The Relationship Between Geological and Environmental Aspects with the Anomalies of Track Elements and Heavy Metal Elements in the Volcanic Area of the Muria Peninsula

Tri Winarno[1*], *Purnama* Sendjaja[2], and *Faris* Rizaldy Wibowo[1]

[1]Geological Engineering Department, Universitas Diponegoro, Jalan Prof. Soedarto, SH, Tembalang, Semarang, 50275, Indonesia
[2]National Research and Inovation Agency, Jalan Sangkuriang, Dago, Bandung, Indonesia

Abstract. The Muria Peninsula is a complex of volcanic activity located in the back arc of Sunda, which includes Kudus, Jepara, and surrounding districts. Volcanic activity on Mount Muria, can be used to study geological conditions, which were closely related to chemical elements. The presence of chemical elements in the river sediments of the Muria Peninsula was also influenced by anthropogenic heavy metal pollutants present in river deposits along the Muria Peninsula. The purpose of this study was to determine the relationship between the geological conditions and the environmental conditions of the Muria Peninsula with the anomaly of track elements and heavy metal elements. The methods used in this research were the pick test method, XRF geochemistry and the results were correlated into a geochemical anomaly map. The results showed that there were trace elements anomalies of Ce and Nd in Jepara area which were influenced by Muria shoshonitic rocks. Anomaly of Cu element was found in Jepara area, anomaly of Mn element was found in Jepara and Demak, and anomaly of Zn element was found in Jepara and Demak. Anomaly of Cu, M,n and Zn elements were high in upstream area and caused by land use of dry agriculture, paddy fields and settlement areas.

1 Introduction

Indonesia is a country which has the most volcanoes in the world. The tectonic setting in Indonesia is the meeting of four tectonic plates, they are Indian, Australian, Eurasian, and Pacific plate, causing the formation of a series of volcanoes (ring of fire). One of the areas experiencing the influence of this tectonic plate meeting is the Muria Peninsula. The Muria Peninsula is located in the northern part of Java island, precisely in the back arc of Sunda, which is a volcanic complex area. The Muria Peninsula is located northeast of Semarang, the capital city of Central Java Province. This area is divided into three regencies, they are Jepara Regency in the west-north, Pati Regency in the east-southeast, and Kudus Regency in the

* Corresponding author: tri.winarno@live.undip.ac.id

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south. Muria volcano is the largest and highest in the Muria Peninsula region, reaching a height of 1625 m above sea level [1].

The presence of volcanic rocks in the research area indicates the existence of magmatic activity. Magmatic activity can be used to study geological conditions. This condition is closely related to the presence of geochemical elements in the area [2]. The presence of chemical elements in the river sediments of the Muria Peninsula is not only caused by geological processes and volcanic activity but heavy metal pollutants are found in river deposits along the Muria Peninsula. Indications of heavy metal pollution caused by these anthropogenic pollutants are estimated to increase from year to year [3].

The main purpose of this study is to determine the relationship between regional geological conditions and environmental conditions with the anomalies of track elements and heavy metal elements in the Muria Peninsula, and to provide a new perspective on the existence of these anomalies.

The Muria Peninsula is located in the districts of Jepara, Kudus, Pati, and Grobogan, Central Java Province (**FIGURE 1**).

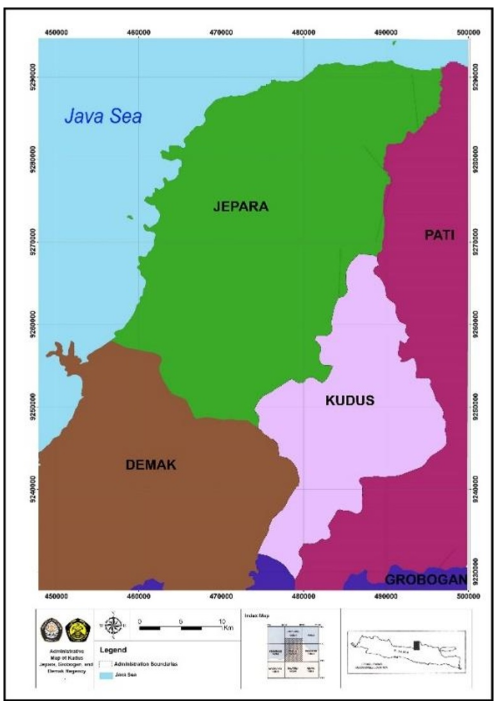

Fig. 1. Administrative map of the research area [4] [5]

