The spatial distribution of nitrate and phosphate in Sempor Reservoir, Kebumen Regency, Central Java

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Abstract. Sempor Reservoir is used for irrigation, domestic, industrial, and tourism purposes, as well as hydroelectric power plant and inland fish farming in pens. The land use in its catchment area is mainly plantation (74%) and, followed by, rice field (8.13%), dry farmland (7.74%), and settlement (5.69%). Agricultural activities, both in irrigated and rainfed farming systems, apply fertilizers to maintain crop quality, but when these substances washed away by surface runoff and transported through the drainage system, they end up increasing nutrients in water bodies. Excess nutrients like nitrate and phosphate induce a rapid growth of algae and aquatic plants, disrupting the ecosystems. This study was designed to identify the spatial distribution of nitrate and phosphate in Sempor Reservoir by field observation, water sampling, and laboratory analysis. The water was collected from 25 sampling points distributed at the outlet (close to the spillway), in the middle and the upstream of the reservoir, and around the fish pens (near the check dam). The results showed that nitrate was present on the reservoir water surface and at a depth of 1 meter at varying concentrations, i.e., <0.01-0.36 mg/L. The phosphate levels were <0.01-0.31 mg/L on the surface and <0.01-4.78 mg/L at a depth of 1 meter. The upstream had very high nitrate concentrations both on the surface and at a depth of 1 meter, while the outlet had very high content only at a depth of 1 meter. As for phosphate, very high concentrations were identified in the middle surface of the reservoir (near the pier) and at 1m depth around the fish pens.

1. Introduction
Reservoirs, as water bodies, are artificially built for specific purposes [1]. In addition to irrigation, domestic, and industrial used, Sempor Reservoir was constructed for power generation, aquaculture (fish pens), and tourism. Like other reservoirs, it accommodates excess water in rainy seasons and supplies water to drought-affected areas in dry seasons.

Many forms of land use occupy the catchment area of Sempor Reservoir, including plantations, irrigated and rainfed rice fields, settlements, shrubs, and dry farmlands. Plantations occupy more than two-thirds (74%) of the total area. Rice fields (8.13%), dry farmlands (7.74%), and settlements (5.69%) also use some portions of the land in the catchment area.

Intensive farming activities in irrigated and rainfed rice fields affect the number of nutrients in the reservoir water. The use of chemical fertilizers in the upstream potentially increases the nitrate (NO₃) content in water [2]. Substances in fertilizers are transferred by rainwater, surface runoff, and drainage flow into the reservoir. Apart from farming activities in the upstream or catchment area, inland aquaculture with floating fish pens in the reservoir contributes to the elevated levels of another nutrient, namely phosphate (PO₄), through metabolic waste products and uneaten fish food [3].

Although nutrients are needed by aquatic biota to metabolize, they can cause phytoplankton to multiply explosively and reduce the dissolved oxygen if their presence in waters is too high [4]. At a concentration of greater than 0.2 mg/L, nitrate can cause eutrophication, which in turn will increase the growth of algae and aquatic plants rapidly. Along with nitrates, excessive phosphate levels also trigger a fast growth of algae. A massive layer of algae on the surface can inhibit the penetration of oxygen and sunlight into the water and disrupt aquatic ecosystems [5].
The presence of nitrate (NO₃) and phosphate (PO₄) in Sempor Reservoir positively affects the water quality. Because the reservoir is also used as the source of drinking water and a place for floating fish pens, monitoring its water quality parameters becomes necessary. Therefore, this study was intended to determine the spatial distribution of nitrate and phosphate in the Sempor Reservoir, Kebumen Regency, Central Java.

2. Methodology

2.1 Research Location

The research took place in Sempor Reservoir, which is administratively located in Sempor District, Kebumen Regency, Central Java Province. Geographically, it is situated at 07°29’S and 109°29’E, as depicted in Figure 1. Sempor Reservoir occupies an area of 270 ha, with a catchment area of 43 km² [6]. The catchment area consists of several villages in Sempor District, namely Sampang, Sempor, Tunjungseto, Donorojo, Kedungwringin, Kenteng, and Somagede Villages. This reservoir dams both Sampang and Cincingguling Rivers that are part of Telomoyo Watershed.

