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GROUNDWATER VULNERABILITY STUDY TO TRADITIONAL GOLD MINE PROCESSING POLLUTION USING SYNTACS METHOD AND GIS APPROACH

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ABSTRACT

Groundwater vulnerability study research conducted in Paya Ateuk Village, Pasie Raja District uses the SINTACS method. This method is an overlay method that combines 7 primary maps, namely soil texture maps, infiltration maps, slope maps, groundwater depth maps, rock unit maps, aquifer lithology maps, and hydroulic conductivity maps. Then the results of the assessment on the primary map parts are multiplied by the weight on the SINTACS classification and the results are combined into 1 groundwater vulnerability overlay map. The results of the map overlay produce 822 sections that have a range of groundwater vulnerability values at a score of 103.75 – 201.5 with low to high classification. Karst hill areas generally have moderate vulnerability values. Whereas in the lowlands with residential land use has a high vulnerability. This is due to the flat slope with sandstone, and moderate infiltration. Based on measurements of the quality of groundwater in wells owned by residents, it shows that the groundwater in the research location is of good quality. This is due to the large number of natural phytoremediation plants around the research area. Although the quality of groundwater is in good condition. The government as the policy maker still needs to regulate and provide official permits for traditional gold miners who are classified as illegal and continue to monitor the environment around traditional gold processing areas.

INTRODUCTION

Groundwater as a renewable natural resource has an important role in supplying water needs for various purposes (Yuan et al., 2017). The increasingly vital role of groundwater, making its utilization must pay attention to balance and preservation. In addition, groundwater as a water resource has now become a complex problem, so various activities are needed to reduce the negative impacts that arise as a result of uncontrolled exploitation of groundwater (Prastistho et al., 2018).

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Groundwater has generally good quality, but groundwater is very dependent on the nature of the soil layer (Rahmatillah & Husen, 2018). If the environmental sanitation conditions are very low, it will be contaminated by bacteria. If it is adjacent to an industry with a high pollution load and does not have a water pollution control system, it will be affected by pollution seepage (Erwin & Malik, 2018; Prastistho et al., 2018). According to Surisman (2016) water quality includes three characteristics, namely physical, chemical, and biological. Physical characteristics include the overall solid material (floating and dissolved), turbidity, color, odor, and taste and temperature. Chemical characteristics include pH, alkalinity, cations and anions, solubility and hardness, while biological characteristics include the content of macroscopic, microscopic and bacterial species which are generally indicated by Escherichia Coli (Djuwansah et al., 2009; Surisman, 2016).

The quality of groundwater is strongly influenced by the presence or absence of sources of pollutants or pollution contained in groundwater. In PP No 22/2021 concerning Water Pollution Control, "Water Pollution is the entry or inclusion of living things, substances, energy, and or other components into water by human activities so that they exceed the established Water Quality Standards. To find out the occurrence of groundwater pollution, it is necessary to review how and where the groundwater is located. The distribution below ground level in the vertical and horizontal directions should be taken into consideration (Almar, 2022; Niwele et al., 2022). The geological zones which greatly affect groundwater and its structure in terms of its ability to store and produce groundwater must be defined. Assuming that hydrological conditions provide water in the underground zone, the underground layers will carry out the distribution and affect the movement of groundwater so that the role of geology in groundwater cannot be ignored (Cordova & Muhtadi, 2017; Tufano et al., 2020).

One of the activities that affect the decrease in groundwater quality is mining activity (Hardjowigeno, 2007; Niwele et al., 2022). According to Law Number 4 of 2009 concerning Mineral and Coal Mining it is stated in article 1 paragraph 1 that mining is part or all of the stages of activity in the framework of research, management and exploitation of minerals or coal which includes general investigations, exploration, feasibility studies, construction, mining, processing and refining, transportation and sales, as well as post-mining activities (Mahmudi et al., 2015).

One example of mining that can cause groundwater pollution is gold mining. Traditional gold mining generally uses mercury in the processing stage which is then discharged into the river after processing is complete. One of the traditional gold mining which causes indications of groundwater pollution is traditional gold mining in Paya Ateuk Village, Pasie Raja District, South Aceh Regency, Aceh Province. Most of the local people depend for their livelihood as gold miners. Local residents dig hills containing gold and then bring the excavated chunks to the gold panning process. At the gold mining site, the excavated lumps are put into a traditional grinding machine which is mixed with mercury. This aims to destroy and separate the rock with gold. The results of the crushing of rocks produce waste containing mercury, which flows directly into river water (Djuwansah et al., 2009; Tufano et al., 2020).

Based on research on the analysis of mercury content conducted by Febriarta (2021) in the traditional gold mining processing area in Paya Ateuk Village, Pasie Raja District, it shows that the Paya Ateuk Village area has experienced mercury pollution (Febriarta et al., 2021; Febriarta & Shofarini, 2021). This is based on testing 3 water samples taken in the upstream, middle and downstream of the rivers in the area. The result was that one of the three samples contained positive mercury with values in the upstream 0.00052, middle <0.0005 and downstream 0.02145. In addition, the results of interviews with six residents in Paya Ateuk Village also found that four people who used river water in the area experienced itching on their skin and two people experienced headaches. Apart from this, the local people no longer dare to take fish in the river.