2 Literature Review

2.1 Regional Geology

The research area is in the Muria Peninsula, which includes Pati, Kudus, and Jepara Regencies and is included in the regional geological map of Kudus sheet (FIGURE 2). The Muria Peninsula is in the Quaternary volcanic area [6]. The regional stratigraphy of this area consists of five formation units, from oldest to youngest they are the Ngrayong Formation, Bulu Formation, Patiayam Formation, Quaternary volcanic rocks, and Alluvium [7].

a. Ngrayong Formation (Tmn).

This formation consists of several lithologies such as the alternation of marl, sandstone, and claystone with interbedded of sandy limestone. The age of this formation is Middle Miocene.

b. Bulu Formation (Tmb)

This formation is unconformably overlaid by the Patiayam Formation which consists of interbedded between tuffaceous sandstones and tuffaceous conglomerates, with intercalations of claystone, limestone, and breccia. The age of this formation is Pliocene.

c. Patiayam Formation (Tpp)

This formation consists of alternation of tuffaceous sandstone and tuffaceous conglomerate with intercalations of claystone, limestone, and breccia. The age of this formation is Pliocene.

d. Quaternary Volcanic Rock Formation (Qvtm and Qvlm)

This formation consists of several rock units which unconformably overlaid above the older rocks. This formation is composed of the activities of Mount Muria (tuff, lahar, breccia, and lava) and the activity of the Genuk Volcano (lava, volcanic breccia, and tuff and fractured basalt, leucite, syenite, and andesite).

e. Alluvium (Qa) deposits which spread out along the west coast and the southern part of the study area

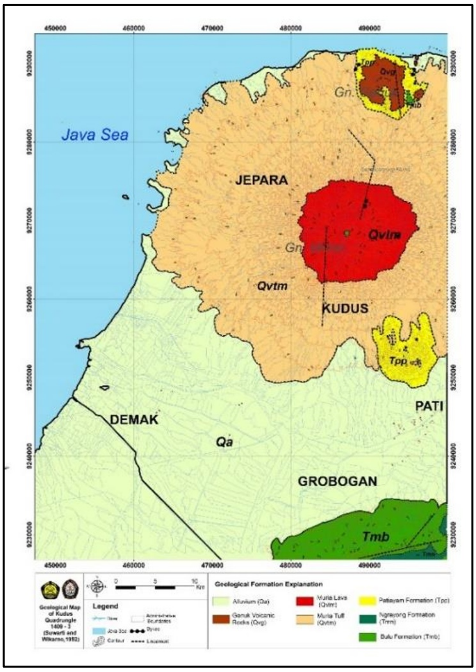

Fig. 2. Regional geological map [7]

2.2 Anthropogenic Pollutants

Anthropogenic pollutants are pollutants caused by humans [8]. These pollutants can be preserved in sediments and can affect the living organisms, directly or indirectly [9]. Anthropogenic sources such as domestic and industrial wastewater effluents, urban and agricultural runoff, fossil fuel combustion, atmospheric deposition, and antifouling paints from ships (mainly tin and copper) can increase metal concentrations in marine environments to higher than background levels [10].

2.3 Heavy Metal Elements

Heavy metal is a general term for metallic elements that have an atomic weight higher than 40.04 (atomic mass of Ca) [11]. Heavy metal elements can be divided into metallic elements and metalloids [12]. There are four processes that cause the increase in heavy metal elements, they are the weathering process of the bedrock making up sedimentary particles, industrial and household process activities involving the use of heavy metal elements, the leaching process from the accumulation of garbage or landfilling of solid waste, and the results of excretion from animals and plants that contain heavy metals [13].

3 Methods

The methods used in this research pick test method, X-Ray Fluorescence (XRF) analysis, and petrographic analysis.

3.1 Pick test

The field validation analysis of the picking test aims to ensure that the data to be entered is appropriate and the source and validity of the data can be explained. The conditions of the research area that are considered are geological aspects, topographical aspects and land use aspects. The identified aspects are geological data by identifying the lithology of the watershed, topography, river data, and land use.

