The Mapping of Contamination Potential Surrounding Bakung Landfill Based on Geological Studies

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Abstract
This study examines the contamination radius that caused by Bakung Landfills and the impact to the surrounding community. The study was carried out based on geological and hydrogeological surveys. Regional geological conditions of this area identified as volcanoclastic rocks. Volcanoclastic rocks are interpreted as the aquifers in this area. This has rock has able to moderately pass the water. It means the leachate from the surface will infiltrate to the subsurface and might cause the contamination of the groundwater system of the study area. The hydrogeological study was carried out by measuring the depth of the bore wells around the study area to identify the groundwater flow in the unconfined aquifer of this area. Hydrogeology study of this areas also gives the information regarding the groundwater levels, which is ranging from 19-66 m below mean sea level. In addition, the direction of groundwater flow from the Northwest direction towards the South-Southeast. This indicates the South - Southeast region will be affected worse than the Northwest region.

Keywords: Bakung landfill, leachate, groundwater, contamination potential

1. Introduction
Industrial development and population growth could have a negative impact to the environment. One of the environmental damage is caused by the high number of waste material (garbage) that produced every day. This also occurred in the city of Bandarlampung as the capital of Lampung Province. The final waste of Bandarlampung resident is entirely disposed on the Bakung Landfill (TPA Bakung). The location of the Bakung Landfill is located on the hills (highland) with an open disposal system (Figure 1).
Groundwater contamination around the Bakung landfill is caused by leachate from the Bakung landfill which infiltrate from the surface. Leachate is a liquid from waste that contain dissolved and suspended elements [1] such as metals and harmful substances such as Hg, H2S and others [2]. Based on data from Bappeda of Bandarlampung city in 2012, the TDS value at the sampling point in the Bakung Landfill IPAL showed a value of 3327.5 mg/l while the standard value was 50 mg/l. The COD value from test results is 422.5 mg/l, while the standard value is 100 mg/l [3].

This research was carried out by using geological and hydrogeological methods to see the potential leachate distribution which might contaminate the groundwater in unconfined aquifers. The geological survey was carried out to see the type of rock in the study area. The hydrogeological method is carried out by measuring the groundwater level which obtained from the dag wells of residents around the Bakung Landfill for mapping purposes.

2. Methodology
To obtain a desired result, the methodology for this research are including field survey and data interpretation. The purpose of conducting the field survey is to gather geological information, groundwater elevation, and to observe the environment surrounding the study area. By the combination of these information, it will use to interpret the flowing direction of groundwater. In addition, field observation was used to understand physical properties of surface water and groundwater. This will help to see the qualitative impact of the contamination that produced by this landfill. The physical parameters that have been observed are smell and color. Determination of sampling points on particular dag well is based on several factors, including the location of the dag well which is located at the downstream from Bakung Landfill area. In addition, the factor of determining the sample point is also based on the availability of dag wells that can be sampled. Sampling is limited to conventional dag wells because most of the wells that owned by the local residents are a drill well type where the pump has been installed and the well are covered by ceramics or safety cage so the sampling is not possible. The collected data is summarized in the form of a map to make it easier to see the overall picture of the research that has been conducted. This map will be used to make an interpretation so the final conclusions of conducted research can be made.

3. Result and Discussion
3.1 Geology
Based on the geological map from the Tanjungkarang Quadrangle, the study area is located on the Tarahan Formation [4]. The age of Tarahan formation is Paleocene until early Oligocene dominated by Tuff and Breccia with tuffite lenses. Based on the literature studies, Tuff in this formation has purple and
light green color. It also has a fracture structure. In addition, Tuff from Tarahan Formation has breccia with a brownish-yellowish gray color that has andesite lava, claystone and siltstone as clasts. Moreover it also can be found very fine, solid and well-coated white Tufit with a thickness of 5-20 cm [4]. Geological Map of study area can be seen in (Figure 2).

Based on a field survey that was conducted around the Bakung Landfill area, the rock found was also accordance with the Regional Geology of the study area. In the Southeastern part of the study area, rock outcrop was founded and believed to be the Tuff units from Tarahan Formation. The Tuff in this region has a characteristic of green color with a narrow set of fracture. This Tuff is believed to be the major rock in the study area and becomes a groundwater aquifer in this region. This rock outcrop can be seen in (Figure 3). In the Northern part of the landfill, the rocks found with slightly different in characteristics compare to previous outcrop. The rock outcrops in Northern part look lighter in color with more dominant quartz minerals. Besides that, the rock did not look solid compare to the outcrops that was found in the Southeastern part. This outcrop is shown in (Figure 4).

