Water quality analysis of Bembem Doline Pond in Gunungsewu Karst area, Gunungkidul regency

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Abstract. Dry seasons often lead to drought in Panggang Subsystem, part of the undeveloped Gunungsewu Karst that has minimal water resources in its springs and underground rivers. The local people have relied on karst lakes as the primary water source for various activities, such as bathing and cloth washing. Bembem Doline Pond is located in Giriasih Village, Purwosari District, Gunungkidul Regency and is part of the Panggang Subsystem. Aside from its intensive use, many factors are contributing to its water quality degradation, namely seasons, doline pond characteristics (e.g., water volume), landuse on the watershed, and the pattern of water use. This research intended to identify (1) the characteristics and (2) the water quality of Bembem Doline Pond in the early and mid-rainy season. For the water quality analysis, samples were collected from five points, which were selected by purposive sampling technique. This sampling took into account the location of the water inflow and part of the doline pond where human activities took place in November 2018 and January 2019. The test included three types of water parameters, namely physical (temperature, EC, and TDS), chemical (pH, nitrate, phosphate, detergent, and BOD), and biological (total coliform). The results showed that the water volume of Bembem Doline Pond in the mid of rainy season is 1,467.4 m³. Landuse in the watershed are dominated by plantation (45%) and dry farmland (34%), and some were covered by water bodies (14%), roads (2%), buildings (4%), and settlements (1%). The water quality of the doline pond was found to depend on seasons and human activities on the doline pond considerably. The pollutant levels inclined to be higher in the early than the mid-rainy season. In the former, human activities mostly played a part as pollutant supplier, while in the latter, runoff water from agricultural fields in the watershed contributed the most. According to the Regulation of the Governor of the Special Region of Yogyakarta No. 20 of 2008, the majority of the test parameters exceeded the quality standards for Class II water.

1. Introduction
Karst is a terrain with typical hydrological characteristics and landforms formed due to the combination of rocks with high solubility and well-developed secondary porosity [1]. Examples of these rocks include gypsum, rock salt, and carbonate rocks. However, since carbonate rocks have the widest distribution, karst landscapes often develop in them. In Indonesia, karst covers approximately...
20% of its total area [2]. One of the most extensive karst ecosystems in this archipelagic country is Gunungsewu Karst, which is partially located in Gunungkidul Regency. According to Lehman (1936), the morphological stage of Gunungsewu Karst shows a mature karst development in which cone karst or kegelkarst is the most common morphology [3]. Another widespread landform in Gunungsewu and other karst regions worldwide is doline [4]. Doline is a rounded or egg-shaped enclosures depression with a size of several meters to one kilometer [1]. A doline that is temporally or perennially filled and inundated with rainwater is called doline pond[5].

Panggang Subsystem, part of Gunungsewu Karst, is a drought-prone area. Compared to Wonosari-Baron and Sadeng Subsystems, it is a less developed hydrogeological subsystem. The drought is attributable to the typically scarce spring water and underground river [6]. Doline pond, one of the surface waters often found in karst regions [7], once supplied up to 90% of the local water needs before the 1990s [3]. Unfortunately, many doline ponds in Gunungsewu Karst are damaged. Their environmental issues can be categorized into three, namely reduced water storage, rapid water loss, and deteriorated water quality [3]. In Gunungsewu, meteorological conditions strongly influence the availability of pond water. In contrast to rainy seasons, the number of doline ponds in dry seasons decreases [8]. Gunungsewu Karst has a total of 443 doline ponds; however, only 30 of them are perennial, and the rest are periodic or seasonal [3].

Bembem Doline Pond administratively located in Giriasih Village, Purwosari Subdistrict, Gunungkidul Regency, and is part of Panggang Subsystem in Gunungsewu Karst. The local people depend on this perennial pond for their primary water source, especially in dry seasons. Aside from human activities on the doline pond, water volume that is sensitive to seasonal change can decrease water quality. Accordingly, this research was designed to discover (1) the characteristics and (2) the water quality of Bembem Doline Pond in early and mid-rainy seasons. The results are expected to recognize the effects of meteorological seasons on Bembem water quality.

