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D. F. Yudiantoro, B. Agus Irawan, I. Paramita Haty, D. S. Sayudi, A. Suproborini, B. Sekarwati, P. Ismaya, and M. Abdurrahman

Distribution of Acidic Condition of River Water from The Ijen Active Volcano Crater in Banyupait River Asembagus Situbondo, East Java, Indonesia

DF. Yudiantoro[1,a)], B. Agus Irawan[1)], I. Paramita Haty[1)], DS. Sayudi[2)], A. Suproborini[3)], B. Sekarwati[1)], P. Ismaya[1)], M. Abdurrahman[4)]

[1)] *Universitas Pembangunan Nasional Veteran Yogyakarta Jl. Padjajaran (Lingkar Utara) Condongcatur, Sleman, Yogyakarta, 55283, Indonesia*
[2)] *Geology Agency, Indonesia*
[3)] *Pharmacy Study Program of PGRI Madiun University, Indonesia*
[4)] *Petrology, Volcanology and Geochemistry Research Group, Department of Geology, Institut Teknologi Bandung, Indonesia*

[a)]Corresponding author: d_fitri4012@yahoo.com, d_fitriyudiantoro@upnyk.ac.id

Abstract. The Ijen volcano was a Pleistocene volcano and is one of the stratovolcanoes which was active in East Java Province. This volcano erupts by magmatic and phreatic eruptions. This volcano has the largest natural lake in the world, measuring around 960 x 600 m. Embankments limited the morphology of the crater with heights between 2.145-2386 m. The lowest height of the western embankment was upstream from Banyupait River. The water volume of the crater lake of Ijen volcano is quite large and very acidic. The acidic water from the crater lake flows from upstream Banyupait River to the north to the lower direction of the Asembagus Situbondo area. The purpose of this research was to study the pH distribution of the Banyupait river flow from upstream to the coast. It was because that Banyupait river acid water was used by residents for daily life and agriculture. The methodology used in this research was conducting field survey and measurements. Field survey was carried out along the flow Asembagus river in Banyupait, which started from the village of Bantal to the river mouth in the Java Sea. In conducting a field survey pH measurements were also carried out from the river water of the Kali Banyupait. The observations showed that the river water upstream of Banyupait River had a pH of around 2-3, while the more towards the downstream the pH of the river water changed to an increase of around 3-4. The acidic water of this river experienced dilution from several rivers in its area. Whereas in river estuaries, the river water mixes with the sea, so water has a pH of 4.2. Because river water is acidic (low pH), no biota along the Banyupait river was found. Besides that, the other characteristics of river water are brown. Rocks exposed to the river flow will be reddis, experiencing iron oxide. It was due to the interaction process of acid river water with rocks. However, the river water was used by residents around the river for agriculture and daily necessities. Consequently, the health of the population around Bantal village was low.

Keywords: Acid, Banyupait river, Crater, Health, Volcano

INTRODUCTION

Situbondo was one of the regencies located in the eastern region of East Java province and known as the tourism area of Pasir Putih Beach. Meanwhile, the research area was located on the north slope of the Ijen volcano, which was in Asembagus area (**FIGURE 1**). This location was about 26 Km eastwards of the capital of Situbondo. Geographically the area was bordered to the north Madura Strait, the east Baluran volcano, the south was Ijen

volcano, and the west was the city of Situbondo. The northern part of the area was the coastal plains extending from west to east, while the southern part was a weak wavy hill area that was part of the northern slope of the Ijen volcano. So this area was created by the Quaternary volcanic sediment of Ijen and in the north was the alluvial beach deposition.

Ijen volcano, which was located near Banyuwangi was volcanic Pleistocene [1] which was also the easternmost volcano in Java. Ijen volcano was a strato volcano composed of basalt-andesite to andesitic [2, 3].The large caldera complex contains a number of volcanoes which Ijen and Raung are the most active volcanoes. The Ijen crater lake was a lake that has a pH <0.5. The water that has a low pH was usually very related to volcanic activity that was interacting with the volatile magmatic (such as SO_2, H_2S, HCl, CO_2). So that it can increase the concentration of heavy metals and other toxic elements derived from magmatic liquids [4, 5, 6]. Magmatic eruption in 1817 was the most recent eruption in the form of phreatic and geyser eruptions, and the crater lake became unstable due to increased seismicity [7, 8, 9, 10]. The solfatara located on the shores of the lake, continues to produce native sulfur, and is currently mined by local workers. The phreatic eruptions occasionally occur, so that it was a major danger lately. The lahar hazard was another potential hazard, and the nature of acidic water also produces environmental problems. In 1921 a dam was built to regulate the water level, but water seeped through the dam wall, so that the seepage formed upstream of the acid river with a river flow length of 40 km and flowed to reach the alluvial plains inhabited by residents and irrigate agricultural fields before reaching the Java Sea. Various health cases occur along the Banyupait river in Asembagus area. Because Ijen crater lake water is very acidic around the pH of < 0.5. Effluent from this lake contaminates all locally available surface water, which together forms the Banyuputih river. The river in the area Asembagus used for irrigation to the northern coastal areas. According to [11], the river water contained elements that endanger human health such as levels of F to reach 500 mg/kg.

