Development of Catchment Area Approach in Management of Acid Mine Drainage

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Abstract Ukud River in Lati Coal Mine, East Kalimantan, is suffering with acid mine drainage (AMD) problem generated from mine pit as well as overburden disposal and characterized by maximum measured flow rate of 13.38 m^3 /s with pH value of 4.3. Its catchment covers a total area of 1738.67 Ha that consists of disturbed area (48.6%) and natural area (51.4%). The AMD was generated particularly in overburden disposal because there was no segregation between potentially acid forming material and non-acid forming material when dumping the overburden. The program was developed to improve the Ukud river quality into normal natural condition. This case encourages the development of catchment area approach in management of AMD. Ukud catchment area was studied dan its characterization was developed which included the determination of sub-catchments, water quality and flow measurement in streams, and hydrological water balance in sub-catchments and total catchment. It is expected that this approach could be integrated into the mine planning process especially when determining the out pit overburden disposal areas.

Key Words acid mine drainage, catchment area approach

Background

The important role of coal to fulfil the energy demand both domestic and overseas had lead to the significant development of coal mines in Indonesia since 1990s. Many coal mines have been developed particularly in main coal basins such as East and South Kalimantan and South & Central Sumatra. The national coal production rapidly increased from 10 million tonnes in 1990 up to 300 million tonnes in 2010.

One of important environmental issues in coal mines in Indonesia is acid mine drainage. Although lots of effort have been made by the government agencies in mining and the environment to control such issues in coal mining activities and to promote good AMD management practice, as well as the issuance of various environmental regulations (Gautama, 2009), AMD problems are still exist in many coal mines, for example low pH water in coal pit lake in South Kalimantan (Rahmawati & Gautama, 2010; Saputri & Gautama, 2010) and low pH in Ukud River impacted by AMD in Lati coal mine in East Kalimantan (Abfertiawan, 2010).

An integrated approach in managing the AMD which includes the development of geochemical overburden model, AMD prevention through encapsulation of potentially acid forming (PAF) material and active as well as passive treatment methods has been introduced. Geochemical overburden model is encouraged to be developed by geochemical characterization of overburden samples collected during exploration drilling campaign. It determines the distribution of PAF and Non-acid forming (NAF) materials in overburden. Such model is then used to develop overburden excavation and dumping strategy and planning to prevent AMD generation since selective dumping or encapsulate the PAF material with NAF rocks becomes the best practice in overburden management.

Ukud river which flows in Lati coal mine has been indicated to be impacted by past mining activity and overburden disposal. It is characterized by low pH caused by AMD generated mainly in overburden dump. This paper discussed the catchment area approach as one of the alternatives in mitigating the low pH problem of Ukud river.

Concept of Catchment area approach

A surface coal mining area generally consists of mine pits and out pit overburden dumps before space for in pit dump is available for backfill. From AMD management point of view, mine pit is the source of AMD because the exposure of potentially acid forming materials in the pit wall and pit wall could not be avoided. The acid mine water is collected in a pit sump before being pumped out of the pit into the treatment pond. Other source of AMD is overburden disposal. Although selective dumping to prevent AMD becomes standard best practice in most mining operation there is still risk of AMD generation. This risk is obvious if selective dumping is not being implemented.

The generated AMD if not being captured and treated will flow to the receiving stream and finally impact the gaining main stream. It means that the water quality in the main stream will be influenced by the water quality in the sub-catchment stream network which is characterized by mixing and/or dilution process. This is the basic concept of catchment area approach in AMD management. Through understanding the AMD potential, process and risks in every site or sub-catchment critical areas could be simulated and appropriate and cost effective measures to control the AMD could be defined.

Model development for Ukud catchment area at Lati Coal Mine

Ukud River characteristics

Lati coal mine is one of the three mine sites owned and operated by PT Berau Coal and is located in East Kalimantan. The mine is suffering from AMD problem since most of the overburden as well as interburden materials is classified as potentially acid forming. Unfortunately the past mine operation did not consider the potential of AMD generation particularly in the overburden disposal.

Ukud river is located in the southern part of Lati mine and characterized by pH of 3 to 4 due to AMD. It is flowing to the east and gaining into the Lati River. Its catchment area covers 11 sub catchments with total area of 1738.67 Ha (Figure 1) and considered as suitable area for overburden disposal from the mine pits located in the northern boundary of the catchment area. At the moment 48.6% of total area has been used for overburden disposal since late 1990s and the rest (or 51.4%) is still in natural condition. Only 48% of the disturbed area has been re-vegetated. There is plan to develop some pits as well as overburden disposal in this catchment area in the future.

