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Hydrogeological Studies in a Slag Disposal Plan at Morowali Area, Central Sulawesi Province, Indonesia

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ABSTRACT

In the Morowali area, the potential of soil and sediment eroding into and degrading surface water quality is a serious problem. Slag disposal sites are a necessary part of mining industrial infrastructure in Morowali area. Suitable new sites must be found and suitable methods must be available to show that sites have layers in the surface that can function as a barrier the entry of contaminants into the environment. Furthermore, it is worth mentioning that the site is planning to be developed in the groundwater protection purposes. Therefore, hydrogeological characteristic in the slag disposal plan is important. Thus to achieve this aim, geophysical survey, sub surface geological information, and rock permeability assesment, as well as complementary assessment of slag disposed at the site, were conducted. As geological surface investigation, the lithology of a Morowali area is divided into three lithologies: peridotite, sandstone, and conglomerate. Based on the hydrogeological characteristics of the working location, the potential for groundwater contamination at the location of the work resulting from smelter waste disposal activity is difficult to occur due to an impermeabel layer close to the soil surface with a very small permeability value that is less than 9.6 x 10^{5} cm / s, with ground water flow laminer and close to the soil surface that is less than 4m. Therefore some of the liquid waste will flow along the surface stream.

INTRODUCTION

For most mining projects, the potential of soil and sediment eroding into and degrading surface water quality is a serious problem (Amar.N.S, etc, 2015). One important question, in determining whether a proposed mining project has environmental issues regarding disposal of high-volume toxic waste material (ELAW, 2010).

The impact of slag, waste rock, heap leach, and dump leach facilities on water quality can be severe. These impacts include contamination of groundwater beneath these facilities and surface waters.

Tailings (a by-product of metallic ore processing) is a high-volume waste that can contain harmful quantities of toxic substances, including arsenic, lead, cadmium, chromium, and nickel. Although it is rarely an environmentally-preferable option, most mining companies dispose of tailings by mixing them with water (to form slurry) and disposing of the slurry behind a tall dam in a large wet tailings impoundment. The resulting waste contains large amounts of water, and generally forms ponds at the top of the tailings dams that can be a threat to wildlife because the ore is usually extracted as slurry.

In special situations, tailing ponds will either dry, in arid climates, or may release contaminated water, in wet climates. In both cases, requirement to close these waste repositories and reduce environmental threats are specific management techniques.

Socio-economic impacts on downstream communities are product from Environmental changes caused by riverine disposal inevitably (IIED, 2002). Physical changes, such as degradation of water quality, widening of river channels, changes in flow, over-bank deposition of tailings and flooding can impose a number of alterations in community lifestyles.

Slag disposal sites are a necessary part of the infrastructure of a mining industry in Morowali area. Suitable new sites must be found and suitable methods must be available to show that sites have layers in the surface that can function as a barrier to the entry of contaminants into the environment. Furthermore, it is worth mentioning that the site is planning to be developed for groundwater protection purposes. Thus to achieve this aim, geophysical survey, hydrogeological assessment, as well as complementary assessment of the slag disposed at the site, were conducted.

MATERIAL AND METHODS

Study Area Description

The analysed slag disposal site is a part of the industrial facilities of the formal Morowali Industrial Park. The whole complex is situated at a distance of 5 km from urban areas. On the east part of the slag disposal planning area the Morowali Industrial Park is located. The material disposed on the landfill consisted of industrial slag product from nickel processing of the Indonesian Morowali Industrial Park. A total area of the landfill planning is 25 ha (**Fig 1**).

Fig.1 A study area of slag disposal plan in at Morowali Area, Central Sulawesi Province, Indonesia.

The study area is located at an altitude of 19 -106 m above sea level. The watershed area 2.03 km^2 with surface water flow pattern showing the direction of flow to the north of the disposal slag plan location. The main stream is at the center of the location. The small river relatively flows in an East-West direction. The river flow pattern is classified a dendritic flow pattern with the river genetic type of consequent. Rainfall data obtained from PT.Sulawesi Mining Investment for the period of 2015. Intensity of rainfall in January to March showed an increase in intensity ranging from 300 to 600 mm. Furthermore, in March to May showed a decrease in rain intensity ranging from 600 to 300 mm. In June - August showed very small rain intensity which ranged from 14 - 40 mm. While in September - November there is no rain. And in December, rainfall occurred with an intensity of 148.9 mm.