Research on pollution due to the processing of the Paya Ateuk gold mine has been proven to contaminate surface water (Ionita & Mocanu, 2015). This can also affect the quality of groundwater in the region. Surface water that infiltrates into the groundwater will greatly affect the quality of the water in it (Niwele et al., 2022). While groundwater in the area is the main clean water commodity for the community, especially regarding the use of wells. So according to the author it is very necessary to assess the vulnerability of groundwater in that location. Whether groundwater is affected by surface water quality or the environment can also carry out self-purification, which is greatly influenced by several environmental factors. So that in determining research studies, a study/research formula is needed using the method of combining the values of several factors which are combined and then analyzed. Based on these reasons, the author decided to research the area around traditional gold mining processing in Paya Ateuk Village, Pasie Raja District, South Aceh District uses the SINTACS method with the aim that the author knows the level of groundwater vulnerability in the area around the gold mine processing location. The SINTACS method was chosen because it is a multi-parameter method. So that in drawing conclusions and directives for further management, many aspects can be considered, which then the results can become recommendations for the community and local government to determine policies to protect public health and the environment around traditional gold mining processing sites. The research was conducted with the aim of: So that in drawing conclusions and directives for further management, many aspects can be considered, which then the results can become recommendations for the community and local government to determine policies to protect public health and the environment around traditional gold mining processing sites. The research was conducted with the aim of: So that in drawing conclusions and directives for further management, many aspects can be considered, which then the results can become recommendations for the community and local government to determine policies to protect public health and the environment around traditional gold mining processing sites. The research was conducted with the aim of; (1) evaluating groundwater conditions around the traditional gold mining processing site in Pasie Raja District, (2) evaluating the zoning level of groundwater vulnerability around the traditional gold mining processing site in Pasie Raja District using the SINTACS analysis method, and (3) determine the direction of recommendations resulting from the measurement values and analyzes carried out to maintain and improve the quality of the environment and health around traditional gold mining processing sites.

METHODS

The research method is used as a reference in the procedures and system steps in conducting research. This study aims to determine the level of vulnerability of groundwater to potential pollution from gold mining processing in Paya Ateuk Village, Pasie Raja District, South Aceh District using the SINTACS method. The subjects studied in this study were the potential susceptibility of groundwater to pollution due to traditional gold mining processing and laboratory testing of groundwater samples at traditional gold mining processing locations whether they contained mercury and other contaminants that exceeded established environmental quality standards.

The results of previous research conducted by Suryani, 2021 show that traditional gold mining processing in Paya Ateuk Village, Pasie Raja District has been proven to cause pollution in surface water because it contains mercury above environmental quality standards. Surface water flow samples taken were river water samples in Paya Ateuk Village. In this study samples were taken from the upstream, middle and downstream of the river and then laboratory tests were carried out using the SNI 6989.78-2019 method. Based on the evidence of contamination at the traditional gold mining processing location, it is also necessary to conduct a groundwater vulnerability study to prove whether groundwater at that location has the potential to be polluted. The research was conducted using the SINTACS method by considering several measurement aspects such as groundwater depth,

By measuring the level of vulnerability of groundwater and checking directly on the chemical condition of groundwater quality, it is expected to be able to show the original condition of the environment in the traditional gold mining processing area. This condition is then expected to become material for consideration in making policies, especially for the government in granting business licenses for processing traditional gold mines, the use of B3 chemicals or directions for the government and the community in carrying out environmental management as well as recommendations for appropriate management using several comparative options in dealing with problems and prevent contamination at the research site.

RESULTS AND DISCUSSION

A. Topography and Slope

Topography measurements in the field took 11 sample points spread throughout the study area. The lowest point of measurement results is 8 meters above sea level which is in the lowlands to the west of the study site and the highest point is 490 meters above sea level which is to the east of the study location. The traditional gold mining location is located in the eastern area of the study which has a hilly natural appearance. While the gold mine processing location is in a residential area with a lowland natural appearance.

Based on the results of observations and measurements in the field, it shows that the research location in Pasie Raja District has various contours. The area in the west extending from north to south is lowland with a slope of 0 - 8% which is classified as flat. This area is generally used by the community as agricultural land and residential locations. This area has a height between 1-19 meters above sea level. Meanwhile, in the middle of the study area is an area with mixed contours between 9-15% and 16-25% which is classified as sloping to slightly steep. This area is generally used by the community as plantation land for teak, mahogany, and hard root woody plants. While in the eastern region of the study area generally has contours above 30%.

Topography that is flat to sloping in the SINTACS scoring has a high value in influencing groundwater vulnerability. This is because the flat topography will make the water flow more vertically into the ground. Meanwhile, the steep topography makes the water flow horizontally down to the surface. So that in the research area. The west-south research area has a high vulnerability value to groundwater contamination and the east-north research area has a low vulnerability value to potential groundwater contamination.

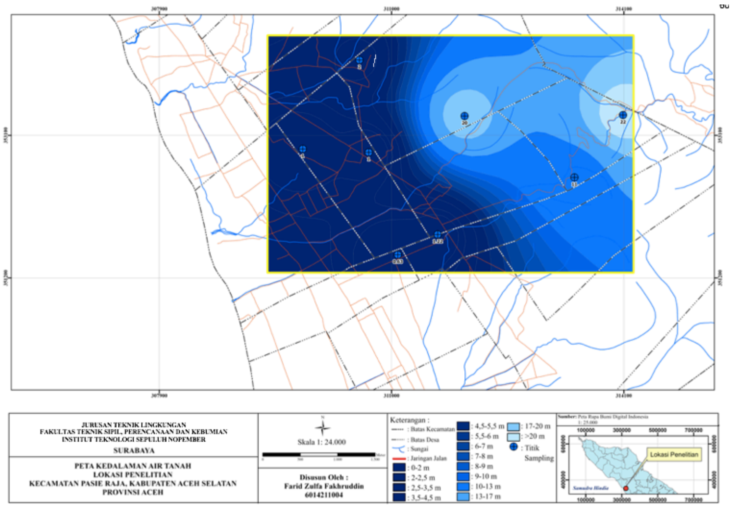

Figure 1. Slope Map

B. Groundwater Depth

Measuring the location of the groundwater table to the ground surface in the field took 8 cross-check points spread throughout the study area. The 4 crosscheck points are groundwater depth points checked at community well locations. While the other 4 crosscheck points use the help of groundwater levels that appear on the surface of the river. The lowest groundwater depth point is at crosscheck point 1 with a depth of 0.63 m. This area is a lowland with a flat slope and dry land use. While the point of the deepest depth is at crosscheck point 4 with a depth of 22 m. This area is an area with forest land use and has a steep slope. The 8 crosscheck points are then processed into a groundwater level map as shown in Figure 1 Groundwater Depth Map

