THE INFLUENCE OF ROCK MINERALOGY ON GROUNDWATER IN THE KAMPUNGBARU FORMATION,COAL MINING AREA, ANGGANA AND SURROUNDING AREA, DISTRICT. KUTAI KARTANEGARA

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Abstract

Coal mining activities using the open pit mining system method will have impacts, both positive and negative impacts, positive impacts will cause changes in improving socio-economic life, while negative impacts will affect changes in hydrogeological conditions and environmental changes such as increasing soil/rock acidity so that it will cause water contaminated. This condition has an impact on decreasing the quality and quantity of groundwater as a source of clean water. The purpose of this study was to determine the hydrogeological conditions around the study site, and the influence of rock mineralogy as a potential source of groundwater contamination, especially in the Kampungbaru Formation. The methods used to obtain data such as; pumping test, rock mineralogy analysis (knowing the characteristics) by conducting studies; petrography, microscopic analysis of ore, XRD analysis, XRF analysis and analysis of the potential of acid mine water, while knowing the chemical characterization of water by analyzing the concentration of anion cations, and classifying water classes. Knowing the characterization of rock mineralogy and water chemistry, the level/value of potential groundwater contamination in the study area will be known. The hope of this research is to know and understand the characteristics of mineralogy of rocks and groundwater chemistry, as well as hydrogeological conditions in Kampungbaru Formation, so that groundwater contamination can be known. Specific benefits of the research, which is to explore more detail hydrogeology of the mine and surrounding areas, to understand the characteristics of rock mineralogy and the characteristics of groundwater chemistry, and to know the source of groundwater contamination of the research area. Practical benefits can provide information to the public and government about the potential of good quality groundwater around the research area and know the groundwater location of good quality. The results of hydrogeological studies, study of mineralogy characterization and groundwater chemistry will be obtained conclusion such as: 1) Characteristics of aquifer in Kampungbaru Formation included in the category of productive aquifers. 2) Mineralogy of rocks affect the chemical concentration .. 3) Kampungbaru Formation has the content of metal mineral elements and water chemical concentrations that contain many sulphide compounds as acid mine formers. Stratigraphy of the study area is included in the Kampungbaru Formation and is part of the Kutai Basin (Kutai Basin). Lithology The Kampungbaru Formation consists of a rocky outcrop with sandstone with coal insertions and sandstone units.

Keywords: Hydrogeology, characteristics of mineralogy and groundwater chemistry, contamination

1. Introduction

The research area administratively belongs to Kutailama Village, Kec. Anggana, Kab. Kutai Kartanegara. The area of the district Anggana is about 4,097 km2 and to reach the area from Samarinda, which is 40 km away, can be reached by two-wheeled or four-wheeled vehicles.
Rose and Hartono (1978), that the geological setting of the study area is part of the eastern Samarinda Anticlinorium, and stratigraphically part of the Kutai Basin, part of the Kampungbaru Formation, which is part of the wing of the anticline axis.

The study used in the research area carried out several approaches, such as the hydrogeological approach, namely by measuring the pumping test directly in the field which aims to determine the characteristics of the rock layer aquifer (Fetter, 1998), the approach with the analysis of the mineralogy characteristics of the rock with laboratory tests which includes petrographic tests, ore microscopy, XRD, XRF (geochemistry) and acid mine water potential (Sobek, et al, 1978), and a water chemical analysis approach that aims to determine water quality (Effendi, 2003), namely by knowing the concentration of anion cations and the class water.

The hydrogeological research area is estimated to have a closed aquifer, chemically the water is estimated to contain sulfide and mineral characteristics contain a lot of metal oxide minerals such as FeO_2, Al_2O_3, MgO, MnO, and easily react with sulfide compounds such as H_2SO_4, H_2S and form pyrite or hematite minerals. (Plummer and Mc. Geary, 2001). Each formation has different characteristic levels and depends on the concentration of metal elements and sulfide compounds. The purpose of this study was to determine the mineralogy characteristics of the rocks and the chemical characteristics of groundwater, so that the sources and differences in the level of contamination of groundwater from formations (Kampungbaru) in the study area can be identified.

2. Research Methods

The research method used is by way of approach

a. Hydrogeological studies, by carrying out the pumping test method are carried out for hydrogeological studies, namely by carrying out pumping tests at 5 (five) drill points (see figure 2.1 map of pumping test locations).

b. Mineralogical geochemical characterization of rocks, namely by taking an analysis approach to the characteristics of rock mineralogy with the number of samples from both formations can be seen in table 2.1, while the location of rock samples can be seen in Figure 2.2. Map of rock sampling locations.

