Temporal variations in the water quality of beton spring, Gunungsewu karst area, Indonesia

A Cahyadi¹,²,³*, I A Riyanto⁴, T N Adji²,³, E Haryono²,³, M Widyastuti²,³, A P K Aji³

¹Geography Study Program, Faculty of Geography, Universitas Gadjah Mada
²Karst Research Group, Faculty of Geography, Universitas Gadjah Mada, Indonesia
³Department of Environmental Geography, Faculty of Geography, Universitas Gadjah Mada, Yogyakarta, Indonesia
⁴Lentera Geosains, Yogyakarta, Indonesia

ahmad.cahyadi@ugm.ac.id

Abstract. Beton Spring is a water source used for fulfilling the basic needs of domestic activities, irrigation, and fisheries. Concerning water resources, it is particularly unique in that its upper course is an allogenic river with enormous groundwater potential. This research was intended to study the temporal water quality at Beton Spring. For this reason, the spring water was sampled periodically for one year. The water quality was assessed according to the drinking water quality standards, namely Regulation of the Minister of Health of the Republic of Indonesia No. 90 of 2002 and the standards set by experts. The analyses of trilinear and rectangular Piper diagrams were performed in Easy Quim v5.0 software. The analysis results showed that, temporally, the spring water had good quality because almost all samples collected in the dry and rainy seasons met the standards. The trilinear Piper diagram revealed that the Beton Spring mainly contained unpolluted and calcium-enriched groundwater. Meanwhile, the rectangular Piper diagram indicated the abundance of average bicarbonate waters, with only a few samples categorized into cation exchange-controlled groundwater.

1. Introduction

Beton Spring is the primary water source used by Umbulrejo Village residents for domestic activities, agricultural irrigations, and fisheries [1,2]. It is hydrologically unique because its catchment area originates from two allogenic rivers: Seropan and Sawah Ombo [3]. Both allogenic rivers flow from the complex of Miocene Ancient Volcanoes, namely Wonodadi, Panggung, Wuryantoro, and Manyaran [4]. Furthermore, it is part of the Ponjong Subsystem, a hydrogeology block in the Gunungsewu Karst Area with enormous groundwater potential [5,6]. Therefore, Beton Spring possesses scientific interests for research concerning water resources, especially water quality requirements for drinking.

Several water quality studies have been conducted at Beton Spring, but there has been no detailed study of the temporal variations in its water quality. Many scholars have tested the water quality of the allogenic rivers [7] and the spring’s suitability for irrigation in the rainy and dry seasons [8]. Detailed hydrogeochemical studies can overview groundwater evolution and conceptual groundwater models that affect water quality [9,10]. Furthermore, hydrogeochemical properties can manifest in different characteristics depending on geological conditions [11,12]; therefore, Beton is a karst spring with water recharge originating in old volcanic areas and, as a result, has unique characteristics. Hydrogeochemical
studies also provide an overview of pollution and ion enrichments in the water [13,14], information on chemical processes in groundwater [15, 16], and, as one of the most common applications, data for water quality analysis based on predefined standards.

The hydrogeochemical study of Beton Spring was intended to assess temporal water quality to produce information that fully describes the effects of seasonal weathers: dry and rainy seasons on water quality (figure 1). In particular, it aimed to analyze the temporal water quality of Beton Spring throughout one year of observation. The study took place in Ponjong District, Gunungkidul Regency, Special Region of Yogyakarta, part of the Gunungsewu Karst Area. The spring is located at the coordinates -7.9497422 S and 110.727406E. Geologically, it belongs to the Wonosari Formation, which is composed of reef limestone [17]. The study area received annual rainfall in the range of 2,100–2,200 mm [18,19].
conductivity (EC), pH, and total dissolved solids (TDS). The alkalinity test kit was used to quantify CO$_3^{2-}$ and HCO$_3^-$ ions. The sample bottles were used to collect and store water for further tests in the laboratory included Ca$^{2+}$, Mg$^{2+}$, Na$^+$, K$^+$, Cl$^-$, and SO$_4^{2-}$.