3.2 X-ray fluorescence (XRF)

The geochemical analysis was carried out by using XRF analysis. XRF analysis was carried out to analyze the major oxides and trace elements along with their concentrations in the rock deposits using spectrometric methods. Currently, XRF is the most common method of analysis used in the determination of major elements and trace elements on rock samples. It is versatile and can analyze up to 80 elements over a wide range of sensitivities, detecting concentrations from 100% down to a few parts per million [14].

3.3 Composing anomaly map

The anomaly map of track elements and heavy metal elements were composed by overlaying the geological map and the anomaly data provided by geochemical data.

4 Results and Discussion

4.1 Pick test Result

The location of the pick test points is in an area indicated by geochemical anomalies (**FIGURE 3**).

4.1.1 Pick Test in Jepara Regency

There are five pick test points carried out in Jepara Regency. The pick test point 1 was located in the topography with a gentle slope, at height of almost 0 meter above sea level and indicated in the downstream area. The condition of the river was a small river with a width of 3 m and in dry condition. The land used in this pick test area was used for dry land agriculture. Test point 1 is the Patiayam Formation (Tpp).

The pick test point 2 was located in the topography with undulating contour and at an elevation of 0-100 meters above sea level. The condition of the river was a small river, with a width of 3-5 m, with a depth of <10 cm. This pick test point is above the Alluvium (Qa) deposit. The lithology found in this area were gravel, sand and some clay and silt deposits mixed with several volcanic materials (loose fragmental rock and non-fragmental rock in unconsolidated material).

The pick test point 3 was located in the topography with undulating contour and at an elevation of 0-100 meters above sea level. There were no active river in this area, although there were several dry creeks. The land use of pick test 3 area was used for paddy fields. This pick test point was indicated to be in the downstream area.

The pick test point 4 was located in the topography with wavy-steep slope and at an elevation of 200 meters above sea level. The condition of the river in this area was dry, with a width of 2 m. The land use of pick test 4 area was used as paddy fields and dry land agricultural. This pick test point was indicated to be in the upstream area. This pick test point was above the Muria Tuff Quaternary Volcanic Formation (Qvtm), and the lithology found in this area was andesite.

The pick test point 5 was located in the topography with undulating contour, with an elevation of 0-100 meters above sea level. The condition of the river was dry, with a width of 2 m. The land use of test point 5 was used as dry land agriculture. This pick test point was indicated to be in the upstream area. The pick test point was above the Muria Tuf Volcanic Formation (Qvtm), with the lithology of coarse tuff.

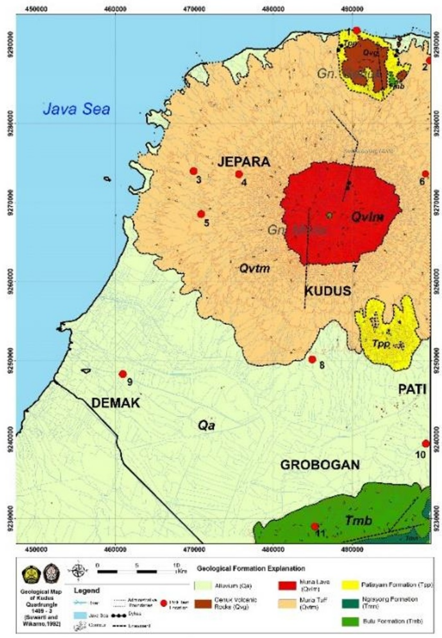

Fig. 3. The pick test point map

4.1.2 Pick Test in Kudus Regency

There are two pick test points carried out in Kudus Regency. The pick test point 7 was located in the topography with steep slope, at an elevation of 1000 meters above sea level. The condition of the river was 5-7 m wide, with a depth <1 m. The pick test point of this area was at the Muria Lava Formation (Qvlm) with lithology of pyroclastic rock (andesite breccia).

The pick test point 8 was located in the topography with undulating contour, with an elevation of 0-100 meters above sea level. The condition of the river was 1-5 m wide, with a depth of 1-2 m. This area was indicated to be the boundary between upstream and downstream. The land use of pick test 8 was used as dry land agriculture. The pick test point was at the Alluvium (Qa) deposit, with lithology of clay and silt deposits mixed with several volcanic materials (loose fragments of rock and non-fragmental rock of unconsolidated material).

