OVERBURDEN TREATMENT TECHNOLOGY IN ACID MINE DRAINAGE PREVENTION

ALI RAHMAT KURNIAWAN AND RETNO DAMAYANTI
R & D Centre for Mineral and Coal Technology
Jalan Jenderal Sudirman 623 Bandung 40211, Ph. (022) 6030483-5, Fax. (022) 6003373
E-mail : ali@tekmira.esdm.go.id, retnod@tekmira.esdm.go.id

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ABSTRACT

The prevention and control of acid drainage is a major issue for mine operators at sites where sulfide minerals occur. On going risk assessment of acid drainage potential and sulfidic waste management during planning, development, operation and closure of mining developments will result in substantial environmental and economic benefits. Overburden treatment technology must be identified and implemented in order to minimize the production of acid mine drainage (AMD). There are many treatment technologies for AMD prevention at surface mining such as alkaline addition and special handling. Overburden analysis (OBA) refers to determination of the acidity or alkalinity producing potential. The addition of alkaline material to surface mine backfill can be an effective method of compensating for overburden and reduce the potential for acid mine drainage. Special handling methods fall into four categories: blending, encapsulation, submergence and alkaline redistribution. Special handling is most effective in conjunction with other best management practices such as alkaline addition. Monitoring during and after mining is necessary to evaluate special handling techniques.

Keywords: overburden, acid mine drainage, alkaline addition, special handling

1. INTRODUCTION

Overburden treatment technology must be identified and implemented in order to minimize the production of AMD (Acid Mine Drainage). AMD is an acidic, iron and sulfate water that formed under natural conditions when geologic strata containing pyrite are exposed to the atmosphere or oxidizing environments. AMD can form from coal mining, both at surface and underground mine. A mine with acid mine drainage a potential for long-term devastating impacts on rivers, streams and aquatic life.

Various techniques are available to evaluate the acid and alkaline potentials of overburden material. But, there is no one technique is successful in eliminating or decreasing effects of AMD in all coal mining. Because of the inherent variability between mines and environmental conditions, no one overburden treatment technology is effective on all sites and selection of the best method on each site is difficult given the array of methods available. This paper describes alkaline addition and special handling as alternative treatment technologies to the AMD in coal mining.

2. SAMPLING AND OVERBURDEN ANALYSIS

Sampling of drilling products to determine sulfide and carbonate content should be representative, based on accepted statistical procedures, and similar to the process used to determine other geological characteristics such as ore grade and reserves. Representative profiles of all geological units should be sampled. Representative overburden sampling is used to: 1) determine overall acid or alkaline-producing potential of a proposed mine, 2) calculate alkaline addition rates, 3) determine the distribution of pyritic zones that may require

Content

special handling or avoidance 4) identify alkaline zones which can be incorporated into a mining plan to prevent acidic drainage (i.e., alkaline redistribution); and 5) determine the economic feasibility of mining without unacceptable environmental impacts.

Overburden analysis (OBA) refers to determination of the acidity or alkalinity producing potential of the rocks that will be disturbed by mining. OBA methods fall into two broad categories: static and kinetic. Static tests are "whole rock analyses" that determine the concentration of elements or minerals. Kinetic tests simulate weathering procedures that attempt to reproduce weathering. In short, static tests measure what is in the rock and kinetic tests measure what comes out of the rock (Tarantino and Shaffer, 1998).

Overburden analysis for surface mining begins with Acid Base Accounting (ABA) to determine toxic, potentially acid producing, neutral, or alkaline producing strata. The horizon thickness, volume, and chemical make up of overburden strata in each category will help determine the level of special handling and blending techniques that are required during backfilling (Perry, 1985).

Observable variations in overburden strata may include changes in horizon thickness, rock type, color, presence of carbonates or pyrite, hardness, dip and strike. As changes are encountered, interpretations must be made and alterations in the mining method or overburden handling techniques can be initiated. Native soils on sites to be mined should be described and analyzed as distinct part of the overburden column and segregated during mining when required for replacement on the backfill. The results of overburden analysis are generally used in two ways: as permitting decision making tool and as a management tool (using the information to design best management practices for avoidance or remediation of pollution).

3. METHODS OF OVERBURDEN TREATMENT

3.1. Alkaline addition

Recent studies have indicated that certain type of alkaline amendments can successfully control AMD from pyritic spoil and refuse (Brady et.al.1990, Burnett et al. 1995, Perry and Brady 1995, Rose et.al.1995, Wiram and Naumann 1995). Published studies on alkaline addition primarily examine mines in the northern Appalachian.