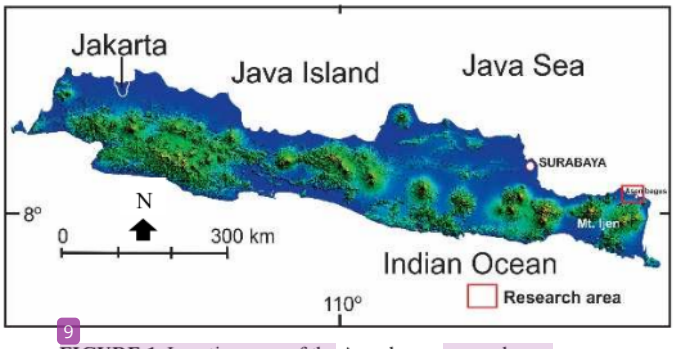

FIGURE 1. Location map of the Asembagus research area.

METHOD

Ijen volcano crater releases SO_2 and HCl gas, and it was very strong. The volcano crater water was very acidic (pH ~ 0), it was as expressed by [3]. Due to volcanic gases, such as: SO_2, H_2S, and HCl in water will form acidic compounds. SO_2 and H_2S, according to [12] are the type of dominant sulfur in the volcanic gas produced by the andesitic magma. The acidic water flows from the crater of Ijen through Banyupait to Asembagus, thereby polluting the area. The purpose of this research was to determine the acid water spread from the Banyupait river. The water was partly used by residents to irrigate agricultural rice fields, so they need to learn the effect of acid water on agricultural rice fields. The research methodology comprised preparing equipment, and field materials. Sampling method begins with determining location point, good water sampling and representative. Measuring the degree of acidity (pH) of water, and examination of color, smell, and taste. Water sampling includes: river water and wells. There were different tools to measure the pH of water and soil. The measurement of Banyupait river water is done by walking down the river from the Bantal village to the north to the coast.

RESULT

River water pH

Water sampling was taken along the flow of Banyupait (**FIGURE 2**), which was passed through Bantal, Banyuputih, and Sumberejo village. pH measurement is performed against 9 locations and the result of a range between 2.7-5.5 (**FIGURE 5a**). It shows the magnitude of a pH acid. The water was acidic, due to the seepage of the crater Ijen. According to [13] the Banyupait water river has pH of between 2.6 – 4.2. According to [13] in 1921 a dam was built on the west bank of the crater. The function of this dam was not only to control crater lake water when it was high, but also to move acid water into the downstream area. During these decades, dam floodgates have not been used, because lake surface water remains below the dam. The sulfuric acid water containing chlorine leaks through rock pores in several locations under the dam, and the total discharge of acidic water that comes out was around 50 L / T. Acidic water from upstream flows through the Banyupait river, then down the volcanic slope through settlements in Paltuding and Watucapil. Acidic wastewater with a pH of 2.5-4.5 [13] containing high concentrations of elements polluting the river downstream used by residents for irrigation [14, 15] of the 3600 ha plantations in Asembagus, which are mostly used for sugar cane, rice and corn plantations. While the pH measurement of water on the downstream the Banyupait river **(FIGURE 5a)**, in east Sukorejo indicates that the pH of seawater was neutral (pH 7.7). It was due to the water of the Banyupait river acid mixed with seawater, so the pH becomes neutral.

FIGURE 2. The pH measurement of Banyupait river water (left image). The river's ground rocks have oxidation due to acidic water reactions (right image).

Soil pH

Soil pH measurement (**FIGURE 3**) was conducted at 26 locations and produced a pH value of about 3.8-7.2. Generally, pH measurements are on the eastern of the river. This research located in the area that was easy to reach by vehicles. At the vicinity of the river upstream, the soil pH was reasonably low. The lowest rate being 3.8, at the center was 4.4, and on the downstream was 5.8, while in the coastal part the soil pH can reach 7.1 (**FIGURE 5b**). It is indicating that the water of Banyupait river acid used by residents as agricultural irrigation affects soil pH. According to [16] it was explained that there was a good correlation between soil pH and metal concentrations in the soil, because it was found that there was an increase in high metal concentrations in rice and vegetables [17, 18]. Some examples namely an increase in levels of Cd, Cu, Pb, and Zn in plants that grow around the Pb-Zn mine and the presence of various cases of Cd poisoning due to chronic exposure through rice containing high Cd, because the rice was produced by Cd polluted paddy fields [19]. [20] explained that irrigation water contamination by Ijen crater lake water waste has caused an increase in the concentration of various elements in the plant. This is due to excessive soil acidity, which causes the availability of these elements in the soil to become high. Although the concentration of toxic metal elements in food is still in the normal range, studies are still needed to estimate the risks to human health. So that active volcanoes that have acid crater lakes will have the potential as a potential source of natural pollution. Another case that can be compared but come from different sources of pollution, the acid mine

drainage (AMD), which has a high acidity and contain high toxic metal elements was also natural pollution problems [20].