The groundwater depth map produced shows that the traditional gold mining area in the mountains to the west of the research area has groundwater depths that tend to range from 13 to more than 20 m. So that the possibility of contamination of groundwater due to contamination of surface water will be small because the percolation process is far away until it enters the groundwater basin in the soil. While the depth of groundwater in the west of the study area tends to be shallow, namely under 2 meters. The percolation process, which tends to be short from the surface to the groundwater basin, makes it possible for groundwater contamination on the surface to greatly impact contamination in the groundwater basin. This is also influenced by the large number of gold processing areas using mercury in the western area of the study area.

Based on the value of the SINTACS scoring parameter, it shows that the shallower the groundwater is measured from the surface, the higher the potential for groundwater contamination. Meanwhile, the farther and deeper the groundwater is, the lower the potential for groundwater contamination. So based on the measurements it can be shown that the west-south part of the study area has a higher potential for groundwater contamination compared to the north-eastern part of the study area. This is also the same as the value shown in the slope parameter. The slope of the slope also affects the depth of groundwater because of differences in elevation on the surface. So that the vulnerability values on the parameters of slope slope and groundwater depth are interconnected.

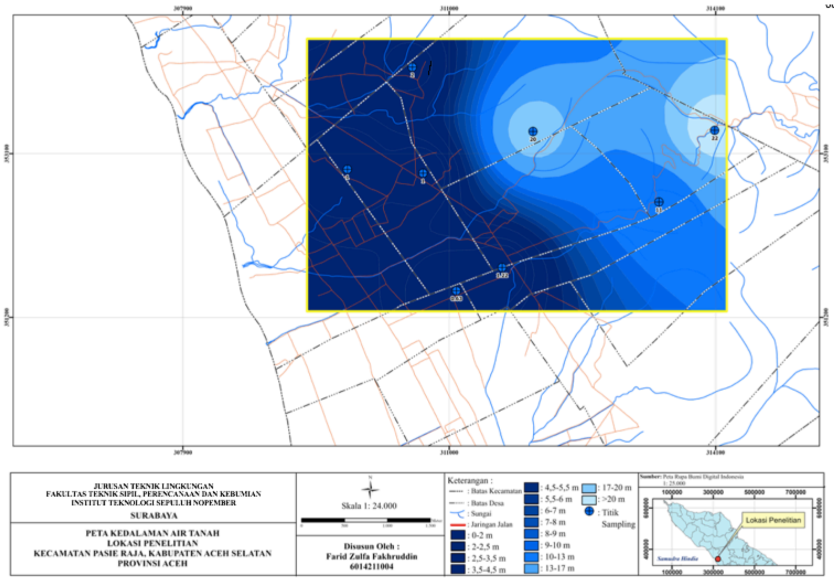

Figure 2. Groundwater Depth Map

C. Rock Unit/ Aeration Condition

Rock unit cross checks were carried out at 6 points to ensure that the rock units or aeration conditions at the study site were in accordance with the thematic maps that had been made. Based on the cross-check in the field, it proves that in the east of the research location up to the east and north of the research boundary there are limestone/ karst rocks. These rocks are located in areas with hilly landforms with plantation or forest land use. While the lowlands to the west have rock types that vary between sandstone and claystone. Sandstone and claystone are in areas with lowland landforms with common land uses being paddy fields and settlements.

Limestone or karst in the study area is characterized by diclasses or fractures. These diaclasts/ fractures are characteristic of karst areas, as a place where surface water runs towards groundwater. This condition allows pollution that is on the surface to directly seep and pass to the groundwater. Furthermore, the third rock is sandstone. The sandstone in the study area is a small size of breccia and limestone. These sandstones tend to be more compact and scattered in lowland areas. When compared to limestone, sandstone is more able to inhibit the rate of infiltration of surface water into groundwater. Sandstone does not have continuous diaclase to groundwater. Thus reducing the possibility of water percolation into the ground.

Based on the classification of the SINTACS parameter values, it shows that the more sedimentary a rock is, the higher the probability that the area will experience groundwater contamination. Whereas the more compact the rock such as metamorphic rock, the lower the possibility that the area will experience groundwater contamination. This shows that the west-south part of the study area has a lower vulnerability to groundwater pollution than the north-east area. These results are also consistent with the groundwater vulnerability values shown in the parameters of slope slope and groundwater depth which both show differences in vulnerability values on the west-south and north-east sides of the study area.