Table 2.1. Number of rock samples by formation

SAMPLE ANALYSIS AND AMOUNT OF ROCK BASED ON ANALYSIS METHOD IN KAMPUNGBARU FORMATION		
NO	Analysis Sample	Number of Samles
1	Petrographi	5
2	Ore Microscopic	11
3	XRD	13
4	XRF	15
5	PAF/NAF	5
Number of samples		49

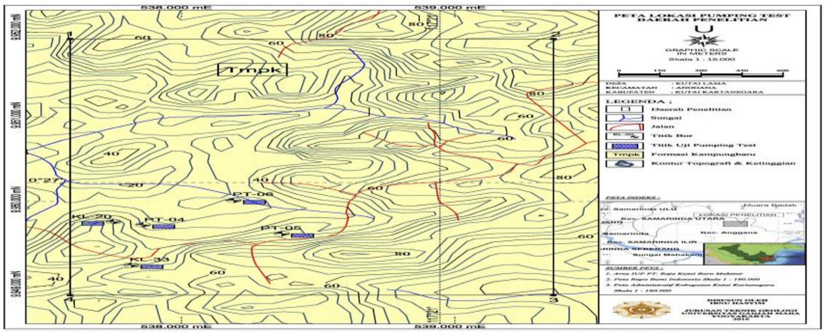


Figure 2.1. Pumping test location in the Kampungbarau Formation

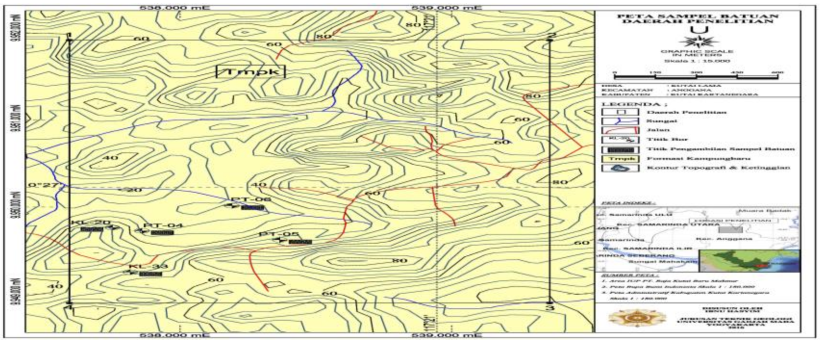


Figure 2.2. Location of rock sampling in the Kampungbaru Formation

c.Chemical characterization of water, namely by taking an analysis approach to the concentration of anion cations and class of water. Water samples were taken from 8 sample points and can be seen in table 2.2. and figure 2.3. Map of water sampling locations as shown below:

Table.2.2. Number of water chemical analysis samples

NUMBER OF WATER CHEMICAL ANALYSIS SAMPLES IN KAMPUNGBARU FORMATION		
NO	Samle Location	Number of Samples
1	Surface Water	4
2	Subsurface Water (Drilling)	4
	Number of Sanples	8