Data Investigation

The aim of the investigation was to determine the hydrogelogical characteristic in the sub surface and include the field permeability of the sub surface rock. The information obtained enables preparation of the engineering work for the slag disposal. The scope of works was divided into four stages and they consisted of :

- Investigation of surface geology
- Geophysical survey with the use of the electrical resistivity method, in order to determine of sub surface rock.

  The geophysical reistivity data were acquired with the Naniura NRD 300. Other materials used in the investigation include two current electrodes and two potential electrodes, four rolls of connecting cables, hammer, and compass. Six geolectric soundings using the vertical electrical sounding technique was conducted in the study area. The Schlumberger array was employed using a current electrode separation of 300 m. The records of the apparent resistivity obtained in the study together with the record of the current electrode separation were used to plot the sounding curves. The record data were employed as input data in a computer based interpretation using the Res2Dinv software to obtain the resistivity and thickness of the subsurface.
- Accomplishment of 3 boreholes of a depth of 25- 40 m (total 95 m of drillings). Three boreholes were drilled to investigate the lithological structure of the subsurface and also to determine the permeability of the subsurface rock.
- Field test of permeability value of sub surface rock. Water pressure test were carried at one location (BH-02) using single packer pressure tester with a thrust capacity of 5 Kg/cm2. The penetration of the test in 5 meters interval where the maximum thrust capacity of the water pressure was achieved.

RESULTS AND DISCUSSIONS

Geological Setting

As geological surface investigation, the lithology of a Morowali area is divided into three units, consisting of; peridotite, sandstone, and conglomerate. The conglomerate rocks are located in the west and east of the study area, and are found in most about 60% of the study area. This conglomerate rock is found in the hills morphological. Based on their physical characteristics, conglomerate units can be compared with Tomata Formation (Tmpt) which its age in Upper Miocene to Pliocene (Sukamto.R, 1975). Underlying the conglomerate units is sandstone unit which located in the center of the study area.

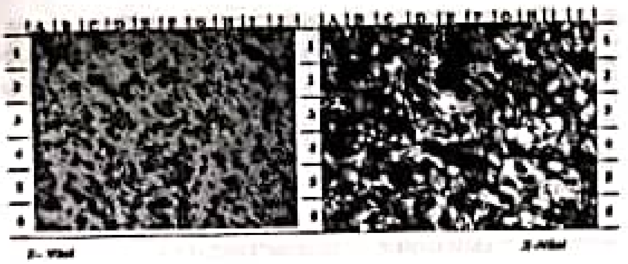

Fig.2. Petrography section of sandstone unit

The sandstone outcrops are found in medium to high weathering conditions, with outcrop dimensions of 0.3 to 5 meters, with northeast-southwest distribution. In the field, sandstone unit shows yellow to brownish yellow colours with a smooth to coarse clastic texture, has a composition of fine-sized material to coarse sand, with cement of non-carbonic material, a layered structure of 1 to 12 cm thick, and some inserted with conglomerates, claystone and siltstone.

Microscopically, this sandstone is brownish-white on the parallel and blackish gray on the cross nikol, the clastic texture, the mineral composition comprising feldspar, piroxin, serpentine, quartz. The granular shape is rounded to angular, the grain size is 0.02 - 0.53 mm (**Fig.2**). The sandstone unit can be compared with Tomata Formation (Tmpt) which age in Upper Miocene to Pliocene (Sukamto.R, 1975). Underlying the sandstone unit is the peridotite unit, which is located in the northern part of the study area and has a distribution of about 20% of the study area. In a microscopic observation has show dark brown color on the parallel nicol observation, and orange color to grayish white in cross nicol. The mineral composition consists of pyroxene, serpentine, and olivine. The pyroxene has a subhedral-anhedral shape, and the mineral size is 0.03 - 2.8 mm. The age of peridotite unit has been compared with Ultramafic Complex which its age is Post Mesozoikum (Sukamto. R, 1975). The geological structure encountered is a bedding of sandstones. Based on field measurements in two locations, the directions of rock bedding are about N 60^{0}E, N 290^{0}E, and the slopes of the bedding rock are 35^0 and 55^0.