The collected data were processed in Easy Quim v5.0 software, through which a trilinear and a rectangular Piper diagram were produced. The water quality parameter values were then inputted to Microsoft Excel and compared with the standards issued in the Regulation of the Minister of Health Republic of Indonesia No. 90 of 2002 and the standards set by experts [20].

The first analysis compared the water quality parameter values with their standardized allowable presence in drinking water. The second analysis was focused on identifying and examining the distribution pattern of the water samples on the trilinear Piper diagram, and the third and last analysis interpreted the rectangular Piper plot. The classification of the trilinear Piper diagram was based on Appelo and Postma (2005) [21], while that of the rectangular Piper diagram was in line with the hydrogeochemical characterization introduced by Kloosterman (1983) [22].

3. Results and discussion

The analysis results of the multi-temporal water quality data at Beton Spring showed that all water samples meet the standards for drinking water, except for samples 7 (due to excessive calcium contents) and 8 (excessive sodium levels) (Table 1). Calcium and sodium at both sampling points were exceptionally high at the end of the dry season because of the rock-water interaction that induced mineral enrichment throughout the season. Because rainwater initiated dilution processes that reduced mineral concentrations, the decreased calcium and sodium levels in the rainy season confirm this finding.

Table 1. The water quality assessment results at Beton Resurgence.

| Dates     | pH  | Ion Concentrations (mg/L) | TDS (ppm) | EC (µS) | Temp. (°C) |
|-----------|-----|---------------------------|-----------|---------|------------|
|           |     | Ca$^{2+}$ | Mg$^{2+}$ | Na$^+$ | K$^+$ | Cl$^-$ | SO$_4^{2-}$ | HCO$_3^-$ |          |
| 21/2/2019 | 7.7 | 40 | 4.86 | 8 | 2 | 4.5 | 9 | 140.35 | 223 | 319 | 25.6 |
| 12/3/2019 | 7.9 | 46 | 4.83 | 7 | 2 | 3.5 | 9 | 158.60 | 235 | 333 | 25  |
| 25/3/2019 | 7.3 | 55 | 5.32 | 5 | 2 | 3.5 | 12 | 170.86 | 246 | 366 | 26  |
| 7/4/2019  | 7.5 | 92 | 8.79 | 8 | 2 | 4 | 8 | 231.88 | 211 | 423 | 26.4 |
| 7/5/2019  | 7.3 | 81 | 11.61 | 6 | 2 | 4 | 6 | 274.59 | 224 | 434 | 26.5 |
| 13/7/19   | 7.4 | 83 | 31.59 | 12 | 1 | 4 | 6 | 305.10 | 263 | 468 | 26.8 |
| 4/8/2019  | 7   | 112 | 7.78 | 10 | 1 | 3.5 | 11 | 311.20 | 260 | 510 | 26.7 |
| 20/9/19   | 6.8 | 100 | 14.58 | 215 | 8 | 4 | 6 | 305.10 | 242 | 490 | 26.6 |
| 22/10/19  | 7.5 | 62.4 | 6.8 | 11 | 1 | 4.5 | 8 | 280.69 | 256 | 511 | 27   |
| 25/11/19  | 6.9 | 68.27 | 30.31 | 3.57 | 2.98 | 5.21 | 1.024 | 274.59 | 261 | 522 | 27   |
| 29/12/19  | 6.9 | 58.4 | 5.8 | 12 | 2 | 4.5 | 16 | 170.86 | 156 | 315 | 26   |
| 27/1/20   | 7   | 61.29 | 1.94 | 10 | 1 | 5.5 | 19 | 207.47 | 182 | 365 | 26.5 |

Source: *Regulation of the Minister of Health Republic of Indonesia No. 90/2002, b [20]

The pH values at Beton Spring ranged from 6.8 to 7.9 or alkaline, which corresponds to limestones that dominate the geological formation of its surroundings. The spring water contained TDS of 156–263 ppm, with a pattern of elevated TDS in the rainy season because of the influx of sediments, i.e., rainwater from allogenic rivers and recharge water from internal runoffs carries sediments through the dissolution channels. The EC values were in the range of 315–522 S or classified as freshwater (<1,000 S). The temperatures varied from 25 to 27°C or within the acceptable range for drinking water.