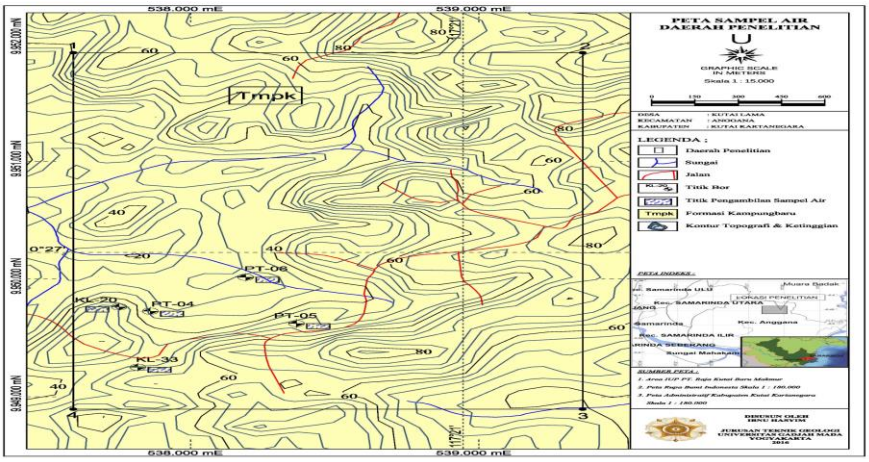


Figure 2.3. Sample Location Map

2.1. Hydrogeology

The single well pumping test analysis method uses the Cooper Jacob formula approach. The analytical method used to obtain hydraulic conductivity (K, m sec-1), and rock transmissivity (T, sec-1). Meanwhile, the slug test method was used to obtain rock hydraulic conductivity data (K, m sec-1) correlated with the results of single/multiple-well pumping tests. Data from the slug test results were then analyzed (mathematical calculations) using the Cooper-Bredehoeft-Papadopulos and Hvorslev methods (Fetter, 1988).

2.2. Rock Mineralogy

2.2.1. Mineralogy Characteristics

- Petrographic Analysis

Petrographic analysis is a thin section analysis of rock samples. Observation of the incision on a microscope with parallel and cross nikol observations.

- Microscopic Analysis of Ore

Ore mineral analysis aims to identify the optical properties of ore minerals and distinguish between transparent and ore minerals.

- *X-ray Diffraction* (XRD) Analysis

X-ray Diffraction (XRD) is a method used to determine the atomic and molecular structure of crystals, in which crystal atoms cause an X-ray beam to bend in many specific directions. From this electron density the average position of the atoms in the crystal can be determined, as well as the mineral's chemical bonds. The XRD test is used to analyze secondary minerals, especially minerals derived from weathering of primary minerals in weight percent using the bulk and fine fraction methods (clay fraction).

2.2.2. Rock Geochemistry

The method used by X-ray fluorescence (XRF) analysis is the characteristic "secondary" (or fluorescent) emission of high-energy X-rays or gamma rays, used for elemental analysis and chemical analysis, especially in metal geochemical investigations.

2.2.3. Potential of Acid Mine Water

NAPP method static test at the Coal and AAT Laboratories. NAPP analysis results include: % TS (Total Sulfur), MPA (Maximum Potential Acidity), ANC, and NAG pH.

2.3.Chemical characterization of ground-water

2.2.1.Water Chemistry Analysis (cation-anion)

Chemical analysis of water to obtain the concentrations of cations (Ca^{2+}, Mg^{2+} dan K^+ + Na^+) and anions (Cl^{-1}, SO_4^{-2} dan HCO_3^-), using the parameters as listed in the table below:

Table 2.4 Parameters for the determination of the Main Anion Cation of water.

PARAMETER	METHOD
Ca^{2+}	AAS
Mg^{2+}	AAS
Na^+	AAS
K^+	AAS
SO_4^{2-}	Spektofotometri/SNI 06-6989.20-2004
Cl^-	Argentometri/SNI 6989.19-2009
HCO_3^-	Titrasi
Fe	AAS/SNI 6989.4-2009
Mn	AAS/SNI 6989.5-2009

2.2.2 Saturation Index Calculation

Calculation of the saturation index (SI) with the Oddo and Thomson methods, namely by using the formula:

$$SI = \log([Ca^{2+}].[CO^{2-}]) - \log K_{sp}$$

Or the ratio of the solubility yield constant (Ksp) of rock minerals to the ion activity product constant (KIAP). The Ksp constant is sourced from the data base of the WATEQ4F program (Ball & Nordstrom, 1991).

2.2.3. Water Class/Water Type Analysis

This analysis aims to determine the type of water or water genetics. The type of water is useful for knowing the rocks that affect the quality differences that can cause AAT as groundwater contaminants. Classification of water types refers to the Kurlov method (Fetter, 1988; Houslow, 1995).

3.Results and Discussion

3.1. Geology, Hydrology dan Hydrogeology

3.1.1. Geology

Lobeck (1939), in the formation of landscapes and morphology is controlled by several factors, including exogenous (destructive), endogenous (constructive) forces, and geological structures such as tectonics which cause folding of rock layers, faults or faults in weak zones.
For a general description can be seen in Figure 3.1. Geological processes that have occurred over a long period of time until now or until research observations are made.

According to Supriatna et al (1995), the stratigraphy of the Kutai Basin from oldest to youngest starts from: (1) Pamaluan Formation (Early Miocene-Lower Miocene); (2) Balang Island Formation (Middle Miocene-Late Miocene); and (3) the Balikpapan Formation (Middle-Late Miocene). From the results of the researchers' observations, that the research area entered into the Kampungbaru Formations, where consists of sandstone units, and siltstone alternating with clay silt with sandstone inserts and coal. The geological structure that develops in the study area is in the form of an anticline, which is heavily influenced by the physiography of the Samarinda Anticlinorium, where this anticline has a relatively northeast-southwest direction with an N direction of 35^0 - 55^0 N, and with a dip direction relative to the southeast, which ranges from between20^0 - 50^0.