2. Method
Bembem Doline Pond was characterized by water volume, land use in the Bembem watershed, and pattern of water utilization. This research employed depth sounding in January 2019 (mid-rainy season) to obtain water volume data and performed field observations and interviews to acquire details on Bembem water use. It also interpreted and delineated the appearance of land use on the aerial photographs of the watershed. The sampling points for depth sounding were determined by systemic random sampling, which divided the water bodies area into 5x5m grids.

The water quality was sampled twice, in November 2018 and January 2019. Five sampling points were selected by purposive sampling method based on the source of pollutants, i.e., any points where human activities like bathing and cloth washing took place, and the position of water inflow. The physical parameters of water quality included temperature, Total Dissolved Solid (TDS), and Electrical Conductivity (EC), all of which were measured with a water checker device. Meanwhile, the chemical parameters (nitrate, phosphate, detergent, and Biological Oxygen Demand (BOD) and one biological parameter (Total coliform) were tested in the laboratory. The center of water mass is assumed at 0.5 depth of the pond; hence, sampling at this depth is considered representative of the average water quality. The secondary data of this research were the DEM of Gunungkidul Regency and Class II water quality standards, as issued in the Regulation of the Governor of Special Region of Yogyakarta (SRY) No. 20 of 2008. The water quality was analyzed spatially with a quantitative descriptive method to explain water quality at each sampling point. The resulting water quality was compared descriptively to each other to obtain the spatial and temporal variation of its parameters. The map of depth sounding and water sampling points is presented in Figure 1.
3. Results and Discussion

3.1. The Characteristics of Bembem Doline Pond

Water volume, landuse in the watershed, and the pattern of water use by the local people are the features that define the water quality of Bembem Doline Pond. This doline pond has an enclosed system with no inlets and outlets. The primary input is rainwater that enters the pond in the forms of surface or channel runoff.

3.1.1. Water Volume

The results of the depth soundings were processed into a bathymetry map, as presented in Figure 2. In January 2019 (mid-rainy season), the maximum depth was 1.2 m, and the water bodies area increased by 204.6 m² from 7,133.7 m² at the beginning of the rainy season. According to the calculation results, the water volume was 1,467.4 m³. Relative to the mid-rainy season, both water depth and volume in November 2018 were lower because rainwater as the major input and determinant of water capacity in Bembem Doline Pond was also smaller.

3.1.2. Landuse in Bembem Lake Watershed

The watershed of Bembem Doline Pond was defined using a 5m contour interval. The calculation revealed that it covered an area of 0.053 km². When rain falls onto the watershed, part of it transforms into surface and channel runoff that fills the lake. Landuse in the watershed, thereby, characterizes the
quality of the runoff water flowing into the water bodies. Based on the results of aerial photo interpretation and validation in the field, the landuse included multi-species plantation, dry farmland, road, built-up land, and settlement (Figure 3).

![Figure 3. The Percentage of Landuse in Bembem Doline Pond Watershed](image)

Multi-species plantation covered nearly half (45%) of the watershed. The species were of monopodial trees with teak trees as the most cultivated vegetation in this landuse. Furthermore, covering 34% of the total watershed was dry farmland. In karst area, the soil is the least potential asset because it has a thin layer, and water as the source of its arability is difficult to access. For this reason, the land is only suitable for seasonal dryland crops, and the local people commonly plant corn and cassava. Based on the interview results, farmers attempted to increase soil fertility by applying manure and urea fertilizer.

In Bembem Watershed, the land is intensively used for agricultural purposes in rainy seasons. It is attributable to the abundant water resource during this season. Nevertheless, agricultural practices in the watershed are still conventional and do not use an irrigation system. To moisten the farm, farmers do not withdraw water from the pond because they prefer to maintaining the availability of its water in the upcoming dry season. Bembem Doline Pond is located near the road, and concrete block pavements have been installed as a walkway around pond to facilitate accessibility. The structure of the doline pond was once renovated in early November 2018 to support the plan to develop Bembem Doline Pond as a place of recreation.