These two founded rocks have a potential to become aquifers in the study area. Tuff has moderate permeability, rather difficult to pass the water, but has fracture as a way out of water [5]. Based on field observations, the soil above the surface also has moderate granules so it is interpreted as not very capable material to pass the water. The ability of this rock to pass the water can be seen indirectly from the level of groundwater contamination in the study area. Leachate from the surface can seep through the pores of the soil through two sequential processes, called infiltration (movement of water from the top into the soil surface) and percolation, which is the movement of water down from the unsaturated zone into a water-saturated zone [6].

3.2 Hydrology dan Hydrogeology
In the Bakung Landfill area there are a number of tributaries. Several tributaries that has been found is located on the Northeast side of the Bakung Landfill. Based on field observations, waste was found at several points around the tributaries environment. Based on physical observation, surface water from the river has black in color and has a very unpleasant smell which is the result of a direct interaction between leachate and surface water. This tributaries flow to the larger river which has the same physical characteristics as a tributary, The condition of the river that is located around this landfill area can be seen in (Figure 5) and (Figure 6).

A total of 12 dagwells were measured its groundwater elevation to determine the direction of local groundwater flow in the study area. This method was carried out to see the direction of the leachate when it affects the hydrogeology system of this region. A total of 11 wells are owned by local residents which are used for a daily routine. While 1 well is a well that is no longer used. This well is closest to the research area and is believed used to be as a monitoring well for the Bakung Landfill itself. The data of 12 dug wells that have been collected can be seen in Table 1
Fig. 2. Regional geological map of Bandarlampung and its surrounding.
Fig. 3. Tuff outcrop which is located at Southeast part of Bakung Landfill area.

Fig. 4. Tuff outcrop that is located at the Northern part of study area.
Fig. 5. Tributaries channel with has characteristic black in color.

Fig. 6. Tributaries channel that pass through the waste from Bakung Landfill.

Table 1
The 12th dag well around Bakung landfill.

| No | Point Name | Elevation (m) | Hydraulic Head (m) | Description                                    |
|----|------------|---------------|--------------------|------------------------------------------------|
| 1  | T1         | 33            | 32,36              | Light brown color                               |
|    |            |               |                    | no smell                                        |
| 3  | T3         | 20            | 19,48              | Yellow in color                                 |
|    |            |               |                    | no smell                                        |
| 4  | T4         | 17            | 14,82              | Yellow in color                                 |
|    |            |               |                    | The water becomes yellow in color when dry      |
|    |            |               |                    | season                                          |
|    |            |               |                    | smell fishy                                     |
| 5  | T5         | 17            | 14,38              | No color                                        |
|    |            |               |                    | No smell                                        |
| 6  | T6         | 17            | 15,92              | No color                                        |
|    |            |               |                    | No smell                                        |
| 7  | T7         | 21            | 20,38              | Cloudy yellow in color                          |
|    |            |               |                    | smelled of mud                                  |
| 8  | T8         | 24            | 21,47              | Translucent color                               |
|    |            |               |                    | smell when rain or flood happen                 |
| 9  | T9         | 37            | 31,3               | Translucent in color                            |
|    |            |               |                    | No smell                                        |
| 10 | T10        | 42            | 38,16              | Clear color                                     |
|    |            |               |                    | when dry season occur, the water become         |
Based on physical observation of the water along with the information from local residents, generally the dag well has no significant smell. Only some location of dag well has significant smell that only occur during dry season. This situation occur due to the evaporation during dry season so the concentration of particular substance also increasing. This evaporation also leads to the evaporation of smell so the smell will increasing significantly.

Bakung Landfill is a highland area which becomes a local recharge area for the surrounding area. It makes the leachate that has been produced flows to the lower region. These 12 dag well are located from the East to Southwest of the Bakung Landfill area. The distribution of the dag wells can be seen in (Figure 7). The value of the hydraulic head has a range between 14-38 m. High hydraulic head values tend to be in the area that are closer to the Bakung Landfill. This hydraulic head value has a tendency to be smaller towards the Southeast, South, and West. In the northern part of the Bakung landfill area, the hydraulic head cannot be measured because the northern part of the research area is a forest area so access to collect the data is not possible.