Water quality of Ukud river was determined by sampling conducted in seven sampling points representing each sub-catchment for parameters: pH, SO_4, Fe^{2+}, Fe^{3+}, Mn^{2+}, Al^{3+}, total suspended solids, and conductivity. Low pH of 3.96 to 4.49 were measured in almost all points except one point (point 2) representing the undisturbed natural condition with pH of 7.01. The lowest pH was measured at point 1 in A1 sub-catchment which is an active mining area. Higher pH values were indicated in re-vegetated overburden disposal area (sub-catchment A3, A4, A5, A6, A7, A9 and A10). The result of water quality analysis for all sampling points is presented in Table 1.

The potential of AMD generation was not being considered during the overburden dumping in the late 1990s and early 2000s. At that time geochemical characterisation of overburden material to identify the potentially acid forming (PAF) material and non-acid forming (NAF) materials.

Table 1 *Water Quality in Sub-catchment of Ukud River.*

Monitoring Point	Sub catchment	Discharge m^3/s	pH	$SO_4^=$ mg/L	Fe^{2+} mg/L	Fe^{3+} mg/L	Mn^{2+} mg/L	Al^{3+} mg/L	TSS mg/L
Point 1	A1	0.37	3,96	148	16.5	8.82	4.81	18.55	3
Point 2	A2	0.21	7.01	94	0	0	0.73	0.2	3
Point 3	A3	0.08	4.49	73	0.06	0.02	5.52	8.12	141
Point 4	A6,A7	0.07	4.45	71	0	0	1.12	1.57	4
Point 5	A8	0.12	4.26	75	19.5	9.36	6.35	12.5	5600
Point 6	A10	0.11	4.17	76	9.39	5.02	4.1	7.97	6
Point 7	CP	1.05	4.23	92.8	9.05	4.62	4.07	9.67	1025