### 3.2. The pattern of Water Use in Bembem Doline Pond

Doline pond is one of the water resources in karst regions, including in Giriasih Village. Direct observations in the field found that the local people used Bembem Doline Pond water for bathing, washing the clothes, and supplying drinking water for livestock. Because they bathe and wash clothes on the banks or the pond instead of in separate structures, the resulting waste accumulates in the water bodies and degrades its water quality in the long run. The research identified certain hours of intensive water use, namely 07.00-09.00 a.m. and 03.30-05.00 p.m. Also, water scarcity in dry seasons intensifies human activities on the pond. The piping network from the regional water company (PDAM) is available in the village, but the less economically disadvantaged residents only use it for drinking water. To reduce water bills, they bathe and wash their clothes on the doline pond.

**Water Quality of Bembem Doline Pond**

#### 3.2.1. Temperature

Temperature is a highly dynamic parameter because it is sensitive to many variables, such as water depth and season. Figure 4 shows the temperature of each water sample in November 2018 and January 2019.
The chart in Figure 4 shows that the average water temperature in Bembem Doline Pond was 33-34.5°C in November 2018 and 30.3-31.1°C in January 2019. This temperature variation was caused by several factors, namely obstructions, air temperature, and time of sampling. Obstructions in the form of vegetation and waste can block sunlight from penetrating the water. For each sampling point with this barrier, the gauged temperature is potentially lower than that of unobstructed waters. The next factor, i.e., time of sampling, is related to sunlight intensity. During the day, the intensity of sunlight is higher than in the mornings and evenings. As sun heating accumulates late in the day, the water temperature becomes warmer.

The water temperature in November 2018 was averagely higher than in January 2019 due to the influence of the season. When the rainy season in November 2018, the air temperature was higher than in January 2019. Sample 3, taken in November 2018 and January 2019, had the lowest temperature because of the depth of the sampling point. The test water was withdrawn from the middle of the water bodies and deeper than the other sampling points. Sample 5 had the highest temperature because it was extracted during daylight between 12.00 p.m. and 01.00 p.m., i.e., when the sunlight is at its most intense. The temperature measurements in the field have several weaknesses, e.g., different time of water sampling can reduce the accuracy in temperature gauging.

3.2.2. Electrical Conductivity (EC)
Electrical Conductivity (EC), or conductivity, is the ability of water to conduct electricity. EC is the amount of salt content and the movement of mobile ions in a body of water [9]. It is also an indicator of water pollution level. Figure 5 shows the electrical conductivity of Bembem Doline Pond.

The EC of Bembem Doline Pond was <900 µmos, indicating fresh water. There was no significant difference between the ECs in November 2018 (averagely 213-221µmos) and January 2019 (138-140µmos). Meteorological season strongly determines electrical conductivity. The addition of water volume in January 2019 causes dilution.

3.2.3. Total Dissolved Solids (TDS)
Total dissolved solids (TDS), or dissolved residues, are a water quality parameter that describes the physical condition of a body of water. TDS is all inorganic substances present in the water in an ionized form [9]. Its concentration depends on factors like bedrock, anthropogenic activity, and surface runoff. The results of the TDS measurement are presented in Figure 6.

![Figure 6](image)

**Figure 6.** The Total Dissolved Solids (TDS) in BembemDoline Pond

There was no significant difference between the TDS levels of the sampling points. However, temporally, TDS in November 2018 was somewhat higher than in January 2019. At the beginning of the rainy season, the high TDS was attributable to increased anthropogenic activities, such as bathing and cloth washing. Also, the natural weathering and dissolution of bedrocks can affect the amount of TDS. In November 2018, high intensity of sunlight raises the average water temperature and, as a result, accelerates chemical weathering reactions in the water bodies. According to the Regulation of the Governor of SRY No. 20 of 2008, the TDS in Bembem Doline Pond is below the threshold for Class II water, i.e., 1,000 ppm.

### 3.2.4. pH

Acidity or pH, plays a crucial role in chemical and biological processes in the water. Fetter (1997) states that pH represents hydrogen ions concentration in water [10]. Low pH (acid) indicates that the observed water is corrosive, whereas water with high pH (alkaline) can form crusts and is less effective at killing bacteria [11]. The pH of uncontaminated water is close to neutral (pH 7) and create a habitable environment for almost all aquatic organisms [12]. The laboratory tests found that the pH of the five water samples of Bembem Doline Pond ranged between 9.2 and 9.5, exceeding the upper threshold for Class II water, i.e., 6-9. The results of the pH analysis are presented in Figure 7.