Geolectric analysis

The geolectric data obtained from the survey was subjected to computer iteration interpretation using the Res2Din software. The resulting plots of the apparent resistivity values for the current electrode separation is presented as shown **Fig.3**. **Fig.3** describes the correlation of the six of geolectrical points from south to north. And this figure was presents the resistivity of current electrodes in the study area. The layers are made up of top soil, conglomerate, sandstone, and peridotite.

The first layer is made up of top soil with a resistivity range of between 1.5 and 11.3 Ωm and a thickness range of between 0.5 and 1.1 m. The second layer is composed of conglemerate with resistivity range of between 15 and 97.7 Ωm and a thickness range of between 21 and 70 m. The third geolectric layer is composed of sandstone and claystone. The resistivity of this layer range between 1.5 and 15 Ωm while the thickness range between 2.8 and 80 m. The fourth layer is composed of peridotite with resistivity range of between 11.3 and 80 Ωm. The thickness of this layer range between 40 and 70 m, and most of the north part of the study area is composed peridotite layer. The third layer is identified as the layer to source groundwater from since the data suggest that the third layer will be more productive than the second layer. This layer will correlated with the lithologic log in the drilling data.

Lithological analysis

The lithologic log obtained from the drilled borehole is presented in Fig.4. There are three points of borehole, such as BH-01, BH-02, and BH-03. The depth of BH-01 is from the surface to 13.5 meters which located in the northern part of study area.

The first layer is composed of conglomerate with a thickness of about 3 m. This layer is divided to two types, such as a weathering of conglomerate and conglomerate with ultramafic rock pragments. The thickness of the both conglomerate rock types are about 2 and 1 m. The both conglomerate rock types show brownish-red and a greenish gray colours. The second layer is composed peridotite rock with a thickness range between 3 and 13.5 m. As the location representative, this drilling data becomes the reference of information about permeability and porosity.

The lithology at BH-02 point is in the middle of study area can be seen in Fig.4. The depth shown is up to 35 m with various variations of lithology. On the surface found 0.5 m thickness of the soil and 0.5 meter conglomerate. An occurence of sandstone and clay layers at intervals range between of 1 and 32 m. The thickness of the sandstone is thicker than the other sandstone layers which are at a depth of 6 to12 m. And the claystone is at a depth of 12 to 20 m. Furthermore, at a depth of 20 to 32 meters dominated claystone layer. And the bottom layer of the BH-02 is a conglomerate that is at a depth range between of 32 and 35 m. The top soil shows gray-colored and the grain size of top soil is clay to gravel. Furthermore conglomerate is greenish gray; and composed ultramafic fragment with the grain size is gravel; sandy sandstone with grain size ranges from 2 to 1/16 mm; and claystone is grayish greenish color with grain size less than 1 / 16mm.