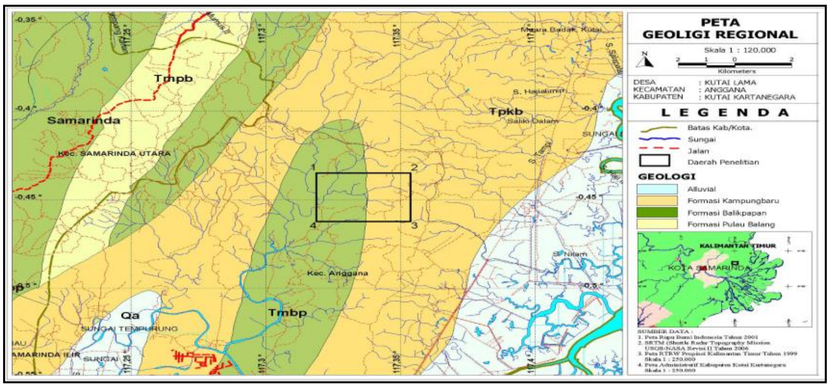


Figure 3.1. Regional Geological Map

Figure 3.1. Shows a regional geological map, the study area is included in Balikpapan Formation and Kampungbaru Formation.

3.1.2. Hydrology

Several factors influence the role of the continuity of the hydrological cycle, such as geology, morphology, land use conditions and climate. Hydrological conditions have an important and decisive role in the process of calculating groundwater recharge in terms of the quantity and capacity of groundwater and surface water (surface water discharge). Surface water capacity is strongly influenced by the characteristics of watershed conditions, land use, catchment area and local rainfall.

From these hydrological factors, the calculated values for the study area are obtained as shown in Table 3.1.

Table 3.1. Calculation of the hydraulic characteristics of the study area.

DATA	UNIT	VALUE	LOCATION
Hydraulic conductivity	m det^{-1}	1,98×10^{-2}	Upper Aquifer
		8,19×10^{-4}	Bottom Aquifer
Boundary Conditions (*boundary*)			
- *Constant head*	m	160–170	Groundwater separator boundary
- *River, stream*	m	40–65	River network
		30–40	Mahakam River
- Groundwater recharge	mm th^{-1}	562,13	
- Rock Porosity	%	10–65	

3.1.3. Hydrogeology

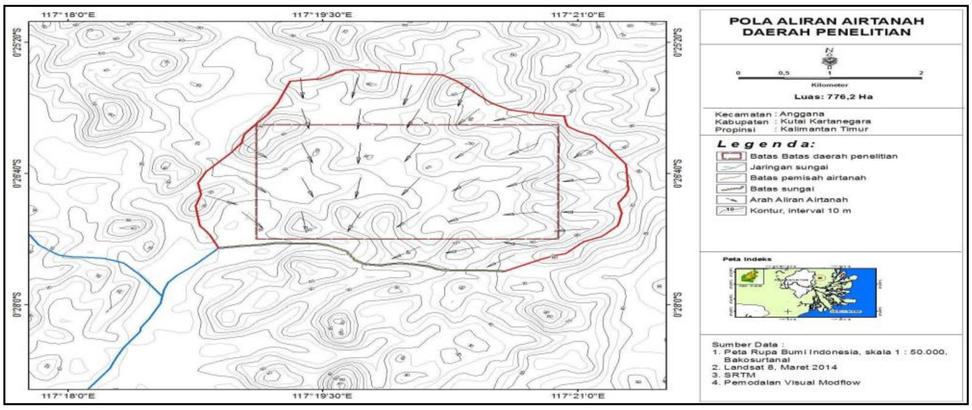
The hydrogeological conditions are strongly influenced by the rock lithology of the study area, such as the characteristics of the aquifer rock layers and the availability of water sources. Based on the classification of Mandel and Shiftan (1981), and by Irawan and Puradimadja (2013), adapted to Indonesia's geomorphological and geological typology, the study area is included in the typology of folded sedimentary rock aquifer systems. Folded sediments are sedimentary layers that are influenced by folding structures, such as the anticline structure in the study area which stretches in a relatively southwest-northeast direction. Based on the division of lithostratigraphic and stratigraphic units, the hydrostratigraphic unit in the study area is part of the Hydrogeological Unit of the Folded Sedimentary Rock Aquifer System

The results of the pumping test measurements obtained the hydraulic conductivity results as shown in Table 3.2.