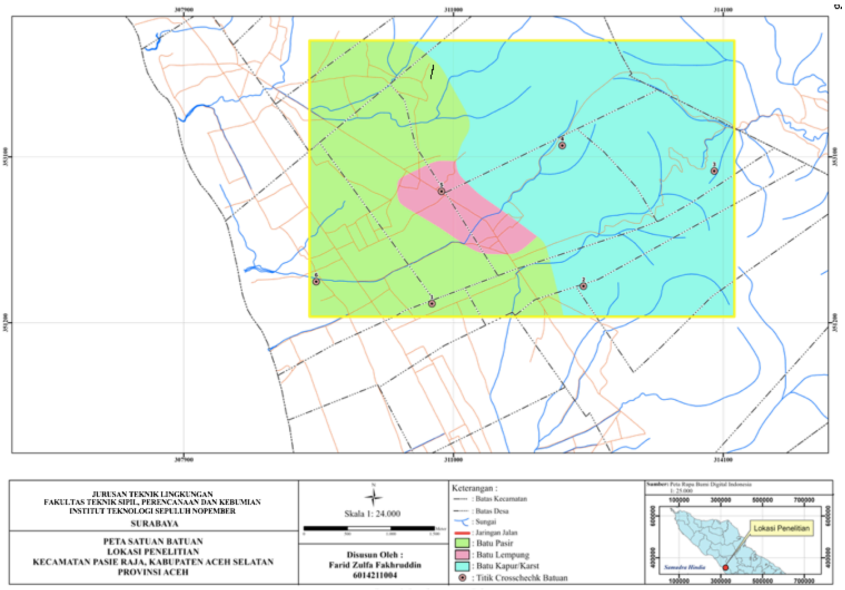

Figure 3. Rock Unit Map

D. Soil Texture

Soil texture measurements were carried out at 3 measurement locations based on land use and soil type. The use of a land use map as a reference is considered because soil texture is strongly influenced by land preparation or activities carried out and the activities of living things on it. Based on the thematic map made, there are 3 main land uses, namely forest-garden land use, residential-moor land use and paddy field land use. Each land use area was sampled to determine the value of sand, clay and silt content.

Based on laboratory results, it was shown that forest-garden land use had a dusty clay texture value with details of 31.92% sand, 51.06% dust and 17.02% clay. The texture of paddy fields has a dusty loam texture with a texture value of 51.35% sand, 39.80% dust and 8.85% clay. Whereas the soil texture of residential-moor land use has a sandy loam texture type with a texture value of 82.90% sand, 8.55% silt and 8.55% clay.

Based on the classification of SINTACS values, it shows that the more sandy the texture of the soil, the higher its susceptibility to possible groundwater contamination. Meanwhile, the clayier the texture of the soil, the lower the possibility of groundwater contamination. So that in the research area it can be concluded that the west-south research area has a higher vulnerability value than the north-east research area. The texture in the field is also influenced by the underlying bedrock. So that the value of groundwater vulnerability in soil texture parameters is almost the same as the distribution of groundwater vulnerability values in rock parameters, where there are differences in the west-south and north-eastern parts of the study area.

Soil texture greatly affects the water system in the soil and the level of soil infiltration. The finer the texture of the soil, the smaller the surface area of the texture. So the ability to hold water will be lower. The results of measurements in the field show that the type of texture is Garden/ Forest land use < Paddy fields < Settlements/Moor fields with details of the texture of dusty clay < dusty loam < sandy loam. The ability to pass water affects the opposite infiltration value, namely Gardens/Forests > Paddy Fields > Settlements/Moorlands.

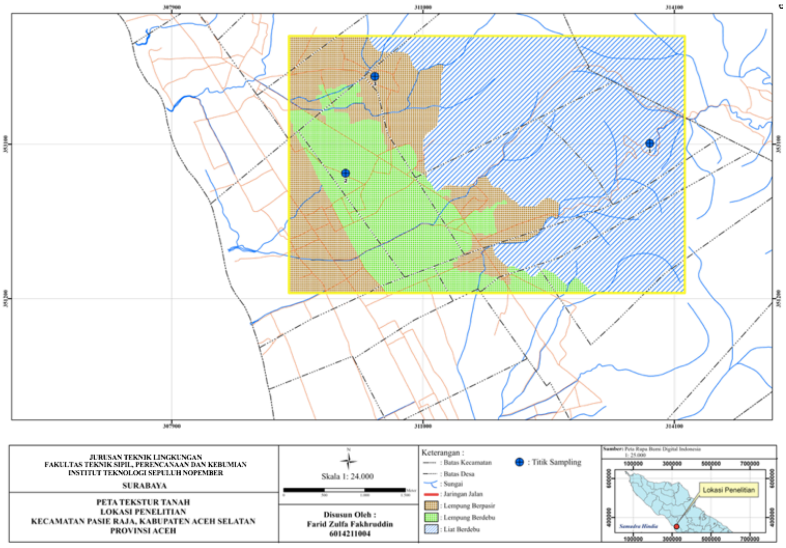

Figure 4. Soil Texture Map

E. Soil Infiltration

Infiltration measurements were carried out at 4 measurement points taken based on soil type. The types of soil that exist in the location are inceptisol and entisol soil, then 2 sample points are taken for each type of soil. Inceptisol soil is in the lowlands with sandstone rocks and a flat slope. While the entisol land is in the hills with karst rocks and a gentle-steep slope. Based on measurements in the field, the entisol soil type was measured 2 times at 2 points. The first point is stopsite 2 which has an infiltration value of 65.96 mm/hour. Whereas at measurement point 5 has an infiltration value of 91.02 mm/hour. These two measurement points are included in the fast infiltration classification because they are in the range of 65-91 mm/hour. The rapid infiltration rate at this location is due to the type of entisol soil in the location which is the weathered product of karst rock which has a dusty clay texture. So the rate of water penetration into the soil is very high. Small soil particles also reduce soil resistance to water.