STRATIGRAPHIC SECTION BH-03 and BH-02

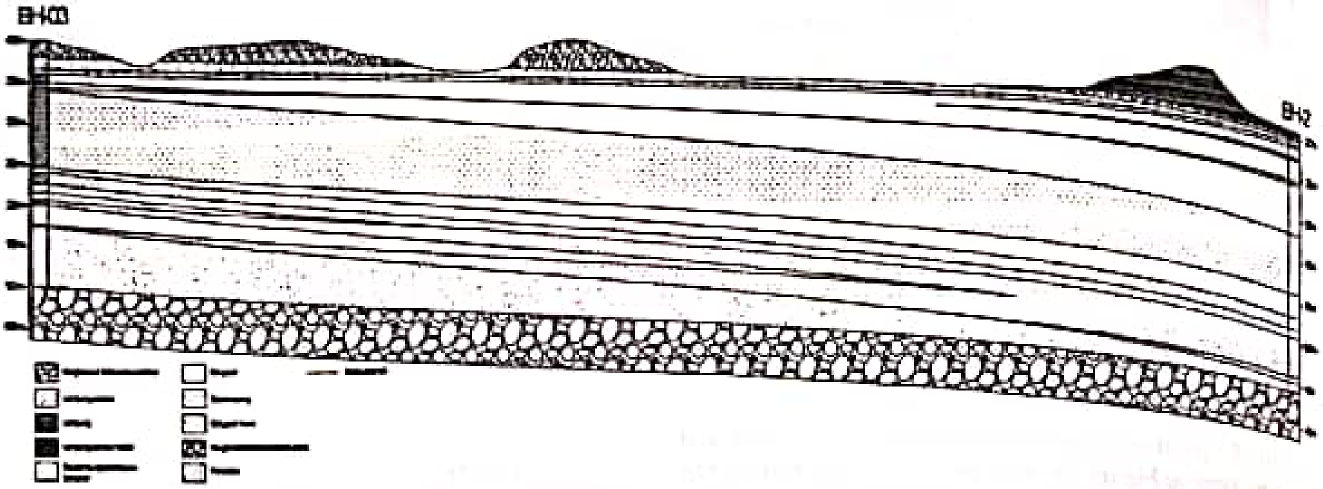

Fig.4 Stratigraphic Profile of BH-02 and BH-03 sections with the north part (BH-03) and the south part (BH-02).

Tabel 1 Packer test results in the BH-02

No	Depth (m)	Lithology	Permeability values (cm/det)		Flow type
			Min	Maks	
1	0-5	Claystone-Sandstone	9.4×10^{-5}	23.6×10^{-5}	Laminar
2	5-10	Claystone-Sandstone	8.9×10^{-5}	21.2×10^{-5}	Blockage
3	10-15	Sandstone-Claystone	8.1×10^{-5}	20×10^{-5}	Laminar
4	15-20	Claystone	7.9×10^{-5}	20.6×10^{-5}	Laminar
5	20-25	Sandstone- Claystone	9.9×10^{-5}	25.8×10^{-5}	Laminar
6	25-30	Claystone-Conglomerate	7.3×10^{-5}	20.6×10^{-5}	Laminar
7	30-35	Sandstone-Conglomerate	9.9×10^{-5}	26×10^{-5}	Laminar

CONCLUSSIONS

The result of this study has helped to explain the subsurface hydrogeological of Morowali area that to purpose of the slag disposal plan through an analysis of geoelectric information, log boring, and permeability of rock. The sudy has shown that the six geoelectric points were delineated with the fourth layer identified as the formation to assess hydrogeological overview. The study also revealed that the resitivity range of the aquifer layer in from 1.5 to 15 Ωm while the depths to the aquifer table range from 2 to 80 m. The result of this study showed that the permeability value 7.3×10^{-5} cm/det in minimum and 20×10^{-5} in maximum. Based on the hydrogeological characteristics of the location of the work, the potential for groundwater contamination at the location of the work resulting from the activity of smelter waste disposal is difficult to occur because of impermeabel layer close to the soil surface with a very small permeability value.