4.1.3 Pick Test in Pati Regency

There are two pick test points carried out in Pati Regency. The pick test point 6 was located in the undulating topography with elevation of 200 meters above sea level. The condition of the river was 5-7 m wide, with a depth <1m. This area was indicated to be the boundary between upstream and downstream. The land use of test point 6 area was used as dry land agriculture. The pick test point was at the Quaternary Muria Tuff Volcanic Formation (Qvtm), with lithology of breccia.

The pick test point 10 was located in the undulating topography, with an elevation of almost 0 meters above sea level. The condition of the river was 3-5 m wide, with a depth of 10 cm. The pick test area was in the downstream area. The land use of the pick test area were used as settlement areas and dry land agriculture. The pick test point of this area was at the Alluvium Deposit (Qa) with lithology of gravel, sand, and some clay and silt deposits mixed with several volcanic materials (fragmental rock and non-fragmental rock in unconsolidated material).

4.1.4 Pick Test in Demak Regency

The pick test point 9 was located in the flat topography with an elevation at almost 0 meters above sea level. The condition of the river was medium-large river, 10 m wide, with a depth of > 5 m. This pick test point was in a downstream area. The land use of this pick point area was used as settlement area. The lithology of this pick test area was alluvium.

4.1.5 Pick Test in Grobogan Regency

The pick test point 11 was located in an undulating topography, and has an elevation of 200 meters above sea level. The condition of the river was a dry river, with a width of 5 m. The pick test point was in an upstream area. The land use of this pick test area was used as dry land agriculture. This pick test point was at the Bulu Formation (Tmb) with lithology of calcarenite limestone.

4.2 Track Element Anomalies

The trace elements detected in the study area were cerium (Ce) and neodymium (Nd) which were member of light rare earth element (LREE). The Ce element (Serium) had a high elemental content in the Muria Peninsula area (Jepara and Kudus), which was marked on the map with a red legend (**FIGURE 4**) . Demak and Grobogan regencies experienced a decrease in elements which were indicated by a green legend, then the Pati regency had moderate levels of elements, indicated by a yellow legend. The pick test point which contained high Ce element were pick test point 2 (2.48 ppm) and pick test point 3 (2.62 ppm). Both pick test point indicated to have geochemical anomalies because they have passed the threshold value [15].

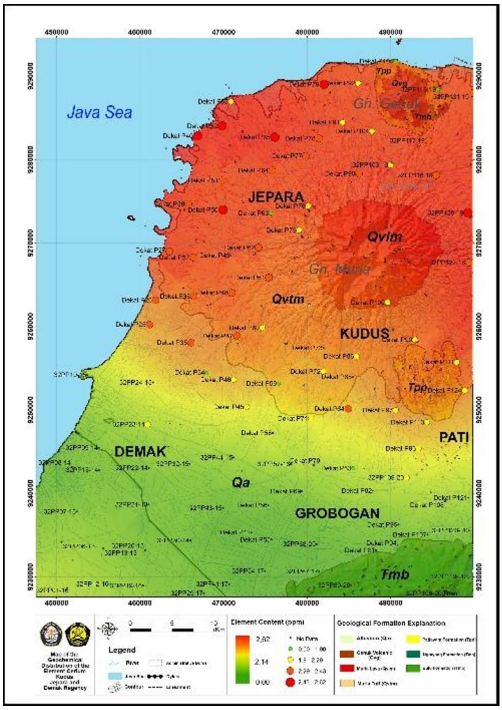

Fig. 4. The Ce anomaly map

The Nd element (Neodymium) had a similar results as cerium. It had high elemental content in the Muria Peninsula area (Jepara and Kudus), which was marked on the map with a red legend (**FIGURE 5**). Demak and Grobogan regencies experienced a decrease in elements which were indicated by a green legend, then the Pati district had moderate levels of elements, indicated by a yellow legend. The pick test point which contained high Nd element were pick test point 2 (2.48 ppm) and pick test point 3 (2.62 ppm).

Both of pick test points containing Ce and Nd anomalies were located in the Muria Quaternary Volcanic Formation with lithology of breccia rocks with andesite fragments. The elemental anomaly was correlated with the geochemistry of Mount Muria rocks, which were classified shoshonitic series [16]. The shoshonitic rock series was characterized by enrichment of light rare earth elements (LREE) [17]. Thus it can be concluded that the enrichment and geochemical anomalies of light rare earth elements were caused by the control of the shoshonitic rocks of Mount Muria [16].