Measurements in inceptisol soil types were carried out at 2 points. The first point is stopsite 4 which has an infiltration value of 47.39 mm/hour. The second measurement point is at stopsite 8 with an infiltration value of 50.34 mm/hour. Both of these infiltration values fall into moderate infiltration susceptibility which is between 20-65 mm/hour. The rate of infiltration is slower than infiltration in entisol soils due to the larger grain size of the soil. Inceptisol soil is a young soil resulting from weathering of parent rock so that its size tends to be large which has implications for a larger surface area of the soil grains. So that the ability to hold water will be even greater.

Based on the distribution of groundwater vulnerability values on the infiltration parameter, it shows that the higher the infiltration value, the higher the groundwater vulnerability to contamination. Meanwhile, the slower the infiltration, the lower the value of groundwater vulnerability. The results of infiltration measurements show that the west-south area of the study site has a higher vulnerability to groundwater pollution than the north-east area of the study. Meanwhile, if a relationship is drawn, this result is in line with the results of the vulnerability values on the parameters of slope, groundwater depth, rock condition and soil texture which indicate that there are differences in values seen in the western and eastern areas of the study.

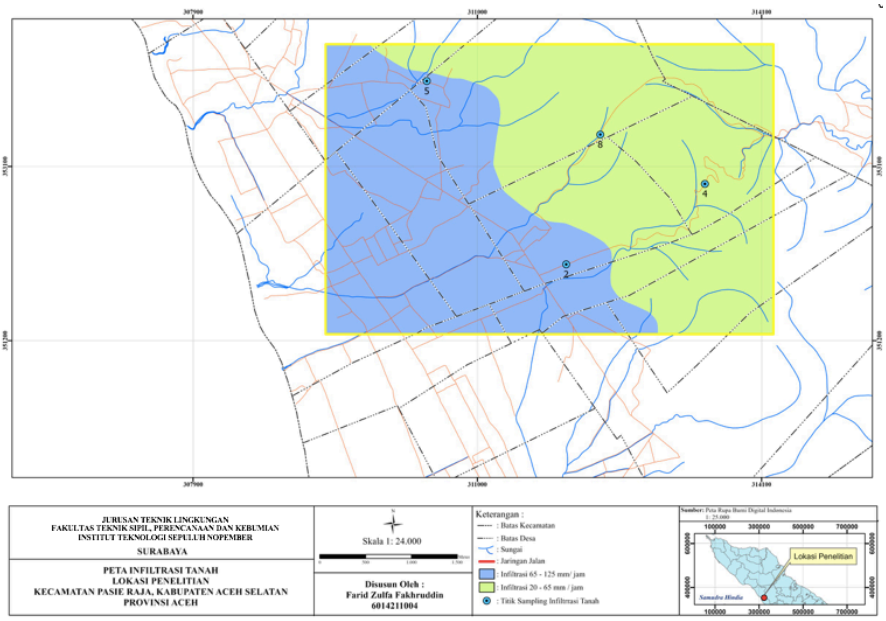

Figure 5. Soil Infiltration Map

F. Aquifer Lithology

Based on checking aquifer lithology using the help of thematic maps from ESDM, it shows that the research area has 5 types of lithology that are in aquifers or underground. The rocks include breccia in the east, limestone in the north and spreads to the south, sandstone in the west, coarse alluvium on the southwestern tip and a small amount of clay in the middle of the study area. Aquifer lithology affects the rate of hydraulic conductivity. Water absorbed in the soil will continue to be absorbed in the rock.

Breccia rocks are volcanic rocks, more precisely, sedimentary rocks from igneous rocks. These rocks have characteristic fragments or patterns in the rocks. In the research location there are several breccia rock fragments. However, during the crosscheck, no intact breccias were found. So it is most likely that the broken breccias found are the result of hill fragments dredged for gold excavation. This breccia rock is more compact than the rocks next to it, namely limestone and breccia stone, are better able to hold polluted water in the ground and do not pass deep underground. Furthermore, limestone or karst. Limestone or karst is a rock with a characteristic diaclase or fracture. These rocks are generally located in the hills. These rocks are located in karst areas which are formed from the results of dissolution and sedimentation. The most prominent feature of this rock is its high ability to transmit water below the surface of the soil. So if there is contamination on the surface will greatly affect the quality of water in the ground.

Next is sandstone. Sandstone is a rock formed from clastic sediments with the size of the constituent minerals in the form of sand. Sandstone has a fine but dense grain. So that the percolation of water that passes through these rocks will be filtered and of better quality than limestone which is in the form of fractures. Sandstones are in the lowlands with a small slope. Besides that, in this area there is also claystone which has a very small area of coverage in the use of paddy fields. Clay rock has the ability to hold water above it so that it is not transported and spreads widely besides that the penetration of water into the ground is also low. While the last lithology is alluvium rock. Alluvium rocks are in the southwest of the study area. This area is very close to the sea and into the coastal area.

