [12]. In natural waters, heavy metals are commonly found in minute quantity [13–15], and pH strongly determines their toxicity. Therefore, when heavy metals are present at high concentrations, they must be generated by human activities like industries. The observation points in Bribin Management Unit had low heavy metals, especially those directly connected to the pipeline network. It indicates that the pipe installation may release a minute amount of heavy metals to the water, which in terms of health, is still safe for use.

4.2. Spatial Variation in Water Quality from Bribin Underground River to the Customer Taps
In addition to the laboratory tests, this research performed a direct insitu measurement on the pipeline. It tested the physical water parameters (i.e., color, odor, taste, temperature, TDS, EC) and pH. The measurement revealed that these parameters met the standards for drinking water quality based on the Class I water according to the Governor Regulation No. 20 of 2008 and the Regulation of the Minister of Health No. 492/MENKES/PER/IV/2010, except for pH at several sampling points that exceed the maximum value, i.e., 8.5 (Table 2).

The ion content in the water can describe the dissolution process in the karst region. It is measurable by Electrical Conductivity (EC). The EC in karst springs is averagely 300-1000 μS/cm [16], and the insitu measurement detected EC from 279 to 556 μS/cm. A higher EC indicates a higher number of ions in the water.

TDS positively correlates with EC [17]. The direct measurement in the fields found similarities between the values of TDS and EC (Figure 3). This finding proves the relationship between the two parameters, which indicate high dissolved mineral content in the water. In this case, high carbonate content dominates the water extracted from the karst region. The TDS and EC of water samples from Bribin Underground River to the customer taps were relatively similar, except for Customers I (PI) and III (PIII).
Table 1. The field measurement and water quality analysis results at Bribin Management Unit

| No. | Location | Class I Water Quality according to Government Regulation No. 20 of 2008 | Reservoir | Customer I | Customer II | Reservoir II | Customer III | Customer IV | Customer V | Customer VI | Customer VII |
|-----|----------|-------------------------------------------------------------|-----------|------------|-------------|--------------|-------------|------------|------------|------------|-------------|
| 1   | Village  | Dadapayu to Semanu | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 |
| 2   | District | Dadapayu to Semanu | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 |
| 3   | X        | Dadapayu to Semanu | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 |
| 4   | Y        | Dadapayu to Semanu | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 |
| 5   | Time of Measurement | Dadapayu to Semanu | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 |
| 6   | Village  | Dadapayu to Semanu | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 |
| 7   | District | Dadapayu to Semanu | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 |
| 8   | X        | Dadapayu to Semanu | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 |
| 9   | Y        | Dadapayu to Semanu | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 |
| 10  | Time of Measurement | Dadapayu to Semanu | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 | 14/07/2019 |
| Sample Code | Source | BPT/WTP | RI | PI | PII | RII | PIII | PIV | PV | PVI | PVII |
|-------------|--------|---------|----|----|-----|-----|------|-----|----|-----|------|
|             |        |         |    |    |     |     |      |     |    |     |      |