The use of alkaline additions can be devided into several categories, including: 1) blended with potentially acid producing material to either neutralize the acid, 2) applied as trenches to create alkaline groundwater conduits through the reclaimed mine, 3) applied on or near the surface plant growth and create an alkaline wetting front that will migrate downward through the overburden and, 4) applied as a chemical cap to create a hardpan (either on the surface of the mine). There are a number of alkaline materials that can be used or applied by various methods such as limestone and coal ash (Wiram and Naumann, 1995).

The other alkaline reagents such as; hydrated lime (calcium hydroxide), quick lime (calcium oxide), caustic soda (sodium hydroxide) and caustic magnesia (magnesium oxide). The appropriate alkaline reagent will depend on cost and availability, and the target pH of the final effluent. The popularity of using coal ash as an alkaline additive is demonstrated by the fact that it is being practiced in Colver, Pennsylvania. The alkalinity generating properties of coal ash vary depending on the type of power plant producing the ash. The ash can be 10 to 20 percent calcium carbonate equivalent. As can be seen, not all coal ash is alkaline. In fact, some ash has to have alkaline material added for proper disposal. A problem that exists with using coal ash as an alkaline additive is an activator that can make the ash into cement (Scheetz et al., 1997).

3.2. Special Handling

Special handling of overburden is the preferred AMD management practice during mine operations. Overburden characterization is important as the problematic material can be identified and appropriate waste storage facilities designed to handle the waste to minimize the potential impact on the environment. As toxic material is encountered, the primary strategy is to segregate and place this material as quickly as possible off the pit floor and away from the high wall to limit its exposure to air and water (Skousen et al., 1987). There are four methods of special handling and rely on different methods of avoiding acid production:

Content

There are four methods of special handling and rely on different methods of avoiding acid production:

a. Blending method

Blending is the mixing of rocks on a mine site to promote the generation of alkaline drainage. The term "blending" has been used widely in the past to refer to the mixing that occurs during the routine mining process. This technique has been recognized since at least the mid 1970s. Anecdotal information exists to suggest that it is an effective practice. It can be effective if sufficient carbonates are present and can maximize the contribution of carbonates by mixing them with acid-forming rock. This can inhibit oxidation of pyrite as well as neutralize acidity. In theory, it is possible to blend rocks from virtually any position in the overburden column, but the actual practice is dependent on the mining method and spoils handling equipment.

b. Alkaline redistribution

Alkaline redistribution is a special handling strategy that is used when only a portion of a mine site contains and large portions are devoid of calcareous materials. Without redistribution or off-site importation of alkaline materials (alkaline addition), the portions of the site lacking calcareous materials will produce acid mine drainage (Figure 1).

Steps in blending and alkaline materials methods :

1. conduct drilling and blasting to expose acid materials,
2. remove acid materials with a loader or dozer,
3. blend the acid the acid and alkaline materials,
4. complete the reclamation and revegetation as quick as possible.

c. Submergences method.

Submergences are placement of acid materials consistently below the water table. Submergences relies on the fact that water can contain only a small amount of dissolved oxygen (at most ~ 10 mg/L) and that water is therefore an effective barrier to atmospheric oxygen. This lack of oxygen reduces the potential for the pyrite to oxidize and produce acid mine drainage.

Watzlaff (1997) showed that complete submergence will virtually shut down pyrite oxidation, even with maximum dissolved oxygen. Submergence generally requires a relatively flat area with a thick saturated zone. A stationary water table helps to produce a near stagnant condition. This lack of oxygen reduces the potential for the pyrite to oxidize and produce acid mine drainage (Figure 2).

Steps in submergence method :

1. conduct drilling and blasting to expose acid materials,
2. remove acid materials with a loader or dozer,