![Figure 7](image)

**Figure 7.** The pH values of Bembem Doline Pond

The pH of Bembem Doline Pond is influenced by the condition of the bedrock, i.e., limestone. The bottom of the pond may interact with limestone, which contains calcium that can raise pH. Also, as runoff flows on the ground surface and through channels, direct contact allows it to dissolve the...
materials and transport them into the water bodies. Therefore, although the main water source of the pond is rainwater (pH = about 5.6), the pH of the doline pond water is alkaline. If consumed, hard water can cause kidney stones.

3.2.5. Biological Oxygen Demand (BOD)

High BOD concentrations mark a high presence of organic matters in the water [13]. The laboratory tests revealed that the BOD of Bembem Doline Pond varied from 4.4 mg/L (mid-rainy season) to 10.6 mg/L (early rainy season), exceeding the standards for Class II water quality (Figure 8). As written in the Regulation of the Governor of SRY No. 20 of 2008, BOD in Class II water must not be higher than 3 mg/L. In Bembem, high BODs are originated in metabolic wastes. People bathing in the pond often at the same time dispose of their excreta and urine. Since Bembem is also used for a fishing pond, fish feces and food are other pollutants that can elevate BOD levels.

Compared to the mid-season, BOD was higher in the early rainy season because of several factors. The first factor was the intensity of human activities on the doline pond that increased in the early rainy season, especially bathing. The second one was the closed system of Bembem Doline Pond, allowing organic matters to accumulate and decompose. Decomposition by microorganisms consumes a high amount of dissolved oxygen. When rainfall increases, it raises the water level (volume) then dilutes organic substances in water bodies.

![Figure 8. The Biological Oxygen Demands in Bembem Doline Pond](image)

3.2.6. Nitrate

Nitrate is a stable compound present in agricultural waste, fertilizers, animal dung, and human excreta [14]. Based on the laboratory test results, the nitrate content was in the range of 0.05 and 1.06 mg/L. This range is far below the maximum amount of allowed nitrate content in Class II water, i.e., 10 mg/L. The nitrate levels in November 2018 and January 2019 are depicted in Figure 9.
Figure 9. The Nitrate Levels of Bembem Doline Pond

When nitrate reaches 1,000 mg/L, this may indicate that the body of water collects runoff water from agricultural land treated with a considerable amount of fertilizer [9]. Figure 10 shows that there was a wide distance between the nitrate levels of the five water samples in November 2018 and January 2019 and the maximum threshold (the orange line), meaning that there is no pollution from agricultural activities. The landuse in Bembem watershed, which is mainly multi-species plantation and dry farmland, does not involve intensive land management. This situation supports the results of the nitrate analysis.

3.2.7. Phosphate

As issued in the Regulation of the Governor of SRY No. 20 of 2008, the phosphate content in Class II water has to be below 0.2 mg/L. There are three types of phosphorous compounds in waste, namely organic phosphate, orthophosphate, or polyphosphate [15]. Organic phosphate comes from human excreta and food scraps, while orthophosphate is from fertilizers and polyphosphate from the use of synthetic detergents. The laboratory test results of the phosphate levels in Bembem Doline Pond are shown in Figure 10.

Figure 10. The Phosphate Contents of Bembem Doline Pond

The phosphate levels of Samples 3, 4, and 5 were 1.34 mg/L, 1.89 mg/L, and 1.86 mg/L, respectively, exceeding the standards for Class II water quality. In the early rainy season, the local people still washed their clothes on the doline pond, resulting in high phosphate concentrations. Samples 4 and 5 were the closest to the part of the doline pond where the villagers commonly washed
their clothes. In this case, the phosphate contents were the accumulation of the chemicals washed away in these two sampling points. As opposed to Samples 4 and 5, Sample 3 was located in the middle of the doline pond. Despite its relatively far distance to the banks where cloth washing frequently took place, it contained high phosphate levels in the early rainy season. These findings indicate that the wind blows the water on the banks to flow or circulate to the middle of the pond.