2.2 Methods

The study was conducted in Sempor Reservoir, Sempor District, Kebumen Regency, Central Java. The water was sampled at one point in time (grab sampling) in February 2019, representing the rainy season. The sampling locations were in four (4) zones, including the outlet (close to the spillway), the middle of the reservoir, around the fish pens, and upstream of the reservoir (nearby the check dam). The tools used in the study were sample bottles, cooler boxes, sampling equipment (sticks), GPS, and cameras. Then, the water samples were preserved by cooling. The research materials were nitrate and phosphate levels in the water of Sempor Reservoir.

This research employed field observations, water sampling, and laboratory analysis. Field observations aimed to find out the activities taking place in the reservoir, validate the land use data, and perform documentation. The water was collected by non-random (non-probability) sampling, in which the sampling sites were selected with specific considerations [7]. Sampling with intention, or called purposive sampling, was designed to identify the distribution of nitrate and phosphate in the reservoir evenly as an attempt to represent the actual conditions in the field, mainly on the surface and at a depth of 1 meter from the surface. The research procedure started with direct observation and water sampling in the field and continued to water sample analysis at the Hidrology and Environmental Climatology Laboratory Faculty of Geography, Universitas Gadjah Mada (UGM). The water samples were spread in 25 points, as presented in Figure 2.
The laboratory test results were processed descriptively and comparatively, i.e., by comparing the measured nitrate and phosphate concentrations with the water quality standards issued in the Government Regulation of the Republic of Indonesia No. 82 of 2001.

3. Results and Discussion
Based on the laboratory analysis results, the nitrate and phosphate levels in Sempor Reservoir are presented in Table 1 (surface) and Table 2 (at a depth of 1 meter). On the surface, the nitrate levels were <0.01-0.36 mg/L, while at a depth of 1 m, they were present at concentrations of <0.01-0.36 mg/L. As for phosphate, its content on the surface varied from <0.01 to 0.31 mg/L, while at a depth of 1 m, it was between <0.01 and 4.78 mg/L.

On the surface, the highest nitrate and phosphate concentrations were each found at point 20 (0.36 mg/L) and point 2 (0.31 mg/L). At 1 meter deep from the surface, the highest nitrate content was detected at points 7 and 19 (0.36 mg/L), while the highest phosphate level was at point 25 (4.78 mg/L).

The laboratory analysis revealed that the water samples on the surface and at a depth of 1 meter had much lower nitrate than the acceptable benchmark for Class I and II water according to the Government Regulation No. 82 of 2001. The high nitrate concentration at point 20 (0.36 mg/L) is attributable to the sampling location, that is, a sediment trap where relatively slow water movement allows a considerable amount of nutrient to settle. Besides, the water condition during the sampling was slightly turbid, signifying the dissolution and erosion of nutrient-rich soils that both lead to high nitrate levels.

![Figure 2. Map of the Water Sampling Locations in Sempor Reservoir](source: Data Processing, 2019)

Table 1. The Laboratory Analysis Results of Water Quality on the Surface of Sempor Reservoir

| Surface Water |
|---------------|
| Point | Nitrate (mg/L) | Phosphate (mg/L) |
|-------|----------------|------------------|
| 20    | 0.36           | 0.21             |
| 2     | 0.31           | 0.01             |
| 7     | 0.36           | 0.31             |
| 19    | 0.36           | 0.31             |
| 25    | 0.25           | 4.78             |

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The laboratory test results also confirmed that when compared with the water on the surface, the samples at a depth of 1 meter contained nitrate with more diverse levels. Referring to Table 2, the highest nitrate content at this depth are at points 7 and 19 (0.36 mg/L) because of their proximity to tributaries that discharge water with high domestic waste from settlements and plantations to the reservoir. The same case applies to point 18 where the second-highest nitrate content was identified (0.3 mg/L). This point is also located close to several tributaries that feed into the reservoir. As a result of the current flows, the organic content from the plantations upstream is transported by the tributaries and potentially flows in and around the sampling location.

Figure 3 shows the distribution of nitrate levels on the surface of Sempor Reservoir, while Figure 4 presents the one at a depth of 1 meter. The laboratory test results suggested that the water samples from the surface showed an elevation in nitrate levels as they became increasingly closer to the sediment trap in the north of the reservoir. Contrary to this finding, the nitrate levels at a depth of 1 meter tended to be diverse, e.g., some locations had very high nitrate content, whereas some others did not. As seen in Figure 4, the high nitrate contents are centered at points 7 and 19. Different flow velocities are believed to have caused this variation. Compared with the surface, the water at a depth of 1 meter has a slower flow rate. Consequently, nitrate spreads more slowly and is concentrated on several points.