Physical Parameters

- **Color**: Colorless, colorless
- **Odor**: Odorless, odorless
- **Temp. (°C)**: Deviation from air temp.:
  - 3°C: 23, 23, 20.5, 23.7, 22.4, 19.7, 19.7, 21.3, 19.9, 19.9, 21.2
|               | TDS (mg/l) | TSS (mg/l) | Turbidity (NTU) | Chemical Parameters |
|---------------|------------|------------|----------------|---------------------|
|               | 1000       | 500        | 1000           |                     |
|               | 389        | 394        | 389            |                     |
|               | 373        | 387        | 373            |                     |
|               | 326        | 198        | 326            |                     |
|               | 233        | 364        | 0              |                     |
|               | 377        | 375        | 377            |                     |
|               | 375        | 376        | 375            |                     |
| TSS (mg/l)    | 0          | Not listed | 36.4           |                     |
|               | 12.2       | 15.3       | 12.2           |                     |
|               | 16         | 12.3       | 16             |                     |
|               | 14.2       | 17.6       | 14.2           |                     |
|               | 14.9       | 14.5       | 14.9           |                     |
|               | 12.5       | 18.4       | 12.5           |                     |
| Turbidity (NTU)| 5          | 5          | 0              |                     |
|               | 0.67       | 0.36       | 0.02           |                     |
|               | 1.22       | 0.96       | 0              |                     |
|               | 0.79       | 0.9        | 0.13           |                     |
|               | 0.01       | 0.01       | 0.01           |                     |
| pH            | 6 - 8.5    | 6.5 - 8.5  | 7.7            | 8.42                |
|               | 7.7        | 8.42       | 8.63           | 8.12                |
|               | 8.4        | 8.7        | 8.57           | 8.73                |
|               | 8.75       | 8.48       | 8.48           |                     |
| Phosphate (mg/l)| 0.2        | Not listed | <0.01          | <0.01               |
|               |            |            | <0.01          | <0.01               |
|               |            |            | <0.01          | <0.01               |
| Nitrate (mg/l)| 10         | 50         | 6.26           | 6.5                 |
|               | 6.6        | 6.31       | 6.89           | 6.7                 |
|               | 6.02       | 7.04       | 7.04           | 5.44                |
| Parameter      | Unit 1 | Unit 2 | Unit 3 | Unit 4 | Unit 5 | Unit 6 | Unit 7 | Unit 8 | Unit 9 | Unit 10 | Unit 11 | Unit 12 |
|---------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|---------|---------|
| Ammonia       | mg/l   | 0.5    | 1.5    | <0.01  | <0.01  | <0.01  | <0.01  | <0.01  | <0.01  | <0.01   | <0.01   | <0.01   |
| Cadmium       | mg/l   | 0.01   | 0.003  | <0.014 | <0.014 | <0.014 | <0.014 | <0.014 | <0.014 | <0.014   | <0.014   | <0.014   |
| Copper        | mg/l   | 0.02   | 2      | <0.03  | <0.03  | <0.03  | <0.03  | <0.03  | <0.03  | <0.03    | <0.03    | <0.03    |
| Iron (mg/l)   | 0.3    | 0.3    | <0.01  | <0.01  | <0.01  | <0.01  | <0.01  | <0.01  | <0.01  | <0.01    | <0.01    | <0.01    |
| Lead          | mg/l   | 0.03   | 0.01   | <0.1   | <0.1   | <0.1   | <0.1   | <0.1   | <0.1   | <0.1     | <0.1     | <0.1     |
| Sulfate       | mg/l   | 400    | 250    | 0.44   | 0.58   | 0.47   | 0.7    | 0.49   | 0.51   | 0.54     | 0.47     | 0.47     |

Microbiological Parameters
| Fecal Co<sub>lif</sub> | 100 MPN/100 ml | Not listed | <3 | <3 | <3 | <3 | 4 | <3 | <3 | <3 | <3 | 3 | 3 |
|---------------------|----------------|------------|----|----|----|----|----|----|----|----|----|----|----|
| Total Co<sub>lif</sub> | 1000 MPN/100 ml |           | 15 | 64 | 23 | 23 | 9  | 3  | 11 | <3 | 4  | 23 | 93 |

Notes:
- : the water sample has exceeded the standards for Class I water quality per the Governor Regulation No. 20 of 2008
- : the water sample has exceeded the standards for the Regulation of the Minister of Health No. 492/MENKES/PER/IV/2010
- : the water sample has exceeded both standards for the selected Governor Regulation and the Regulation of the Minister of Health

(Data analysis, 2019)
Table 2. The insitu water quality in the distribution pipeline of the Bribin Subsystem-PDAM Tirta Handayani

| Locations        | Color    | Odor     | Taste    | Temp. (°C) | TDS (mg/l) | EC (µS/cm) | pH  |
|------------------|----------|----------|----------|------------|------------|------------|-----|
| Source/Bribin River | Colorless | Odorless | Tasteless | 23         | 394        | 556        | 7.7 |
| BTP/WTP          | Colorless | Odorless | Tasteless | 23         | 389        | 548        | 7.7 |
| R1               | Colorless | Odorless | Tasteless | 20.5       | 373        | 525        | 8.42|
| P1               | Colorless | Odorless | Tasteless | 19.7       | 198        | 279        | 8.63|
| RII              | Colorless | Odorless | Tasteless | 23.7       | 387        | 546        | 8.4 |
| PII              | Colorless | Odorless | Tasteless | 22.4       | 326        | 459        | 8.12|
| PIII             | Colorless | Odorless | Tasteless | 19.7       | 233        | 328        | 8.7 |
| PIV              | Colorless | Odorless | Tasteless | 21.3       | 364        | 513        | 8.57|
| PV               | Colorless | Odorless | Tasteless | 19.9       | 377        | 532        | 8.73|
| PVI              | Colorless | Odorless | Tasteless | 19.9       | 375        | 528        | 8.75|
| PVII             | Colorless | Odorless | Tasteless | 21.2       | 376        | 530        | 8.48|