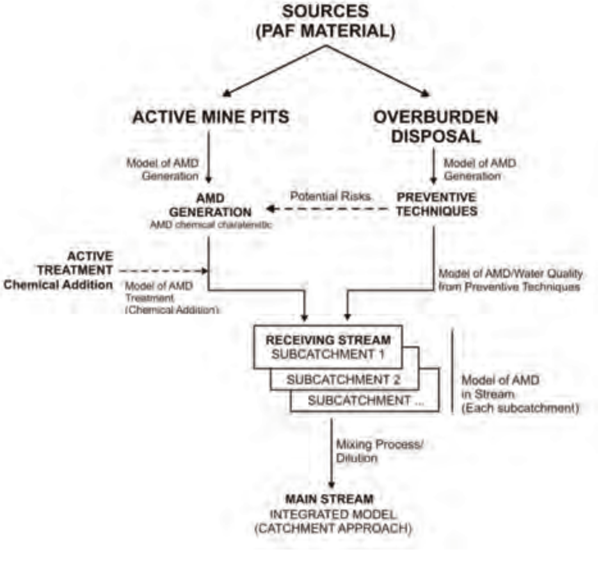

Figure 1 *Basic Concept of Catchment Area Approach.*

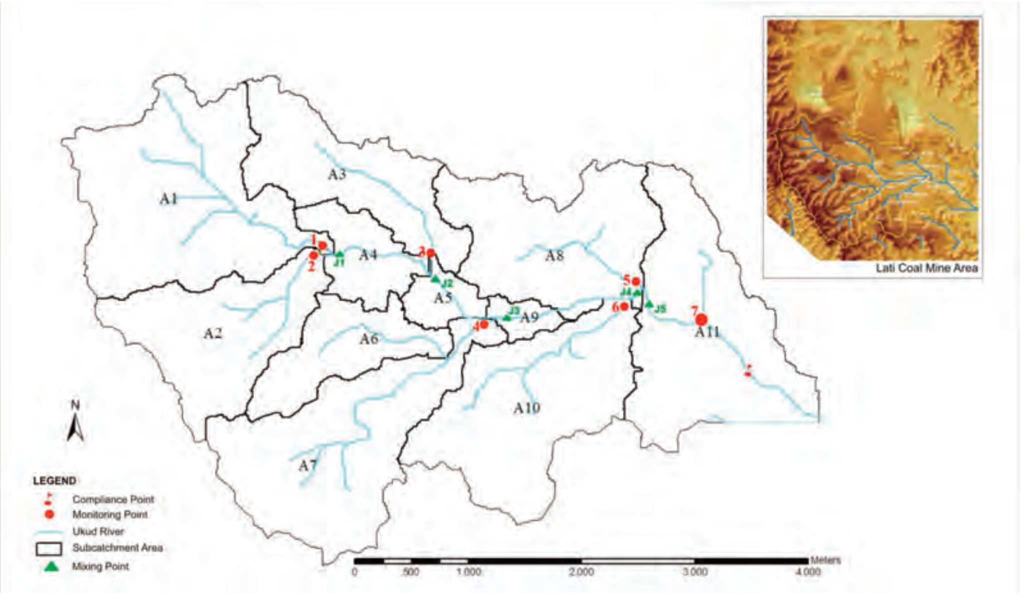

Figure 2 *Ukud River Catchment Area; showing sampling locations*

Ukud catchment characterisation started with the effort to determine the distribution of PAF and NAF material at the surface. As many as 102 rock samples were collected both in disposal area and along the stream and 90 samples were classified as potentially acid forming. Unfortunately the results indicated that there was no pattern in the distribution of rock type which indicated no segregation or stratified dumping occurred.

Determination of critical sub-catchment area

In order to identify the most cost effective methods for the recovery of Ukud river it is necessary to identify the most critical areas that gave significant influence on the water quality in the Ukud main stream. The catchment area approach was developed for this purpose. Since the Ukud catchment consists of 11 sub-catchments and series of joining streams, the water quality in the main stream is controlled by mixing and/or dilution process. Characteristics of each sub-catchments in Ukud river which includes the percentage of sub-catchment from the total catchment area, portion of disturbed, natural and re-vegetated area of each sub-catchment was shown in Figure 3.

Dilution is significant factor in controlling the ion concentration in the acid drainage (Lee & Kim, 2008).There are two approaches used in predicting the pH, namely dilution factor calculated from $SO_4^=$ and H^+ concentration. Precipitation and change in oxidation number could be neglected since the influence to the pH is insignificant. Both approaches have been verified for the case of Ukud river by comparing the calculation results and the actual pH values as shown in Table 2. It could be concluded that in this case the H^+ approach was better than the $SO_4^=$.

Simulation was conducted to identify the critical sub-catchments based on H^+ approach. Different scenarios were then simulated and the result was presented in Figure 4 which identified that sub-catchments A1, A9 and A10 were classified as critical sub-catchments in Ukud catchment area. Controlling the quality in the respective streams

Table 2 *Verification of Dilution Factor.*

Mixing Point	Discharge	Concentration (mg/L)				Dilution Factor $[SO_4^=]$		Dilution $[H^+]$	Actual
	m^3/s	$[SO_4^=]$	$[Fe^{2+}]$	$[Fe^{3+}]$	[Fe] Total	D_i	pH_i	pH_i	pH_i
J1	3.46	133,70	12,11	6,47	18,58	1,362	4,09	4,09	4,27
J2	5.47	84,63	7,91	4,35	12,26	5,216	4,81	4,17	n.d.
J3	7.44	78,69	5,81	3,2	9,01	1,772	5,06	4,22	4,24
J4	9.49	77,1	6,5	3,5	10	2,540	5,46	4,21	-
J5	11.56	76,7	8,8	4,6	13,4	1,218	5,55	4,22	4,37