Table 3.2. Hydraulic conductivity from Pumping test results

HYDRAULIC CONDUCTIVITY IN THE KAMPUNGBARU FORMATION				
NO	**Dominant Lithology**	**Aquifer type**	**K* (m det^{-1})**	**Rock Unit**
1	Sandstone	Upper Aqiufer (AK-1)	1,98×10^{-2} – 2,49×10^{-3}	Claystone and sandstone
2	Sandy Loam	Upper Aquifer (AT-1)	8,49×10^{-4} – 8,16×10^{-5}	

From the measurement results of the pumping test it is known that, from these calculations it can be concluded, that the type of upper aquitar layer (AT-1) is included in the unproductive aquifer category with a permeability value between 8,49 × 10^{-4} – 8,16 × 10^{-5} m sec^{-1}. Meanwhile, data for the characteristics of the upper aquifer layer (AK-^{1}) with aquifer permeability values between 1,98 × 10^{-2} – 2,49 × 10^{-3} m sec^{-1}, the AK-1 aquifer is a productive aquifer and This is part of the Kampungbaru formation which is a very productive aquifer.



Gambar 3.2. Groundwater flow patterns

Figure 3.2. Map of groundwater flow patterns is the result of a study of analytical and numerical calculations that are formulated to mimic the natural conditions of the research area or the original conditions of the field. Factors that affect the flow of groundwater, both caused by natural conditions, such as: recharge area, discharge, rainfall, evapotranspiration, water flow patterns (surface and groundwater), and due to activities that can change natural conditions caused by mining with mining methods open pits.

3.2. Characteristics of Rock Mineralogy

3.2.1.Petrographic Analysis

The results of the petrographic analysis of the rock samples obtained the composition of the mineral constituents of the rock and the physical properties of the rock. The physical properties of the rock include grain size, degree of rounding, degree of sorting, and packing. In the analysis of thin sections of siliciclastic sedimentary rock planting based on Gilbert's classification (1982) and carbonate with Dunham's classification (1962). The results of the petrographic analysis can be seen in Table 3.3 below.

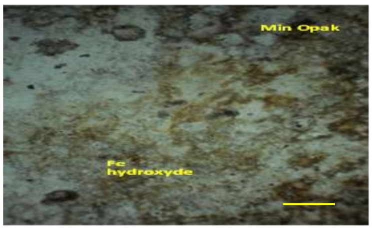
Table 3.3. The mineral content of the side rocks in the Kampungbaru Formation

MINERALOGY OF SIDE ROCKS FROM PETROGRAPHIC ANALYSIS OF KAMPUNGBARU FORMATION		
Rock Name	Mineral Content	Dominant Minerals
Soil (Weathering of Rocks)	Clay (75%), Quartz (5%), Opaque Minerals (5%), Feldspar (5%)	Clay (75%)
Claystone	Clay (80%), Quartz (5%), Opaque Minerals (10%), Feldspar (5%)	Clay (80%)
Sandy claystone	Lempung (55%), Kuarsa (30%), Min.Opak (5%), Feldspar (10%)	Clay (55%)
Sandstone	Quartz (80%), Opaque minerals (10%), Feldspar (10%)	Quartz (80%)

Tabel 3.4. Coal mineral content in Kampungbaru Formation.

MINERALOGY OF SIDE ROCKS FROM PETROGRAPHIC ANALYSIS OF KAMPUNGBARU FORMATION		
Rock Name	Mineral Conten	Dominant Minerals
Coal	Carbon	Carbons (100%)

Table 3.3. Quartz minerals are found in all side rock lithologies in the Kampungbaru Formation. Opaque minerals (metals) are scattered in the Kampungbaru Formation (more composition), and this identifies the Kampungbaru Formation as having a relatively high level of rock acidity. Table 3.4. Carbon minerals dominate coal in the Kampungbaru Formation.



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Kampungbaru Formation

Figure 3.3 Shows opaque minerals in side rocks.