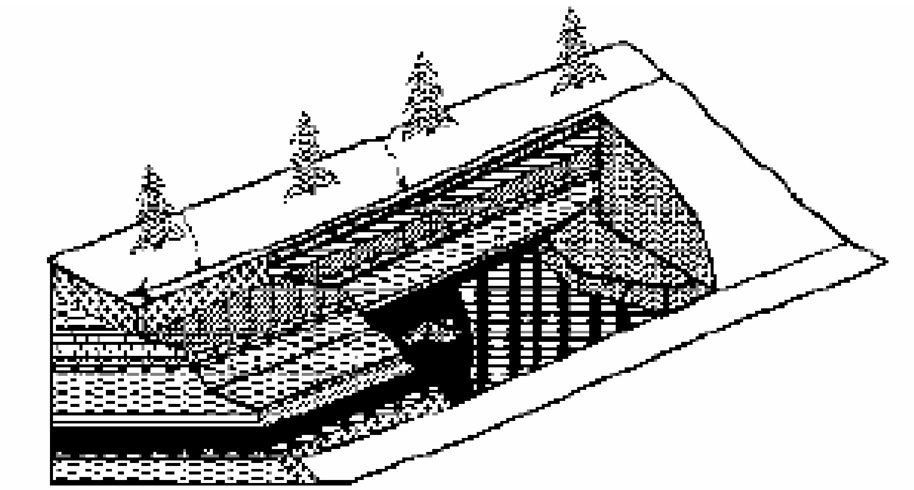

Figure 1. Blending and alkaline redistribution technique do not require the isolated pods Source : U.S EPA (2001)

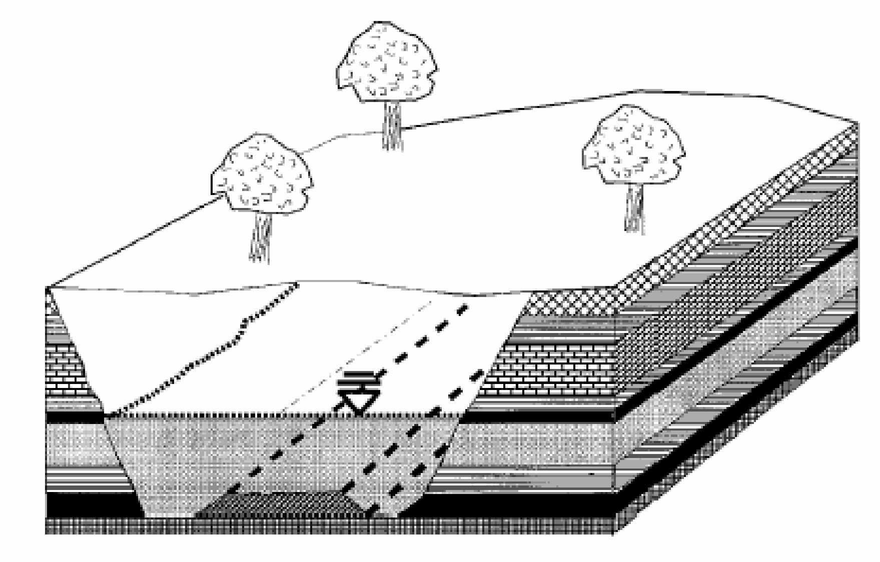

Figure 2. Submergence method
Source : U.S EPA (2001)

3. construct the disposal site in the backfill where :
   - on the mining pit floor
   - below the final water table to developed in the post mining backfill
   - within a hydrologic 'no flow' zone
   - out of the root zone probably at least 10 feet below the surface
4. Add alkaline material to reduce acid generation,
5. Complete the reclamation and revegetation as quickly as possibly,

d. Encapsulation method

Encapsulation method covers acid producing material with an impermeable material to limit its exposure to air and water. The material can be a synthetic liner or it may be a clayey material or other compacted material which results in a layer with a low hydraulic conductivity (Meek, 1994) (Figure 3).

The aim of encapsulation method are

a) to reduce exposure to oxygen and, more importantly in many cases,
b) to reduce contact with water and hence reduce the potential for contaminated seepage.

After placement, compaction and treatment with alkaline material if required, the acid producing material is then covered with local clayey or top soil. This material is also compacted on top of the acid producing material.

4. DISCUSSION

Most successful alkaline addition sites have employed thorough mixing of alkaline material throughout the backfill. This can be done using various methods. One innovative and effective approach is by using the alkaline material as blast hole stemming. Alternately, alkaline material can be placed on the surface of the overburden where it will be subsequently redistributed following excavation and placement. Another method of alkaline addition is to place the material on the surface of regraded spoil and disk it into the upper portion of the spoil. This approach usually is used either in combination with mixing in the backfill or as a remedial measure after the site has already been backfilled. Although it was originally thought that this method would take advantage of the added alkalinity in the most active zone of AMD production and create an alkaline environment, inhibiting AMD formation, most projects that employing only surface application have not been successful.