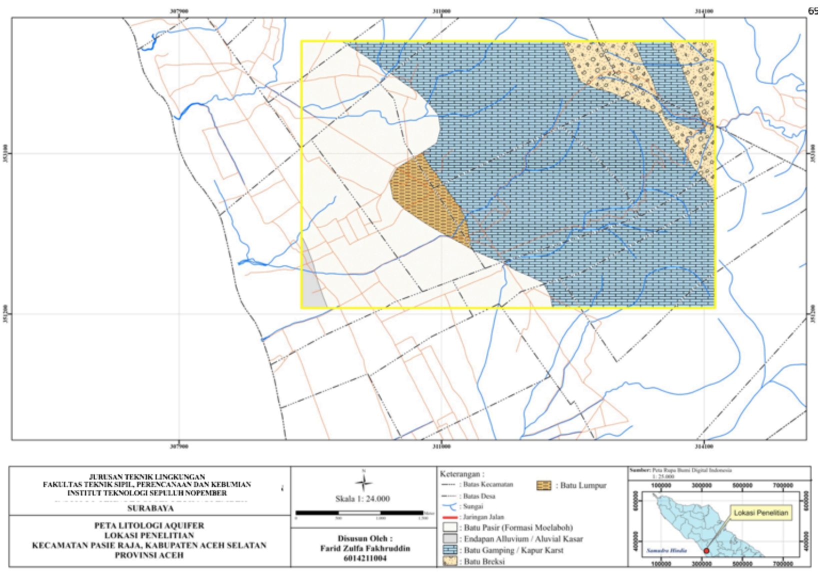

Figure 6. Aquifer Lithology

G. Hydraulic Conductivity

The hydraulic conductivity used in this study is the conductivity data belonging to ESDM where conductivity is the level of water permeability through rock. The hydraulic conductivity is strongly influenced by the rocks in the aquifer lithology so that in making maps it refers to the existing aquifer lithology maps. Based on the results of the analysis, it shows that the aquifer lithology with Breccia and Karst rocks has a conductivity value of 2.5 x 10-3 m/sec. This conductivity is in the high category where the level of water passing through the rock will be easy to get to the groundwater. This is due to the typical rock formation with fractures that make water easily seep in and experience percolation into the ground. This is also proven in the results of groundwater depth measurements in locations with karst and breccia rocks. The depth of groundwater in this location has a depth range of 11 to 22 meters from the surface. The condition of the water that continues to pass into the ground is also influenced by the contours of the area which is in the hills with a fine texture of dusty clay.

Meanwhile, the hydraulic conductivity in aquifer lithology with clay rocks has a value of 2 x 10-4 m/s. Conductivity with this value is low because it is in clay rocks. So that the ease of passing water to the ground is low. Clay rocks tend to be able to withstand the rate of soil infiltration and percolation deep below the surface. This is also evidenced by the results of groundwater depth measurements which show that this area has a groundwater depth of only 1-1.22 meters.

The next hydroulic conductivity is the hydroulic conductivity in aquifer lithology with sandstone rocks. In this area has a conductivity value of 2.5 x 10-4 m/s. This conductivity value is the smallest of the two previous values. This is influenced by sandstone which has more compact and denser grains than previous rocks. In addition, the location of the area in the lowlands makes these rocks tend to be saturated with water. So that surface water escape into the ground is not as significant as surface water escape in areas with hilly landforms. In addition, the texture of the soil in the form of sandy loam to dusty loam also makes the soil lower in porosity and permeability than the texture on the hills.

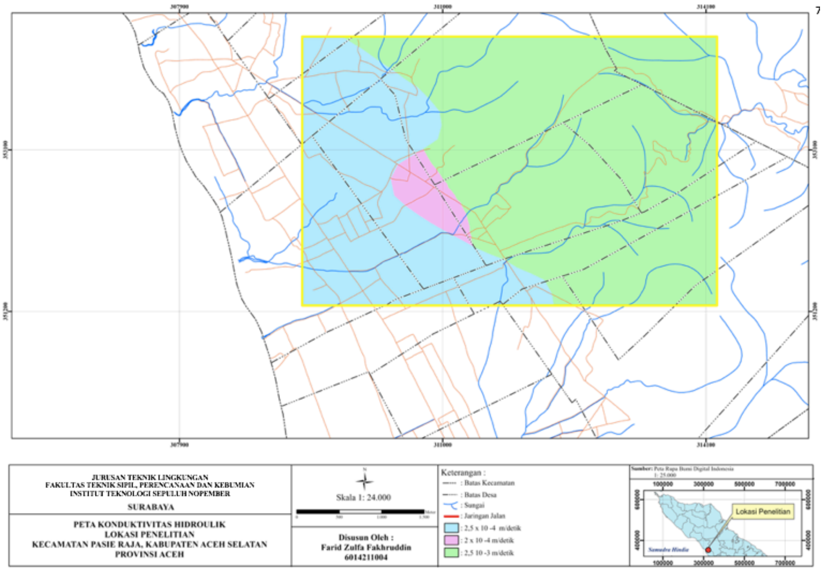

Figure 7. Hydraulic Conductivity Map

H. SINTACS Method Scoring

Based on the results of the 7 primary maps that have been made, multiplication of the SINTACS scenario weights is performed. This weight is a description of the actual conditions in the field. So the value generated from the SINTACS Method is relevant to the existing conditions. The research location consists of residential land use, paddy fields, dry fields, gardens and forests, the majority of which have been processed by humans. Although in the eastern part, especially the karst hill area, it is still an area with forest land use. However, the forest in the research location is a cultivated forest which is often influenced by human interaction in that location. So that in multiplying the scenario weights, the option "Normal Impact" is taken.

The resulting SINTACS scoring method shows that there are 821 formations with values ranging from 103.75 to 201.5 which produce four classes, namely low, medium and high. Low values are only in a very narrow area in the use of paddy fields with clay soil types. Clay soil conditions make it difficult for water to seep into the ground. While the value of moderate vulnerability is in the majority of research locations with a range of 90% of the area. Generally it is a karst hill area that has a high slope and high water permeability. In addition, the distance from the surface to groundwater is also far, so that pollution that occurs on the surface does not have a significant impact on the vulnerability of groundwater.

Scores with high scores are in the middle of the research area with the use of paddy fields. This paddy field has a moderate level of infiltration, but the distance between the surface and groundwater is very shallow and the fine texture of the soil makes it possible for surface contamination to greatly affect the quality of the water in the soil. In addition, this area is also land that is in an area with a flat slope. So that a lot of water will run into the ground and spread.