The phosphate contents of all samples in the mid-rainy season also exceed the safe amount of phosphate in Class II water. In rainy seasons, the dry farmland in Bembem watershed is plowed and added with fertilizers containing phosphate. Therefore, when rainwater falls onto this land and transforms into runoffs, the excess water transfers soil and fertilizers to the water bodies, resulting in contamination. Samples 2 and 5 were the closest sampling points to the channel that discharged runoff water from dry farmland into the water bodies. According to Mackentum (2005), fertile waters contain phosphate of above 0.009 mg/L, but if this compound increases to more than 1 mg/L, it can cause eutrophication [16]. In general, Bembem Doline Lake is fertile waters and has the potential for eutrophication.

3.2.8. Detergent

As a water quality marker, detergents point out whether domestic activities have polluted a body of water. They leave phenolic residues that are toxic to aquatic microorganisms, making them barely decompose [18]. Figure 11 shows the level of detergents in Bembem Doline Pond. The Regulation of the Governor of SRY No. 20 of 2008 dictates that 0.2 mg/L is the upper threshold for detergents in Class II water. The detergents in the early rainy season were higher than in the mid-season and exceeded the standards for Class II water quality because the cloth washing activities on Bembem intensified. The highest detergent content (0.75 mg/L) was found in Sample 4, the point where the villagers commonly washed their laundry.

![Figure 11. The Levels of Detergent in Bembem Doline Pond](image)

While the detergent levels of Samples 1 to 4 in the mid-rainy season exceeded the standards for Class II water quality, Sample 5 had a safe amount of detergent content, i.e., 0.11 mg/L. The detergents were detected in high concentrations because in the rainy season the local people still washed their clothes on the pond though in low intensity.

3.2.9. Total coliform

Total coliform consists of fecal coliform and non-fecal coliform. The former comes from *Escherichia coli* in human and animal feces [5], while the latter is from matters other than excreta, such as decayed animal and plant remains [18]. The test results showed that in the early rainy season, the water samples contained coliforms within the range of 23-1,600 MPN/100 ml, with an average of 1,605 MPN/100 ml. According to the standards for Class II water quality, the total coliforms in these samples are below the upper threshold, 5000 MPN/100 ml. However, total coliform increased in the
mid-rainy season. Samples 1, 3, and 5 exceed the allowed population size of both fecal and non-fecal coliforms. The total coliform in Sample 1 and 3 was 5400 MPN/100 ml. In Sample 5, this parameter reached 16,000 MPN/100 ml, making it the highest among the water samples. Figure 12 shows an increase in total coliform in the mid-rainy season. Such an increase was attributable to the runoff water from the manure applied to dry farmland as fertilizers. Therefore, based on the Regulation of the Governor of SRY No. 20 of 2008, Bembem Doline Pond is likely to have lower total coliform and can be used for domestic and recreational purposes when runoff water does not form and flow into the water bodies or, in other words, during dry seasons.

Figure 12. The Total Coliforms in Bembem Doline Pond

4. Conclusion
Water bodies area and water volume highly depend on the meteorological season. In the mid-rainy season, the area of Bembem Doline Pond grew by 204.6 m² from 7,133.7 m² in the early rainy season and, as a result, the water volume increased to 1,467.4 m³. Since this doline pond does not have outlets, the primary cause of its water loss is evaporation and, for this reason, the pollutants accumulate in the water bodies. The Bembem Doline Pond watershed is mainly used for multi-species plantation (45%), dry farmland (34%), building (4%), road (2%), and settlement (1%). Season and intensity of water use for bathing and cloth washing determine the water quality of the pond. In the early season, the water quality is worse than in the mid-rainy season, as evidenced by increased temperature, EC, and pH and high concentrations of TDS, BOD, nitrate, phosphate, and detergents. Although dilution potentially occurs in the mid-rainy season, the local people bath and wash their laundry on the pond more intensively and generate more pollutants than in the early rainy season. Spatially, the distribution of the high-level contaminants coincides with the part of the pond where these activities take place. Relative to the early rainy season, the total coliforms in the middle of the season are higher, particularly at sampling points located near a sewer acting as the water input to the pond. The source of pollutants in the early rainy season is human activities, while in the mid-rainy season, it is the agricultural practices in dry farmland in Bembem watershed.