### Table 2. The Laboratory Analysis Results of Water Quality of Sempor Reservoir at 1m Depth

| Sampling Points | Parameters       | Parameters       |
|-----------------|------------------|------------------|
|                 | Phosphate (mg/L) | Nitrate (mg/L)   |
| 1               | < 0.01           | < 0.01           |
| 2               | 0.31             | < 0.01           |
| 3               | < 0.01           | < 0.01           |
| 4               | < 0.01           | < 0.01           |
| 5               | < 0.01           | < 0.01           |
| 6               | < 0.01           | < 0.01           |
| 7               | 0.04             | < 0.01           |
| 8               | < 0.01           | < 0.01           |
| 9               | < 0.01           | < 0.01           |
| 10              | < 0.01           | < 0.01           |
| 11              | < 0.01           | < 0.01           |
| 12              | < 0.01           | < 0.01           |
| 13              | < 0.01           | < 0.01           |
| 14              | < 0.01           | < 0.01           |
| 15              | 0.01             | 2.13             |
| 16              | < 0.01           | < 0.01           |
| 17              | < 0.01           | < 0.01           |
| 18              | < 0.01           | 0.3              |
| 19              | 0.13             | 0.08             |
| 20              | < 0.01           | TA               |
| 21              | < 0.01           | TA               |
| 22              | < 0.01           | 0.36             |
| 23              | < 0.01           | TA               |
| 24              | < 0.01           | TA               |
| 25              | < 0.01           | TA               |

Source: Laboratory Test Results, 2019
The spatial interpolation shows that the distribution of phosphate content on the surface forms a particular pattern. Phosphate is relatively very high (0.2498-0.31 mg/L) around the wall of the reservoir (pier) or at point 2 (Figure 5). At this range, the phosphate concentration has exceeded its maximum allowable presence (i.e., 0.2 mg/L) in Class I (drinking) and Class II water [6]. Due to human activities in and around the reservoir area, elevated phosphate at this point falls into the categories of High to Very High. Settlements are the land use suspected of increasing the nutrients in the water due to the disposal of detergents from washing activities into the reservoir. Also, there are no apparent farming activities in areas with High to Very High phosphate contents because the reservoir is used as a tourism site with several supporting facilities, such as food stalls and public toilets. Therefore, there is a small possibility that the phosphate content increases due to runoff from agricultural fertilizers.

Meanwhile, at a depth of 1 meter, phosphate spreads differently from the one on the surface. Although a very high phosphate was found on the surface nearby the pier, at a depth of 1 m, it was detected around the fish pens or at point 25 (Figure 6). Elevated phosphate near the pens is associated with fish excretion or feces that contains phosphate [8]. According to a fish farmer, the mostly bred fish in the area is tilapia, and the fish feed is routinely supplied by each group of fish farmers that manage the pens.
At 1m depth, the phosphate levels varied from 3.8258 to 4.78 mg/L, which are Very High. This range of concentration is far above the standards for Class I and II water quality, namely 0.2 mg/L. Even the Low class of phosphate concentration (0.9632-1.9174 mg/L) has exceeded this benchmark. These findings indicate that at a depth of 1 meter, the water does not flow as fast as the one on the surface and, therefore, allows nutrients to settle and significantly increases the phosphate contents at specific depths. The phosphate on the surface is lower due to the abundance of phytoplankton that absorbs phosphate for photosynthesis [9].

Figure 5. The Distribution of Phosphate Concentration on the Surface of Sempor Reservoir

Figure 6. The Distribution of Phosphate Concentration in Sempor Reservoir at 1 m Depth
4. Conclusions

Based on the laboratory test results, the nitrate levels in Sempor Reservoir are still within the water quality standards, whereas the phosphate contents on the surface and at a depth of 1 meter have exceeded the benchmark. The nitrate levels on the surface and at a depth of 1 meter are <0.01-0.36 mg/L. As for the phosphate contents, they range between <0.01 and 0.31 mg/L on the surface and between <0.01 and 4.78 mg/L at 1 meter below the surface. On the surface, very high nitrate and phosphate contents are centered at the upstream and in the middle of the reservoir (near the pier), respectively. At a depth of 1 meter, very high nitrate content is concentrated at the upstream and the outlet of the reservoir, while very high phosphate level can be found around the fish pens.

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