Some of the ions observed at Beton Spring, Ca$^{2+}$, Mg$^{2+}$, Na$^+$, K$^+$, and HCO$_3^-$, were present at high concentrations in the dry season, whereas Cl$^-$ and SO$_4^{2-}$ levels fluctuated throughout the year (figure 2).
These results differed slightly from Gremeng even though the two springs had the same character, i.e., allogenic recharge. The Ca$^{2+}$, Na$^+$, and HCO$_3^-$ concentrations at Gremeng also increase in the dry season, but SO$_4^{2-}$ and Mg$^{2+}$ ions decrease, and K$^+$ and Cl$^-$ levels fluctuate [23]. Nevertheless, the analysis results at several other springs in the Guungsewu Karst Area show similar chemical patterns with Beton Spring, i.e., Ca$^{2+}$ dan HCO$_3^-$ tend to appear at high concentrations in the rainy season. The same condition has been identified in Petung Allogenic River, Jomblangan Karst Window, Ngreneng Karst Window, Gilap Cave, and Petoyan Spring [24].

Figure 2. Graphs comparing the chemical compositions at beton resurgence in the dry and rainy seasons.

The analysis of the trilinear Piper diagram (figure 3) showed that the spring water samples in the diamond plot (SO$_4$+Cl and Ca+Mg) were clustered in the G quadrant (Unpolluted Groundwater), except for two water samples. Samples 8 and 10 were distributed in the "I quadrant," indicating Sodium Enrichment during the rainy season (figure 2). As described in the first paragraph of the Results and Discussion section, sodium enrichment increases the sodium contents in the spring water to a point where its upper limit value in the predefined standards is exceeded. The left ternary plot (cations) showed that most water samples were clustered in the C region, indicating Calcium Enrichment. Meanwhile, samples 8 and 10 were distributed in the A region (Unpolluted Groundwater), and sample 7 was in the B region (Sodium Enrichment). The ionic compositions of samples 7 (1,003.95 L/s), 8, and 10 were unique because they had the lowest water discharge in the dry season, thus carrying small amounts of pollutants but high dissolved ions (no dilution). The right ternary plot (anions, SO$_4$ and Cl) showed that all samples were plotted in the D region, i.e., Unpolluted Groundwater. The trilinear Piper classification
indicates that Beton Spring contains unpolluted groundwater. Therefore, the multi-temporal water quality analysis is suitable for drinking water and rice field irrigation [8].

![Piper Diagram](image)

**Figure 3.** The trilinear piper diagram of beton resurgence.

The trilinear Piper diagram showed that Beton shared similarities with Gremeng in that most of the samples were categorically unpolluted and calcium-enriched groundwater. Besides, patterns and both types of groundwater have also been identified at springs in the Gunungsewu Karst Area [24] and Jonggrangan Karst Area [25].

The rectangular Piper diagram showed that the Beton Spring was Average Bicarbonate, with only two samples (8 and 10) indicating groundwater controlled by Cation Exchange (figure 4). Average bicarbonate waters are characterized by good-quality fresh groundwater, while cation exchange-controlled waters are fresh groundwater whose hydrogeochemical composition is regulated by cation exchange [22]. The cation exchange in the dry season occurred when the spring had low yields, causing the supplier of the allogenic river to carry more ions from ancient volcanoes than ions from limestone. These results are different from the ionic compositions detected at the Gremeng Spring. The entire samples belong to average bicarbonate and bicarbonate waters [8] because the allogenic rivers flowing into it also receive substantial water supplies from the karst springs upstream.

4. Conclusion
The temporal analysis results indicate that Beton Spring produces good-quality water for drinking in the dry and rainy seasons. The spring mainly contains unpolluted and calcium-enriched groundwater, with a small portion of it having the characteristics of sodium-enriched groundwater. Based on the rectangular Piper diagram, Beton Spring yields average bicarbonate waters, which reflect the water quality of karst aquifers, and cation exchange-controlled waters, representing the influence of allogenic recharge during the dry season.
Figure 4. The Rectangular piper diagram of the Beton Spring.

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