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References
[1] Ford D and Williams P 2007 Karst Hydrogeology and Geomorphology. John Wiley & Sons.
Chiceste: John Wiley & Sons.

[2] Adji T N, Haryono E, and Woro S 1999 Kawasan Karst dan Prospek Pengembangannya. Makalah Seminar PIT IGI (pp. 26–27).

[3] Haryono E, Adji T N, and Widayastuti M 2009 Environmental Problems of Telaga (Doline Pond) in Gunungsewu Karst, Java Indonesia. In Proceeding 15th International Congress of Speleology, 2, 1112–1116.

[4] Haryono E and Adji T N 2004 Bahan Ajar Geomorfologi dan Hidrologi Karst.

[5] Widayastuti M and Haryono E 2016 Water Quality Characteristics of Jonge Telaga (Doline Pond) as Water Resources for the People of Semanu District Gunungkidul Regency. Indonesian Journal of Geography, 48(2), 157–167.

[6] Kusumayudha S 2009 Detecting Springs in the Coastal Area of the Gunungsewu Karst Terrain, Yogyakarta Special Province, Indonesia, Analysis using Fractal Geometry. IPTEK The Journal for Technology and Science, 20(4), 169–176.

[7] Santosa LW 2015 Keistimewaan Yogyakarta dari Sudut Pandang Geomorfologi. (Yogyakarta: Gadjah Mada University Press)

[8] Darmanto D and Cahyadi A 2013 Pengaruh Kondisi Meteorologis terhadap Ketersediaan Air Telaga di Sebagian Kawasan Karst Kabupaten Gunungkidul (Studi Analisis Neraca Air Meteorologis untuk Mitigasi Kekekeran). Forum Geografi, 1, 93–98.

[9] Effendi H 2003 Telaah Kualitas Air: Bagi Pengelolaan Sumber Daya Alam dan Lingkungan Perairan (Yogyakarta: Kanisius)

[10] Fetter C W 1997 Applied Hydrogeology, Third Edition (New Jersey: Prentice Hall Inc.)

[11] Amani F and Prawiroredjo K 2016 Alat Ukur Kualitas Air Minum dengan Parameter pH, Suhu, Tingkat Kekeruhan, dan Jumlah Padatan Terlarut. JETri, 14(1), 49-62.

[12] Syofyan I, Usman, and P Nasution 2011 Studi Kualitas Air Untuk Kesehatan Ikan Dalam Budidaya Perikanan Pada Aliran Sungai Kamar Kiri. Jurnal Perikanan dan Kelautan, 16, 64-70.

[13] Yudo S 2010 Kondisi Kualitas Air Sungai Ciliwung di Wilayah DKI Jakarta ditinjau dari Parameter Organik, Amoniak, Fosfat, Deterjen dan Bakteri Coli. Jurnal Akuakultur Indonesia, 6, 34-42.

[14] Winata I N A, A Siswoyo, and T Mulyono 2000 Perbandingan Kandungan P dan N Total Dalam Air Sungai di Lingkungan Perkebunan dan Persawahan. Jurnal Ilmu Dasar, 1, 24-28.

[15] Khusnuryani A 2008 Mikroba sebagai Agen Penurun Fosfat pada Pengolahan Limbah Cair Rumah Sakit. Seminar Nasional Salins dan Teknologi IST AKPRIND Yogyakarta.

[16] Trofisa D 2011 Kajian Beban Pencemar dan Daya Tampung Pencemaran Sungai Ciliwung di Segmen Kota Bogor. Bachelor Thesis. Institut Pertanian Bogor.

[17] Pakpahan R S, Picauly I, and Mahayasa I N W 2015 Cemaran Mikroba Escherichia coli dan Total Bakteri Koliform pada Air Minum Isi Ulang Escherichia coli Microbial and Total Coliform Bacterial Contamination of 2EILL Drinking Water. Jurnal Kesehatan Masyarakat, 9(4), 310, 307.

[18] Taufik I 2006 Pencemaran Deterjen dalam Perairan dan Dampaknya Terhadap Organisme Air. Media Akuakultur, 1(1), 25–32.