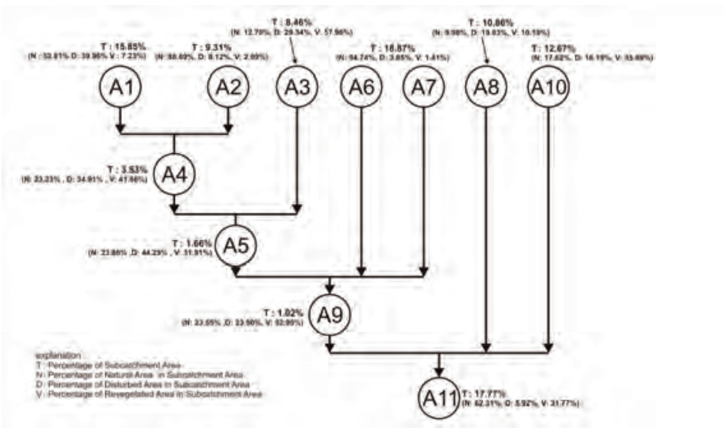

Figure 3 *Sub-catchment characterisation.*

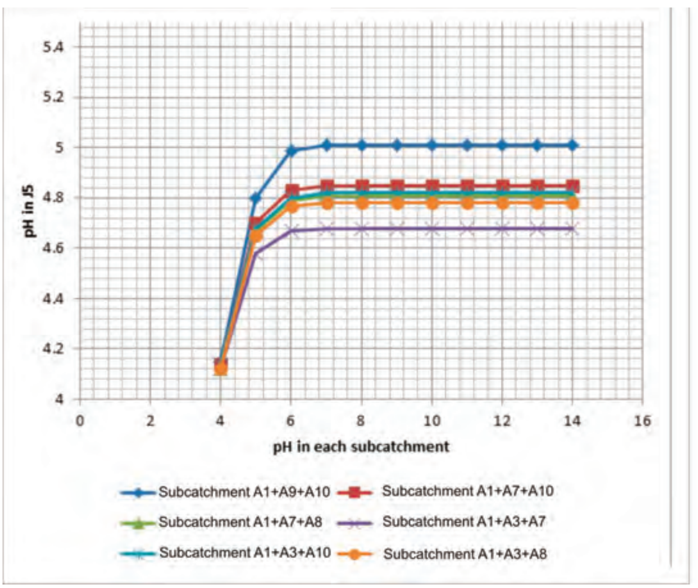

Figure 4 *Result of Simulation.*

gave significant improvement in the water quality in main stream although still below the environmental standard in term of pH. To achieve a neutral quality of Ukud river AMD mitigation efforts should be made in every sub-catchment but particularly those three critical sub-catchments.

Discussion

The case of Ukud river which is heavily impacted by AMD generation both in mine pit and in overburden disposal encourages the development of catchment area approach in AMD management. In this case this approach is used to simulate various alternatives for Ukud river quality recovery and the goal is to determine the appropriate, efficient and most effective mitigation measures. Simulation (figure 4) has shown that efforts to improve the quality of run off water should be focused in three sub-catchments, i.e. A1, A9 and A10. Sub-catchment A1 is dominated by L2 mine pit. It means that mine drainage control should consider the drainage water quality before discharging to Ukud river. Sub-catchment A9 covers overburden disposal area. Since Lati Coal Mine is deficit in NAF material the use of coal combustion ash for cover material in the overburden disposal has been studied (Gautama *et al.*, 2010). But from practical point of view it is recommended to install passive treatment facilities to control the runoff water quality in the critical sub-catchments of Ukud river.

The development of catchment area approach still continue for a more complete, integrated and robust model. Field measurements, particularly to characterize every sub-catchment as well as the whole catchment, are still ongoing. In the future it is expected to integrate the catchment area approach into the mine planning process. Besides the geological and topographical considerations in pit layout as well as overburden disposal area planning, catchment area analysis should also be important factor, not only for mine drainage design purposes but also in AMD management. This will reduce risks associated with the acid mine drainage in a coal mine especially in the post mining phase.

Conclusions

The idea to develop a catchment area approach in AMD management was triggered by the case of Ukud river which is heavily impacted by AMD generated both in mine pits and in overburden dump. This approach incorporates the catchment hydraulic characteristics with the influence on the water quality both in receiving steams and the gaining main stream. Simulation conducted for Ukud river had determined the critical sub-catchments that gave significant impact of the quality at Ukud river meaning that efforts to control the runoff water quality should be focused in those critical sub-catchments. Although the simulated pH value in the main Ukud river was still below the environmental standard, this approach has shown good result in determining the mitigation strategy for Ukud river quality recovery.

This approach seems promising to be integrated into the surface coal mine planning process. Catchment area characteristics should become an important considerations when analyzing the mine area layout and particularly in determination of out pit overburden disposal area to minimize risk of AMD generation.

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References

Abfertiawan M.S., Acid Mine Drainage Management Using Catchment Area Approach, Thesis, June 2010, Bandung (in Bahasa Indonesia)

Gautama R.S., Acid Mine Drainage in Indonesian Mines, Proceedings of Securing the Future and 8th ICARD, June 23—26, 2009, Skellefteå, Sweden

Gautama R.S., Kusuma G.J, Lestari Iin, Anggana R.P., 2009, Weathering Behaviour of Overburden-Coal Ash Blending in Relation to Overburden Management for Acid Mine Drainage Prevention in Coal Surface Mine, Proceedings Mine Water & Innovative Thinking, International Mine Water Association Symposium 2010, September 5—9, 2010, Sydney, Nova Scotia, Canada, pp. 417—420

Lee Ji-Eun & Kim Yeongkyoo, A quantitative estimation of the factors affecting pH changes using simple geochemical data from acid mine drainage, Environment Geology 55:65–75, Springer-Verlag 2008

Rahmawati, A.F. & Gautama, R.S., Back Analysis of Water Quality Forming in Pit Lakes of Coal Mine in Indonesia, Proceedings of International Symposium on Earth Science and Technology, December 7—8, 2010, Kyushu University, Fukuoka, Japan, pp. 241—246

Saputri, E.K.E. & Gautama, R.S., Prediction of Water Chemistry in Pit Lakes of Coal Mining, Indonesia, Proceedings of International Symposium on Earth Science and Technology, December 7—8, 2010, Kyushu University, Fukuoka, Japan, pp. 235—240