3.2.1. Microscopic Analysis of Ore

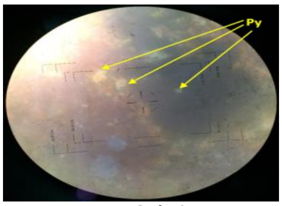
The results of the microscopic analysis of the ore are as shown in Table 3.8 below:

a. Side Rocks

Tabel 3.5. Mineral content of ore in Kampungbaru Formation.

MINERAL ANALYSIS OF SIDE ROCK ORES OF KAMPUNGBARU FORMATION			
No	Kode Sampel	Rocks	Ore minerals
1	IH-PT-04.2	Claystone	Hematite
2	IH-PT-05	Sandstone	Pyrite
3	KL-06	Clay sandstone	Hematite
4	KL-08.5	Fine sandstone	Pyrite
5	KL-09	Claystone	Pyrite
6	KL-26.2	Fine sandstone	Pyrite
7	KL-33	Clay stone	Not found

Table 3.5. Nearly all ore minerals were found from all types of side rocks of the Kampungbaru Formation, and this indicates that almost all of the side rocks have the potential to form acid mine drainage. Judging from the percentage of metal mineral content in the Kampungbaru Formation, it is relatively larger (more acidic).



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Kampungbaru Formation

Figure 3.5. Shows metallic minerals in side rocks

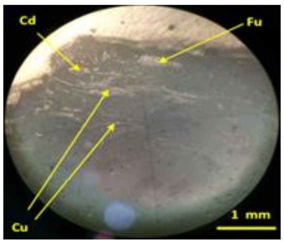
b. Coal

Tabel 3.6. Coal mineral content in Kampungbaru Formation.

ANALYSIS OF COAL ORE MINERAL IN

KAMPUNGBARU FORMATION		
No	Sample Code	Observation of Ore Minerals
1	IH-PT-04	Hematite & Pyrite
2	IH-PT-05	Pyrite
3	KL-09	Pyrite
4	KL-26	Not found ore

Table 3.6. The content of metal minerals/coal ore in the Kampungbaru Formation is more, meaning it has the potential to form acid mine drainage



Kampungbaru Formation

Figure 3.6. Shows metallic minerals in coal.

With a more abundant ore mineral composition in Kampungbaru F., it identifies a higher level of rock acidity.

3.2.2. Analysis XRD

The results of the XRD defraction analysis (Cu-Kα radiation), that the minerals found in the study area by analysis of the angle of defraction (2Θ) and millier index, the minerals composing the rock and their intensity value Å are obtained as shown in Table 3.6 below:

Table 3.6. Coal mineral content in Kampungbaru Formation

ANALYSIS OF X-RAY DIFFRACTION (XRD) IN KAMPUNGBARU FORMATION		
Rock Name	Minerals	Dominant Minerals
Soil (Tanah)	Quartz, Nacrite	Nacrite
Claystone	Quartz, Kaolinite, Montmorillonite, Muscovite, Illite, Bernessite, Dickrite	Kaolinite & Muskovite
Sandy claystone	Quartz, Kaolinite, Illite	Illite
Sandstone	Quartz, Greenalite	Quartz
Fine sandstone	Quartz, Greenalite	Greenalite

3.2.3. Rock Geochemistry

The results of the X Ray Fluorescence (XRF) analysis obtained the chemical composition as

Table 3.7. Coal mineral content in Kampungbaru Formation

ANALYSIS OF X-RAY FLUORESCENCE (XRF) IN THE KAMPUNGBARU FORMATION		
Chemical Composition	Percentage (%)	Dominant in lithology
SiO_2	58.030 - 91,470	Sandstone
TiO_2	0,565 & 0,575	Sandstone & fine sandstone

Al_2O_3	15,750 & 15,970	Claystone & fine sandstone
Fe_2O_3	3,640 & 2,540	Soil (weathered claystone) & fine sandstone
MnO	0,017 & 0,011	Claystone & Coal
CaO	0,649 & 0,047	Soil (weathering) & Coal
MgO	0,894 & 1,110	Claystone/Fne sanstone
Na_2O	0,084 & 1,310	Sandy Clay & Soil
K_2O	1,190 & 1,650	Claystone/sandstone
P2O5	0,023& 0,035	Claystone/Sandy clay
S	0,120 & 0,260	Coal & Claystone
CuO	0,004	Claystone
SO_3	4,655	Soil
Cl	0,004	Fine sandstone
LOI	24,855 & 40,307	Coal & Claystone

Table 3.7. The SiO_2content dominates the Kampungbaru F. sandstones, the Fe_2O_3 content compositionally in the Kampungbaru F. sandstones in soil and fine sandstones. The content of S (sulfur) is found in claystone and coal. The content of SO_3 is found in sandstone. The content of Fe, SO_3 and S are elements that have the potential to form acid mine drainage.