The hydraulic head values from the dag well are used to see the direction of groundwater flow in the study area. The direction of groundwater flow is shown in the form of groundwater flow maps which can be seen in (Figure 8). Generally, the groundwater flows to the South-Southeast direction. The data that has been obtained in the East and West part of the study area cannot be determined its groundwater flow direction due to the small amount of data. But generally based on the tendency of hydraulic head values, groundwater also interpreted will flows to East and West direction. Based on the interpolation of this hydraulic head data, there is a cone of depression zone in the Southern part of the landfill area. This is shown by the small value of hydraulic head concentrated at one particular point so the surrounding hydraulic head will flows to that particular area that has smaller hydraulic head. This might be caused by the natural development of aquifer geometries that has lenses shape [7]. This cone of depression zone can also occur due to the high quantities of groundwater use in high population area so the natural flow system of groundwater is disturbed by the activities of groundwater use in this region.

Groundwater and surface water (rivers) has a relation to each other because one can affect the other. The relationship of groundwater with river can be determined by the contour line of groundwater and river. If the unconfined aquifer has a gradient (hydraulic gradient), the groundwater will flow in particular direction [8]. The relationship between groundwater and river can be divided into 2 categories, that are influent and effluent condition. Influent is a condition when groundwater is filled with river water. This happens when the river elevation is higher than the groundwater level. If the opposite condition happen, it will create an effluent condition. Effluent is a condition where groundwater elevation is higher than river water elevation, so based on the principle of potential difference, water will flow from high to lower potential so that the groundwater will fills the river. The study area is an area that has dominantly occur in influent conditions based on the interpretation from the difference in contours level between river water and groundwater. Even so, river water which has higher pollution does not show a significant impact to the groundwater. This can be interpreted due to the soil layer has low ability to pass the water so that the effects from the surface water did not give significant impact.
Fig. 7. Dag well distribution measured located around Bakung Landfill.
Fig. 8. Groundwater flow direction surrounding research area.

4. Conclusion

Based on field observations and interpretation of field data that has been carried out, it can be concluded several things. Geologically, the Bakung Landfill area consists of greenish color of welded tuffs with narrow set of fractures and lighter color and looser grains of Tuffs. These two rock types are interpreted as aquifers in the study area. The soil from weathering of these two rocks also interpreted as the soil in the study area. The soil characteristics are moderately able to absorb and pass water so it will give the possibility of the leached entered the groundwater system of the study area. The evidence of this situation can be seen by the color of groundwater that is not clear and in some part the water has a smell the dry season. There is a possibility that an impermeable layer beneath the surface prevent a large amounts of leachate infiltrate the groundwater system so that only a small portion of leachate contaminate the groundwater. However the river water shows a slightly different situation. River water in this research area has a bad odor almost everywhere. The presence of waste materials in the river makes the leachate produced by the waste materials directly interacts with the river flow.

Hydrogeologically, groundwater in the study area generally flows to the South-Southeast which is towards the coast that located at the southern part of the study area. With this information, it can be concluded that the leachate that flows to aquifer system also move more dominant to the southern part of the study area.
Base on topography data of the study area, Bakung Landfill which becomes a water catchment area can deliver the water in all directions. However, the data collected is only in dominant at the southern part of the study area, so the conclusion can only be determined in the southern part of the Bakung Landfill. The presence of cone of depression zones founded in the landfill area also gives an interpretation that the possibility of groundwater contamination might concentrated in this zone so it becomes very dangerous. The presence of this zone also means that the groundwater flow in this area is disrupted due to the very large groundwater extraction activities. If contamination areas are concentrated in this zone and groundwater extraction is very large, it will cause problems for people who use groundwater in this zone for daily use.

4.1 Advanced Research

For the next research can further determine groundwater quality by analyzing chemical of the water in the study area. The aim of this analysis is to know the concentration of pollution and the extent to which groundwater and rivers are contaminated in this region. In addition, hydraulic head measurements can be focused on the North, West, and East parts of the Bakung Landfill area to see more precisely the direction of groundwater contamination by the leachate. Moreover, underground contamination zones can also be carried out by using geophysical methods of resistivity. By the combination of geological, hydrogeological, geochemical and geophysical data, it can determine the distribution and concentration of the contamination of Bakung Landfill more precisely.

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