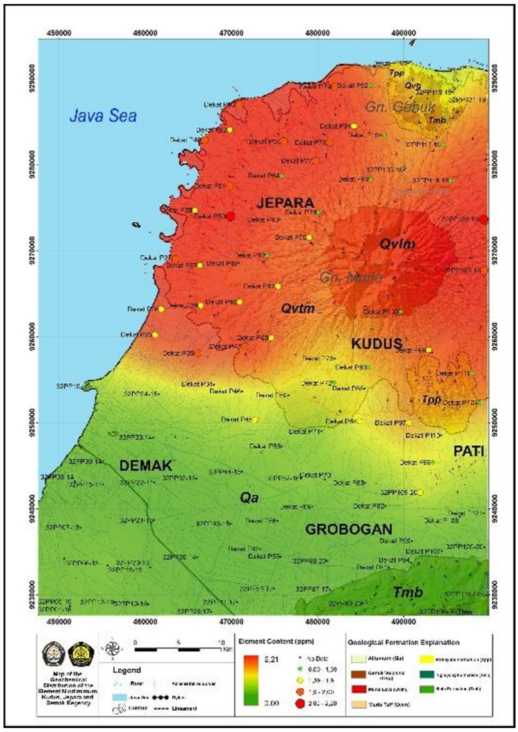

Fig. 5. The Nd anomaly map

4.3 Heavy Metal Anomalies

The heavy metal elements detected in the research area were copper (Cu), Manganese (Mn), and zinc (Zn). Copper (Cu) had a high elemental content in the northern part of the Jepara Regency, and was marked in the map with a red legend (**FIGURE 6**), which covered almost all parts of the Muria Peninsula. The pick test point which had Cu values above the threshold were the pick test point 5 (1.9 ppm) and the pick test point 1 (1.94 ppm). The watershed condition of both pick test points were in the upstream area.

Manganese (Mn) had a high elemental content in the northern part of the Jepara Regency and Demak Regency and was marked in the map with red legend (**FIGURE 7**). The pick test point which had Mn values above the threshold were the pick test point 5 (3.72 ppm), pick test point 9 (3.65 ppm) and pick test point 4 (2.45 ppm). The watershed condition of pick test point 4 and 5 were in the upstream area, while the pick test point 9 was in the downstream area.

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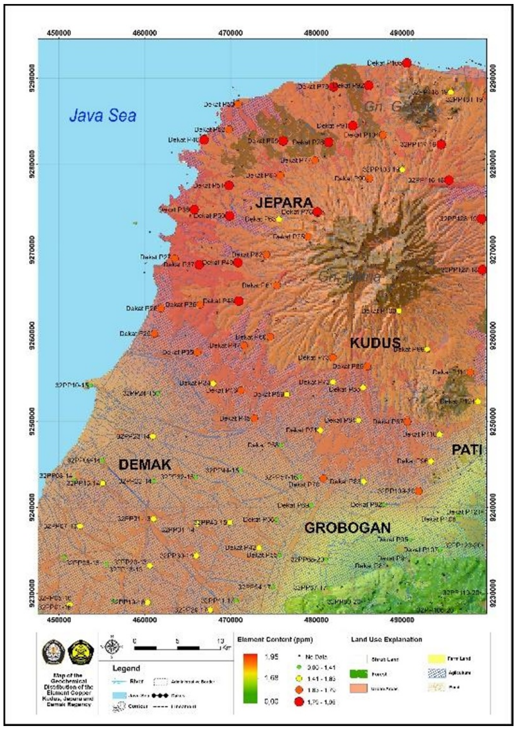