3.2.4. Potential of Acid Mine Water

The acidity level of the rock is based on an analysis of the potential for acid mine drainage on the side rock, namely by carrying out the NAF and PAF static tests as shown in table 3.8 below:
Tabel 3.8. Coal mineral content in F. Balikpapan and Kampungbaru Formation.

ANALISIS POTENSI AIR ASAM TAMBANG FORMASI KAMPUNGBARU				
No	Drill Point	Lithology	NAPP (MPA-ANC)	pH (NAG)
1	DH-PT-O4	Soil	1,1	4,47
		Clay	-4	3,56
		Sandstone	0,2	3,87
2	DH-PT-O5	Hard Sandstone	1,1	3,81
		Sandy Claystone	3,6	2,89
3	DH-PT-O6	Hard Sandstone	0,8	3,63
		Sandy Claystone	2	3,04

Table 3.8. The acidity potential of F. Kampungbaru is relatively high, this can be seen from the comparison between the NAG pH in F. Kampungbaru which has a relatively lower value.

3.3. Water Chemical Characteristics
3.3.1. Cation-Anion Concentration

The average concentration of water main ions (cations and anions) from water samples taken from the two formations is as follows:

Table 3.9. Water chemical concentration in Kampungbaru Formation

AVERAGE WATER CHEMISTRY CONCENTRATION IN THE KAMPUNGBARU FORMATION

No	Parameter	Unit	River water	Pit water	Drill water
Physics					
1	Temperature	ºC	29.10	31.77	28.30
2	TDS	mg L^{-1}	7.00	237.10	35.75
Chemistry					
3	pH		5.31	3.69	5.78
Main cation*					
4	Ca^{2+}	meq L^{-1}	0.064	1.076	0.198
5	Mg^{2+}	meq L^{-1}	0.031	9.197	0.241
6	(K+ Na)		0.058	0.135	0.135
7	Mn^{2+}	meq L^{-1}	0.001	0.623	0.006
8	Al^{3+}	meq L^{-1}		10.923	0.142
9	Fe	meq L^{-1}	0.010	6.163	0.188
Main anion*					
10	Cl^{-1}	meq L^{-1}	0.036	0.177	0.049
11	SO_4^{2-}	meq L^{-1}	0.340	423.223	8.628
12	HCO_3^-	meq L^{-1}	12.000	84.400	23.350

Table 3.9. The pH value (surface and subsurface water) of the Kampungbaru Formation has a relatively low value, while the content of Fe, $Mn^{2+,}$ Mg^{2+} and SO_4^{2-} has a relatively large concentration value and this indicates F. Kampungbaru has a high acidity level value

3.3.2. Saturation Index

Based on the ratio of the solubility yield constant (Ksp) of rock minerals to the ion activity product constant (KIAP). The Ksp constant is sourced from the data base of the WATEQ4F program (Ball & Nordstrom, 1991). Calculation of the degree of saturation index (SI) of water for various minerals, which is based on the concentration of solution ions (water samples), in the study area using the PHREEQC program (Appelo & Parkhurst, 2011), a comparison is obtained as shown in the following table

Tabel 3.10. SI relationship to TDS in KampungbaruFormation.

THE RELATIONSHIP BETWEEN THE SATURATION INDEX (SI) AND THE KAMPUNGBARU FORMATION TDS			
No	Sample	Minerals	Remarks
1	River Water, Pit Water & Drill Water	Al(OH)3	The higher the TDS value, the higher the SI value
2		Anhydrite	The higher the TDS value, the higher the SI value
3		Aragonite	The higher the TDS value, the higher the SI value
4		Calcite	The higher the TDS value, the lower the SI value
5		Chalcedony	The higher the TDS value, the higher the SI value
6		Dolomite	The higher the TDS value, the lower the SI value
7		Greenalite	The higher the TDS value, the lower the SI value
8		Gypsum	The higher the TDS value, the higher the SI value
9		Fe(OH)2	The higher the TDS value, the lower the SI value
10		Kaolinite	The higher the TDS value, the higher the SI value

11		Magnesite	The higher the TDS value, the lower the SI value
12		Quartz	The higher the TDS value, the higher the SI value

The Kampungbaru Formation has a relationship between TDS and SI of mineral elements; $Al(OH)_3$, calcite, calcedone, dolomite, $Fe(OH)_2$, grenaliete and magnesite have a downward (negative) trend, while those with an upward (positive) trend for mineral elements; anhydrite, aragonite, gypsum, halite and kaolinite.