Calcium content of limestone should be as high as possible. Dolomite limestones are less reactive and generally ineffective in treating AMD. Advantages of using limestone include low cost, easy of use, and formation of a dense, easily handled, sludge. Disadvantages include slow reaction time, loss in efficiency of the system because of coating of the limestone particles with iron precipitates, difficulty in treating Acid Mine

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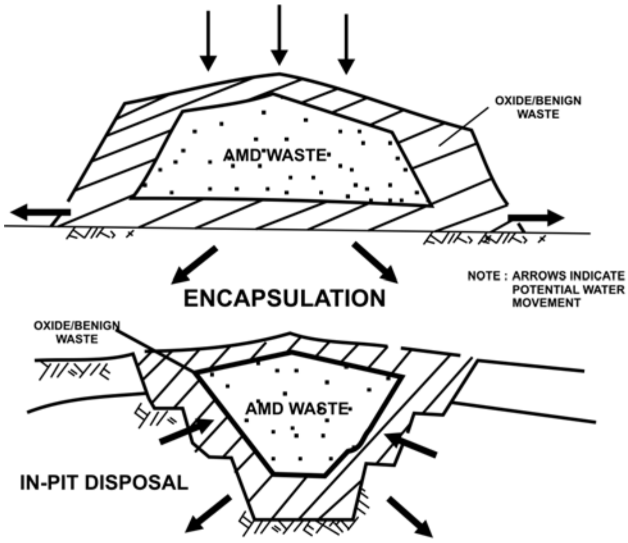

Figure 3. Encapsulation method
Source : Marszalek (1996)

Drainage with a high ferrous-ferric ratio, and ineffectiveness in removing manganese. Limestone treatment is generally not effective for acidities exceeding 50 mg/l.

To successfully prevent the formation of acid mine drainage, a sufficient quantity of alkaline material should be added to the backfill. Most successful alkaline addition sites to date have used substantial application rates, exceeding 500 ton/acre. Lower rates have proven to be effective only for low-cover overburden with very low sulfur content. Alkaline material is best applied by distributing and thoroughly mixing it throughout backfill. It also may be useful to place up to 100 ton/acre on the pit floor.

Blending is generally used where both calcareous and acid producing rocks occur within the stratigraphic column. Blending of calcareous material in the spoil has an advantage of being accomplished during the regular course of mining. Blending is only effective if the calcareous material is can be adequately mixed in spoil. Blending of materials has not been routinely adopted in the Australian mining industry, mainly due to the logistical problems and cost associated with scheduling, delivering and mixing significant volumes of mine wastes.

Encapsulation and submergence method are intended to limit the amount of water and oxygen in contact with the special handled material. Limitation of water will be effectively accomplished if the surface of the special handled pod is sloped to achieve ground-water runoff, the pod is capped with a low permeability material, and the material is placed above the post-mining water table. Encapsulation method, if material is capped and placed above the water table, should reduce the transport of pyrite-weathering products.

Submergence method has a benefit of limiting oxygen available for pyrite oxidation. Encapsulation method has been inadequately studied and some of the studies are inconclusive. Without capping and proper placement it may be ineffective. The post-mining hydrology should be well understood. Effectiveness of encapsulation method is not as clear. Studies that have been performed are few and some are inconclusive.

Alkaline redistribution is used where calcareous materials occur on only part of a site. Excess alkaline material is redistributed to the portions of the site lacking alkaline materials. Alkaline redistribution results in calcareous rocks being distributed to parts of the mine where they did not occur naturally thus provide the benefits inherent in calcareous rocks.

Overburden treatment prevented AMD in Indonesia

Acid drainage is endemic in many Indonesian mining, associated not only with mining, but also with any earthworks exposing pyritic materials. It is important to manage acid drainage because of its deleterious effects on water chemistry, animals and vegetation. In the mining context, perhaps the most significant impact is that acid-producing surfaces will not revegetate

There are many geological, analytical and economical factors that should be considered for overburden handling and placement plan. These factors such as; log and description of the overburden, physical and chemical analyses of the overburden, volume of material to be moved, topography of the site, available equipment and surface or ground water hydrology. Special handling method was chosen by some Indonesian mining such as at PT. Nusa Halmahera Minerals (PT. NHM).

PT. NHM has operated a gold mine using open pit methods and produces gold and silver in Gosowong, Halmahera Island and North Maluku Province. Mining at Gosowong commenced in July 1999 and completed in May 2002. The total production during 3 years mine life of Gosowong was 22,958 kg Gold and 22,906 kg silver. The total amount of overburden which excavated was 12,090,000 tones during 3 years mine life. The waste rock contains 0.1 - 1.1 % sulfide mineral, consisting of pyrite and small chalcopyrite. Finding from geochemical and exploration studies suggested that the waste rock can be divided into 3 types:

1. Type I : Potential Acid Forming (PAF) with total sulphur 1.16 % at ratio of ANC : APP = 0.63,
2. Type II : Potential Acid Neutraliser with total sulphur 0.86 % at ratio of ANC : APP = 1.12,
3. Type III : Non Acid Forming (NAF) with total sulphur 0.34 % at ratio of ANC : APP = 2.75 .