Fig. 6. The Cu anomaly map

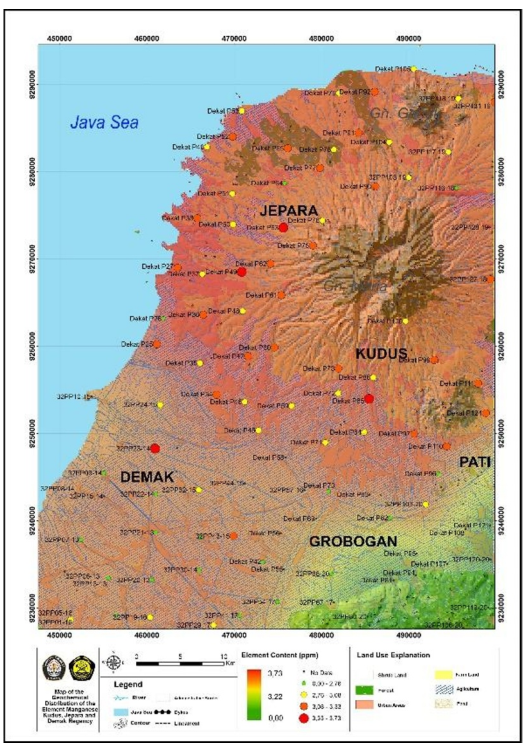

Fig. 7. The Mn anomaly map

Zinc (Zn) had a high elemental content in the northern part of Jepara Regency and Demak Regency which were marked in the map with a red legend (**FIGURE 8**). The pick test point which had Zn values above the threshold were the pick test point 4 (2.68 ppm) and the pick test point 9 (2.47 ppm). The watershed condition of test point 4 was in the upstream area, while the pick test point 9 was in the downstream area.

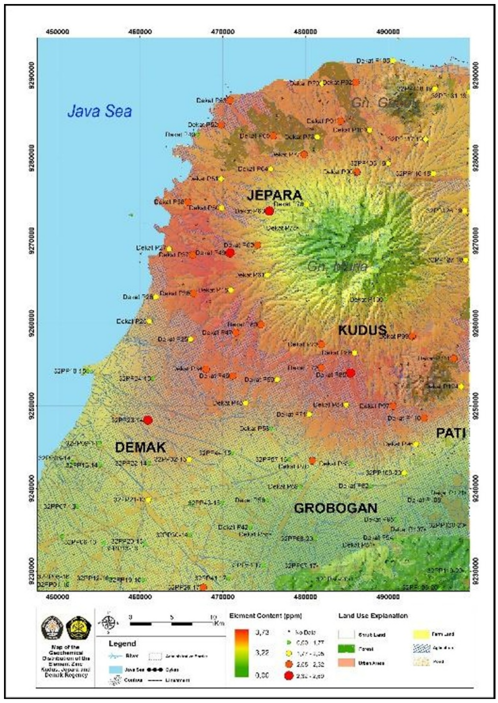

Fig. 8. The Zn anomaly map

In the upstream area, the Cu anomaly was higher than downstream area. The pick test points in the upstream area were pick test point 5 (1.9 ppm) and the pick test point 1 (1.94 ppm), while in the downstream area there are no samples showing Cu content. The Mn anomaly showed similar result with Cu, in the upstream area had a higher anomaly than downstream area. The pick test points in the upstream area were pick test point 5 (3.72 ppm), and the pick test point 3 (3.61 ppm) compared to downstream at the pick test point 9 (2.45 ppm). The Zn anomaly also had similar result, in the upstream area had a higher anomaly than downstream area. The pick test points in the upstream area were pick test point 4 (2.68 ppm) compared to the downstream area at the pick test point 9 (2.47 ppm).

The land uses in the upstream area were used as dry land agriculture and settlement areas. While the land use in the downstream area was used as paddy fields. This indicates that in the upstream area had a higher content of heavy metal elements compared to the downstream area. This distribution pattern of heavy metal elements will be high in the upstream and will decrease towards the downstream of the river [18].

Based on the research results, it can be concluded that the abundances and anomalies of heavy metal elements were caused by land uses of settlement areas and dry land agricultural areas, as well as the topography of watersheds. The increase in heavy metal levels was closely related to the infiltration of waste containing heavy metals [19]. Dryland agriculture was correlated with the increase of heavy metals caused by pollutant from various sources, such as waste from settlements and agricultural activities. The abundance of heavy metal elements were strongly suspected to be anthropogenic pollutants, which was pollutants caused by human activities [8]. Cu and Mn were at moderate levels of heavy metal hazard, while Zn is at less toxic levels [20]. The anomalies of Cu and Mn in the study area could have an effect of health problems in humans.

5 Conclusion

Based on the research results, there are relationship between geological conditions and environmental condition with the trace element and heavy metal element anomalies in the Muria Peninsula. The Muria volcanic rock which is shoshonitic rock is the source of trace element anomaly of light rare earth elements Ce and Nd. While the anomaly of heavy metal of Cu, Mn, and Zn elements are found in upstream areas with land use of dry agricultural land, paddy fields, and settlements.

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