Tabel 3.11. SI relationship to pH in F. Balikpapan and Kampungbaru Formation.

THE RELATIONSHIP BETWEEN THE SATURATION INDEX (SI) AND THE KAMPUNGBARU FORMATION pH			
No	**Sample**	**Minerals**	**Remaks**
1	River Water, Pit Water & Drill Water	$Al(OH)_3$	The higher the pH value, the higher the SI value
2		Anhydrite	Semakin tinggi nilai pH, nilai SI semakin rendah
3		Aragonite	The higher the pH value, the higher the SI value
4		Calcite	The higher the pH value, the higher the SI value
5		Chalcedony	The higher the pH value, the lower the SI value
6		Dolomite	The higher the pH value, the higher the SI value
7		Greenalite	The higher the pH value, the higher the SI value
8		Gypsum	The higher the pH value, the lower the SI value
9		$Fe(OH)_2$	The higher the pH value, the higher the SI value
10		Kaolinite	The higher the pH value, the higher the SI value
11		Magnesite	The higher the pH value, the higher the SI value
12		Quartz	The higher the pH value, the lower the SI value

The Kampungbaru Formation has a relationship between pH and SI of mineral elements; anhydrite, calcedone, gypsum, halite and quartz have a downward (negative) trend, while those with an upward (positive) trend for mineral elements; $Al(OH)_3$, aragonite, calcite, dolomite, grenalite, kaolinite and magnesite.

3.3.3. Water Class

Based on the classification of water types referring to the Kurlov method (Fetter, 1988; Houslow, 1995), which can be seen in Table 3.12

Tabel 3.12. Water chemical concentration in Kampungbaru Formation

RESULTS OF KAMPUNGBARU FORMATION WATER CLASS ANALYSIS	
Water sources	**Water type/class**
River Water 4	Kalium-Alkali-Bikarbonat
Upper Active Pit Water	Magnesium - Sulfat
Central Active Pit Water	Magnesium - Sulfat
Bottom Active Pit Water	Magnesium - Sulfat

Drill Water 1H-PT-04	Kalium-Magnesium-carbonat
Drill Water 1H-PT-05	Kalium-Alkali-Bikarbonat
Dreill water 1H-PT-06	Kalium-Alkali-Bikarbonat
Drill water 1H-KL-33	Magnesium - Alkali - Bikarbonat

Table 3.10. Water type/class F. Kampungbaru for groundwater belongs to the Potassium-magnesium-carbonate, Potassium-alkali-bicarbonate, and Magnesium-alkali-bicarbonate (strong acid) water classes. Surface water (river water) F. Kampungbaru is included in the Potassium-alkali-bicarbonate (weakly acidic) water type. The Kampungbaru Formation mine pit water is classified as magnesium sulfate (strong acid) water.

4. Conclusion

1. The study area is a confined and semi-confined aquifer with a general pattern of groundwater flow in a north to south direction.
2. The results of the chemical characterization of water obtained relatively low pH values (pH < 6), relatively large TDS values (average TDS > 10), relatively varied concentrations of Fe $^{2+}$, Mn $^{2+}$, Mg $^{2+}$ and SO42- anions, water class included in the acidic category moderate to strong.
3. The results of rock mineralogy analysis included petrographic analysis found opaque minerals (metals), microscopic analysis of ore found pyrite and hematite minerals, XRD analysis found illite minerals, montmorillonite containing metal elements, rock geochemical analysis (XRF) found metal oxide minerals such as FeO, MnO, MgO, and analysis of the potential for rock acidity, it was found that rock pH was relatively low with a value of 2.3 to 6.3. While the chemical analysis of water found the type and class of Calcium-Alkali-Bicarbonate to Magnesium-Sulfate, which identified the moderate to strong rock acidity level.
4. Metal minerals such as: pyrite, hematite, which dissolve/react with sulfide compounds to form acid mine drainage.
5. Rock mineralogy is a source of groundwater contamination, due to the presence of metal oxides, sulfide minerals and ore mineral content as a source of acid mine drainage.

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