From the results of soil pH distribution plot (**FIGURE 5b**) indicates that soil pH from upstream of the river to coastal coast showed increased pH. At the upstream of the river, Banyupait acid water was very acidic. so the soil pH of the farm fields also becomes acidic. However, it was different from the towards the downstream river. In the downstream part, there is a water mixing both from water wells/artesian wells and mixed with household waste. So, the water flowing in the irrigation has a dilution making the pH more and more ground in the neutral direction.

FIGURE. 3. Shows some measurements of soil pH at the location around the Banyupait river.

pH Well Water

pH measurement of well water was carried out at 15 wells locations from the upstream of the river in the Bantal area to the coast. Wells in the upstream part of the river are general wells dug that have a depth of about 10-20 m, while on the downstream of the river or the beach water depth of the wells around 1.5 m. The constituent rocks of the wells in the upstream consist of a pumice breccia, while the downstream was a coastal alluvial rock. The measurement result of well pH water at upstream (Bantal village) about 6.2-6.5. However, in the middle of Sodung village, pH of wells water become neutral (pH 7.1-7.2). In addition to the downstream of the river, Sukorejo village pH wells water about 6.2-7.2 (**FIGURE 5c**). Residents used this water for daily living needs. Due to the wells water that was located around Banyupait, then the wells water has been polluted by Banyupait river water. Which was the water from seepage of the low pH of the crater lake water. According to [11] other than that water contained elements that endanger human health, such as: Al, Fe, Si, Ca, F, Mg, Na, P, HCO_3, Ca, SO_4, Cl. In addition, the level of F on the upstream Banyupait river reach very high 500 Mg/kg, but downstream (in Asembagus) reach 7 mg/kg. In the population, wells water has a high F rate (0.1-4mg/kg). According to the regulation of [20] explained that the content of F well water was good for a drink was 1.5 mg/kg. Therefore, people who consume water with an F level of more than 1.5 mg/kg in Asembagus and surrounding districts will experience dental fluorosis. It was as a result of pollution from irrigation water coming from the Banyupait river acid water [11]. As evidence of the pollution of F, there is a child aged six years, as a person with dental fluorosis as shown in **FIGURE 4** The child's teeth were seen brown spots that later when consuming F excessively, then the teeth will become black.

FIGURE 4. Measurements of soil pH at the location around the Banyupait river and the 6-year-old boy who affected F by exposing brown spots.

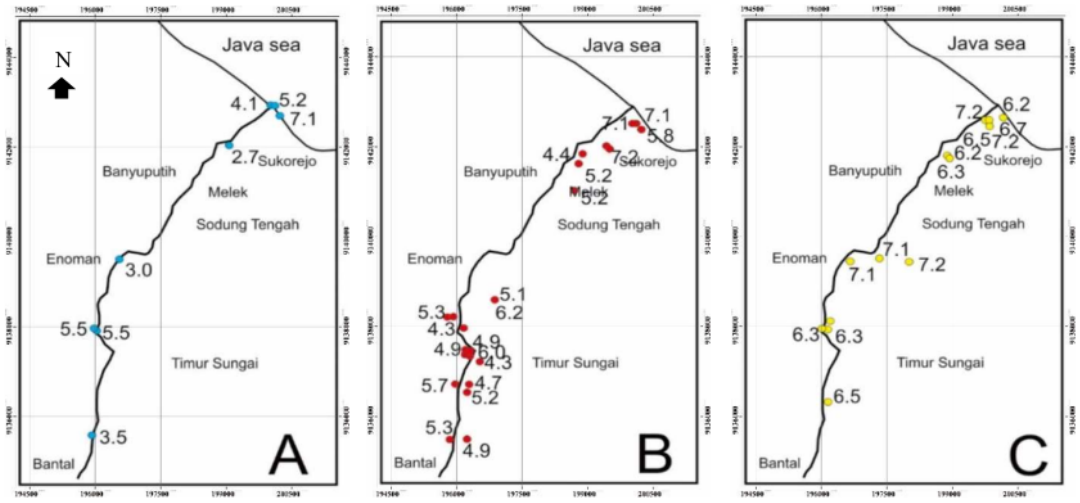

FIGURE 5. A. Map of acidity level (pH) of river water, B. Soil pH distribution, C. The pH distribution of wells water along the Banyupait river to the sea.

CONCLUSION

The study area was flowed by Ijen volcanic crater water seepage, and the water was very acidic (pH ~ 0). The crater acidic water flowed through the Banyupait river downstream or to the coast. Besides the condition of river water was very acidic, this river water also carried heavy metal elements such as: Fe, F, Mg, P and Cl. To date pollute well water and farmland.

During the trip to the downstream of the acidic water, the Banyupait river has diluted, originally from around pH 3.8 to 7.1. So as the level of soil acidity around the river becomes acidic (pH about 3.8). Because the rice fields flowed by the Banyupait acidic water. The acidic water pollution persists, make the wells water was also experiencing pollution, resulting from acid water infiltration. So that wells water around the Banyupait river become more acidic. Not only polluted by acidity, but also polluted by metal elements of which was F. F content was high enough that results in public declining health, the effect in dental fluorosis were children and adults.

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