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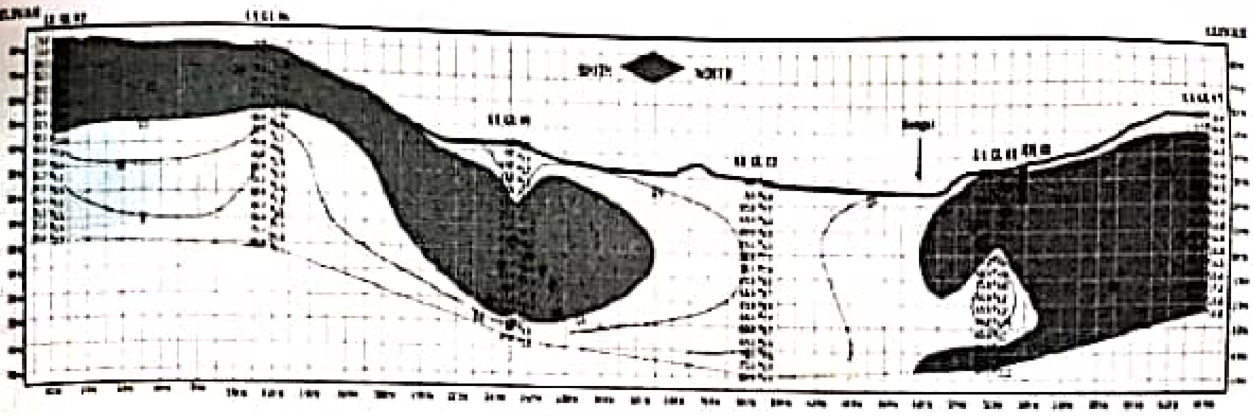

Fig.3 View of stratigraphic section of geolectrical points based on resistivity values

In BH-03 point is in the southern part of study area and can be seen in Figure 3b with the depth about 30m. On the surface of the conglomerate thickness found 2 m. The sequence of sandstone and clay sandstone are at a depth of 2 to 22.5 m. The thickness of the claystone is thicker than other sandstone layers which are in depths of 4 to 17.3 m. And the sandstone depth of thickness is at a depth of 17.3 to 30 m. At this depth the claystone becomes an insertion on the sandstone with an insertion thickness of 0.5 to 1 m.

The appearance of conglomerate colour is greenish gray, the grain size is boulder, the fragment is composed ultramafic; the underlaying layer is sandy sandstone with grain size ranges from 2 - 1/16 mm; and the bottom of layer is grayish greenish claystone with grain size is less than 1/16 mm.

Rock Permeability in the Study Area

The implementation of water pressure permeability test in the field was conducted to obtain the permeability coefficient and Lugeon value of a soil and rock layer by injection of water into the borehole, including calculation and determination of test result. Implementation of field testing refers to Indonesian National Standard (SNI) 2411: 2008 (Test method for water pressure in the field) with the implementation of testing conducted 5m interval in the rock layer. Based on the test results it is known that the characteristics of groundwater flow in the BH-02 work location are described as the permeability value of claystone, sandstone and conglomerate rocks in value ranges between of 7.3×10^{-5} and 26×10^{-5} cm/s. These rock layers has been estimated a direct flow type with the slope of the rock (laminar), however there is a blockage flow at the depth layer of 5 to 10m.

In the plan to utilize this as the location of the disposal area plan, the characteristics of the hydrogeological condition of the work site are described as follows:

1) The type of material that is sub porous to porous form of alluvium deposits, clays, clay gravel, clay and conglomerate (not consolidated) is characterized by bonds between loose particles so that runoff infiltration can occur.
2) As the impermeable layer, closest to the surface layer of claystone, with a depth of 2m (reference BH-02) to a depth of 4m (reference BH-03), and peridotite at a depth of 1.8m (reference BH-01).
3) The groundwater level is at a depth of 0.5m (reference BH-02) to a depth of 4m (BH-03 reference), while in BH-01 no groundwater is found.
4) Based on the reconstruction of the stratigraphic section (Fig.4) it is known that the groundwater flow follows the slope of the rock and the direction of river flow that is south to north. Type of groundwater in the field is including shallow groundwater this is reinforced by the results of testing packer test which shows that the type of flow in general in clay rock in the form of laminar flow.
5) The maximum velocity of groundwater flow in the impermeabel layer is 26×10^{-5} cm / sec.

Based on the hydrogeological characteristics of the location of work, the potential for groundwater contamination at the location of the work resulting from the activity of smelter waste disposal is difficult to occur because of impermeabel layer close to the soil surface with a very small permeability value that less than 9.4×10^{-5} cm / s with ground water flow laminer and close to the soil surface that is less than 4 m so that some of the liquid waste will flow along the surface stream.