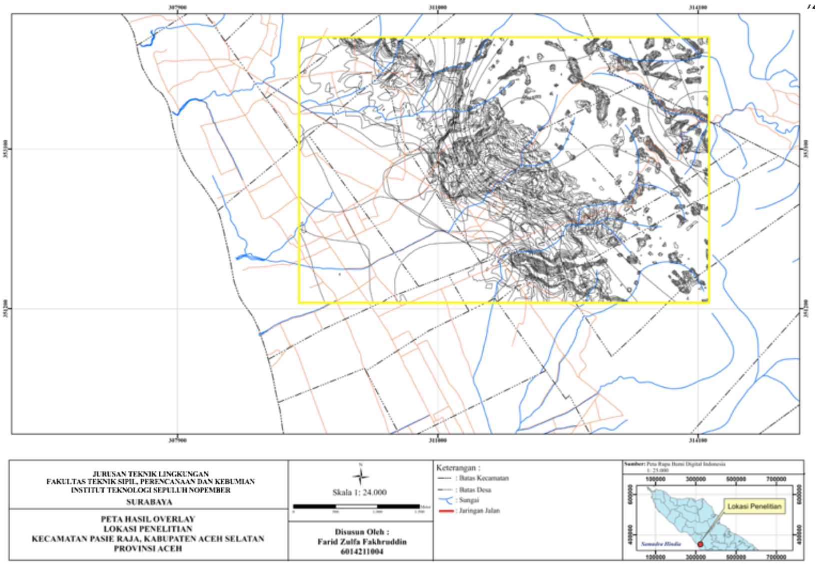

Figure 8. Overlay Result Map

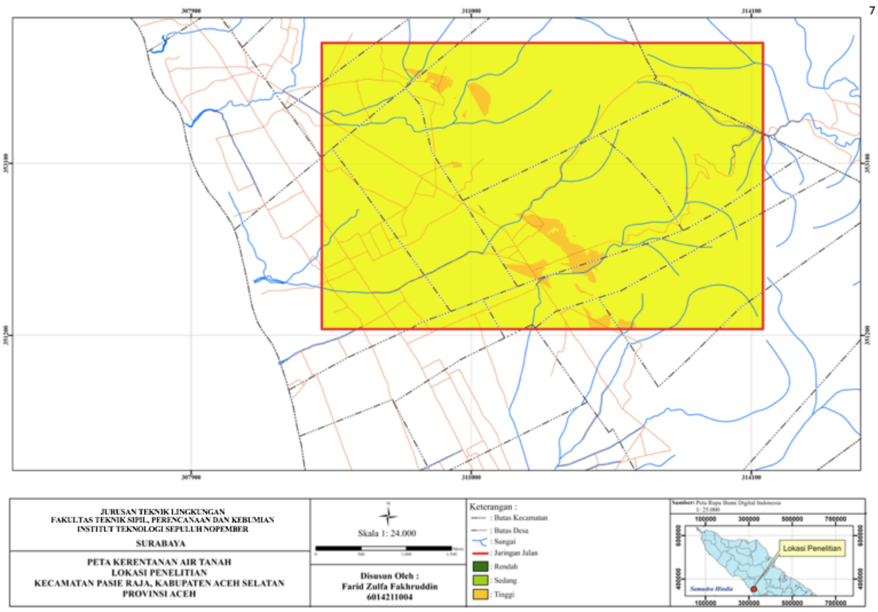

Figure 9. Soil Vulnerability Map

I. Measurement Results of Well Water & Management

Based on the results of measuring mercury levels using the SNI 06-2462-1991 method in 4 water wells around the study area, it showed that the mercury levels in residents' wells were <0.0004 mg/L, so they were still below the quality standard permitted according to Government Regulation No. 82 In 2001, it was 0.01 mg/L. In addition, the value of mercury levels in the river is also at a value of <0.0004 mg/L. This value indicates if the quality of river water is still good and does not indicate pollution. The good quality of river water is because the research was conducted in the rainy season with high rainfall around the study site. The research location which is downstream with a flat topography and under the mountains also causes a lot of water to flow to the surface. So that the pollutant mercury becomes tolerant of environmental quality standards.

Even though mercury levels in well water and river water have good values, based on previous measurements of mercury levels conducted by Suryani (2021) it shows that the river water in Paya Ateuk Village has been polluted. In addition, groundwater vulnerability that has been made using the SINTACS method also shows that almost 90% of the area is in the moderate vulnerability category and 10% has high vulnerability. So that mitigation also needs to be done to prevent the possibility of contamination if the runoff water is small in the dry season.

One of the mitigations that can be done to prevent the possibility of mercury contamination entering the groundwater is by treating gold waste using the in-situ phytoremediation method. Phytoremediation, which is the treatment of pollutants using aquatic plants, is one of the most profitable options in this case study at the Paya Ateuk traditional gold mine. This is because phytoremediation only requires low costs and easy maintenance. In addition, phytoremediation plants tend to be easy to obtain, including water hyacinth and lotus. The choice of the in-situ technique is also due to the fact that this technique has the advantage of low costs because it eliminates waste transportation, and the possibility of contact with waste is low. This is prioritized because work in traditional gold mining generally does not prioritize PPE in work. So reducing the possibility of exposure to pollutants is a good option.

Waste management using in-situ phytoremediation needs to pay attention to geo-hydrological conditions. Due to the possibility of polluted sewage treatment can enter the groundwater and damage the quality of groundwater. Based on the results of monitoring and measurements in the field, it shows that traditional gold mining processing areas using mercury are generally located in community settlements with lowland landforms. In addition, the value of vulnerability to contamination is also moderate to high. So that in its management needs to be a concern. One that can be applied is to use a compartment that has been coated with a permeable layer to prevent water from entering the groundwater. The compartments are then filled with wastewater with the help of phytoremediation plants. Then the waste water can be channeled into the river.