(Direct Measurement Results, 2019)

In sample PIII, TDS and EC decreased as the result of water flow treatment. In Zone 3 (Petir Village, Rongkop District), the raw water from Bribin Cave is first collected in large basins before it is distributed to the customers (Figure 3). This technique gives time for the carbonate content to settle at the bottom of each basin or reservoir, which serves two to three customer houses.
The result of total suspended solids (TSS) analysis generally shows a declining trend of water quality from the water source to the furthest customers as shown by Figure 5. The declining of TSS number significantly seen in the way from source toward reservoir with the water treatment plant (BPT/WTP), where the TSS content in the source is 36.4 mg/l and drops to 12.2 mg/l in the BPT/WTP. Water treatment plant (WTP) has a contribution in order to decrease the TSS number. The water treatment plant (WTP) is both used to settle the mud content and reduce the turbidity of pumped water from Bribin Underground River. Furthermore, the average length of time that water stays in a reservoir and distance of water source toward the piping distribution network affect the TSS value. It also informs that the further piping distribution network exists, the less amount of TSS is transported in the water flows.

Regarding the chemical parameters, there was no significant change in the waters from Bribin Underground River to the customer taps. The analysis also showed that only a few samples exceeded the maximum thresholds, namely pH and nitrate. pH tended to increase as the water flew further from the source (Bribin Underground River) (Figure 4). The high pH value or high alkalinity is attributable to high carbonate content. When the water travels further, it potentially has prolonged contact with the carbonate content left in the pipes.

**Figure 3.** The TDS and EC comparison graph along the distribution pipeline of the Bribin Subsystem-PDAM PDAM Tirta Handayani (Data Analysis, 2019)

**Figure 4.** The pH graph of the water samples along the distribution pipeline of the Bribin Subsystem-PDAM PDAM Tirta Handayani (Data Analysis, 2019)
The results showed that the nitrate concentrations in the pipelines showed a decreasing trend from Bribin Underground River to the customer taps (Figure 6). Nitrate significantly increased in customer tap No. 1 (PI) and exceeded its benchmark for Class I water. This finding illustrates that domestic waste has polluted the water in this customer tap, as it has in some segments of Code River where the surrounding areas are mainly used for settlement [18]. It also shows that there is a leak in the pipe connected to the customer tap PI, which allows domestic waste to enter the pipeline network.

The water quality showed a wide spatial variation in biological parameters, particularly total coliform (Figure 7). The laboratory test identified a high total coliform in Bribin Underground River. However, after undergoing a water treatment process in the WTP, the water had a significantly reduced amount of total coliform. During distribution, the most significant increase was found up to 93 MPN/100 ml in customer tap No. 7 (PVII). This tap is located the farthest from the main source and often experiences water rotation every Friday-Saturday. Therefore, the tap water is first stored in a separate reservoir positioned close to the kitchen where coli bacteria can easily contaminate the water.

In general, the water quality from the source to the customer taps in the Bribin Subsystem of PDAM Tirta Handayani varies considerably. Although the physical, chemical, and biological parameters fluctuate, their values are still below the maximum thresholds according to the Governor and Minister of Health Regulation that is used in this research, except for TSS, pH, nitrate and Total Coliform. This spatial variation also occurred in another source of raw water, namely the Seropan Subsystem that is located in the north of the Bribin Subsystem. Seropan and Bribin have two separate underground river systems [19]. A previous study has confirmed a variation in the water quality parameters of the Seropan Subsystem and claims that turbidity and total coliform are the two parameters that exceed their quality standars [20].

**Figure 5.** The TSS comparison graph of each water sample along the distribution pipeline of the Bribin Subsystem-PDAM PDAM Tirta Handayani (Data Analysis, 2019)
5. Conclusions
After evaluating the raw water quality in the distribution pipeline of the Bribin Subsystem of PDAM Gunungkidul, the research conclusions are as follows.

1. Based on the Governor Regulation No. 20 of 2008, the raw water distributed from the Bribin Underground River to the customer taps meets the standards for Class I water quality, except for the TSS of all samples (a physical parameter) that has exceeded the maximum threshold.

2. Some of the test parameters experience less significant change from Bribin Underground River to the customer taps. Only several of them show significant spatial variation, including pH (the further the water is distributed, the higher the pH is) and total coliform, which significantly fluctuates in sample PVII.

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