Based on Wari Suara's research (2017) shows that traditional gold waste treatment on a home scale can be carried out using the Subsurface Flow Constructed Wetland (SSF-CW) method. This method is carried out by utilizing water jasmine phytoremedias (Echinodorus palaefolius) with zeolite growing media. This system model has dimensions of 820 mm x 320 mm x 585 mm which consists of 3 zones, namely the inlet zone, reaction zone and outlet zone. Water jasmine was planted in the reaction zone with an up-flow method to the reaction zone using a pump. This system is run with 12 hours continuous and 12 hours batch. Based on the results of measurements conducted by Wari suara (2017) it shows that this system can reduce Hg concentrations by up to 91.99% before finally being discharged through the outlet channel.

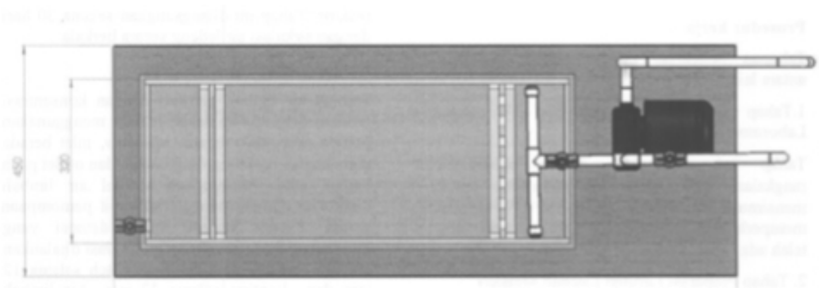

Figure 10. Top View of the Constructed Wetland Design

(Source: Warisaura, 2017)

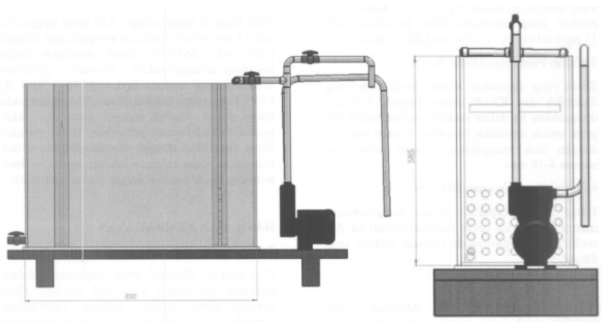

Figure 11. Side View of the Constructed Wetland Design
(Source: Warisaura, 2017)

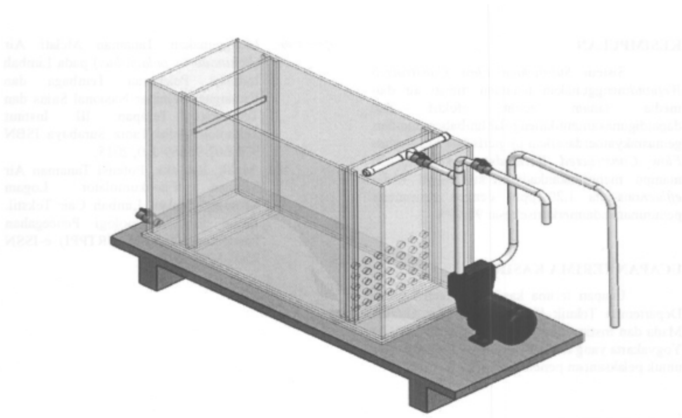

Figure 12. Overall Constructed Wetland Design
(Source: Warisaura, 2017)

River water with wild plants is also capable of natural phytoremediation. The existence of phytoremediation plants that grow naturally in nature is very beneficial. Apart from that, wild phytoremediation plants were also found at the study site, such as buffalo grass, jukut pendul, vines, and pimpernel plants which were widespread. Based on research conducted by Mahmud (2013) on the Tulobol River, Gorontalo shows that some river plants can reduce mercury levels significantly. These plants include Paspalum conyugatum (Buffalo grass) which is known to be able to accumulate 47 mg Hg/kg dry weight, Cyperus monocephala (Jukut pendul) 13.05 mg Hg/kg, Ipomoea batatas (Sweet Potato) 18.57 – 22.57 mg Hg /kg, Digitaria radicosa (Creeps/wild grass) 50.93 mg/Hg/kg,

In addition to the high rainfall factor, the presence of wild phytoremediation plants such as buffalo grass, jukut pendul, sweet potato, vines and wild pimpernel plants in the study area greatly influences the reduction of mercury pollutants in the study area. So that the measured mercury levels in well water and river water are below environmental quality standards. However, in practice it still requires regulation and discipline by the local government to record data on traditional gold mining in the research area and to conduct periodic monitoring of river water and well water owned by residents.

CONCLUSION

The quality of the groundwater in the residents' wells is of good quality with a mercury level value of <0.0004 mg/L. This value is below the allowable environmental quality standard threshold. The low level of mercury in the groundwater at the study site is caused by high rainfall so that the amount of pollutant dissolved by the large quantity of water is high.

The results of the scoring and overlaying of the syntax method yielded 821 subgroups with vulnerability values ranging from 103.75 to 201.5 which resulted in three classes of vulnerability namely low, medium and high. Low susceptibility values are in a small part of the paddy field land use area with clay soil. Moderate susceptibility scores are in about 90% of the study area. Meanwhile, the value of high vulnerability is around 10% of the research area.

Mitigation to prevent pollution in the traditional gold mining processing area in Paya Ateuk Village, Pasie Raja District can be done by phytoremediation in compartments made near the gold processing location.

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