Two methods as advised in the feasibility study and to be chosen i.e.:

1. Blending or mixing method between Type I with Type II and III
2. Implementation of the encapsulation method.

Based on the local conditions include physiographic characteristics, precipitation and material availability PT. NHM decided encapsulation method to control AMD. Before transportation to the waste rock dump, the waste rock is classified using the NAG pH (Net Acid Generation pH) method. In construc- ting the waste rock dump, the waste rock with high potential acid generation is placed in the middle of dumping layer and then encapsulated with a clay layer to prevent water and oxygen penetration. A layer of material that does not produce acid is placed over the clay layer to prevent erosion and protect the clay layer for long term.

The waste was rock separately according to their types. Type I containing sulfide rocks placed in the core zone. One meter thick barrier zone consisting of cohesive clay placed around Type I rocks to protect against water and oxygen. Type II and III placed above and below the clay layer. Oxygen barrier zone was made up of the basal zone to an elevation of 130 m asl, one layer at 130 - 160 m asl and one layer at 160 - 175 m asl (Figure 4).

The construction of the waste rocks dump started at the outmost point of the surface channel water flow in order to minimize and decrease amount water discharging into surface water. Throughout operation, excavation and dumping of rock stock was undertaken based on acidity type of the rocks extracted. In order to ensure continuous selective excavation and dumping, PT. NHM has modeled a mine block based on calculations from the ANC and APP ratio. The waste rock dump was covered by a minimum of 10 cm layer of top soil and prepare for revegetation. The capacity of the Gosowong main settlement pond was 34.000 millions liters and functioned as containment for all surface run off and ground water around the main waste dump.

The critical routine parameters for AMD in Gosowong include pH, electrical conductivity, alkalinity, acidity, dissolved SO_4, Fe, Cu, Mn and Zn. Sampling and analysis are carried out using procedures adapted from 'Standard Method for the Examination of Waste and Wastewater' by American Public Health Association (APHA). In post operation, acidity and alkalinity, sulphate and dissolved metals concentration were decreased, and dissolved metals concentration were in complied with the applicable standards. The pH level was within the acceptance range of 6 – 9. The conductivity remained high and tended to decreases in second year . After two years monitoring results had indicated that encapsulation method shown successful in preventing AMD generation from PAF materials.

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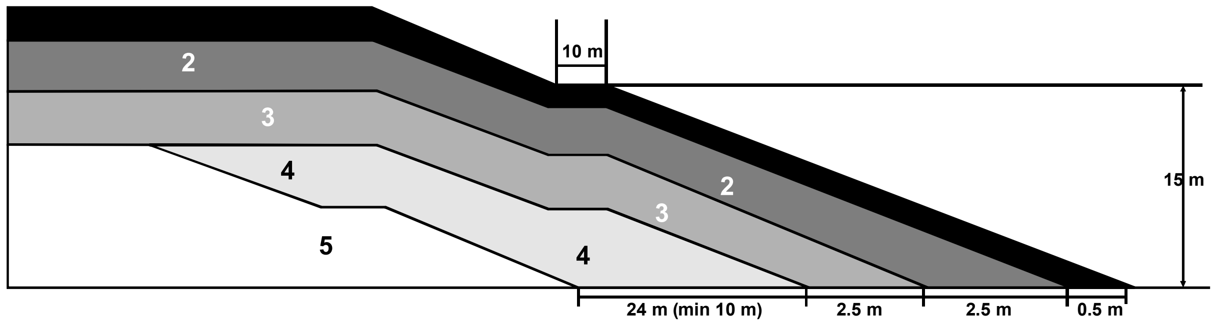

Figure 4. Encapsulation Method in PT. NHM
Source : Sudewo (2004)

Place	Activity
Zone 1 – Top Soil	loose dumped and track rolled with dozer
Zone 2 – Cover (NAG pH < 7)	To protected and buttress clay, 1.0 m vertical thickness. Placed in 0.5 m lifts. Compacted by vibratory roller for a minimum of 7 passes.
Zone 3 – Clay Seal	To seal dump material from air and water 1.0 m vertical thickness on benches and benches placed in lifts and compacted with vibratory roller for a minimum of 7 passes sand density for compaction (to achieve 85 % saturation or permeability of 10 m/sec)
Zone 4 – Facing (NAG pH 4.5 – 7)	24 wide transition zone compact in 0.5 – 1.0 lifts for a minimum of 5 passes
Zone 5 – PAF Material (NAG pH < 4.5)	Compact in 0.5 lifts with 5 passes or 1.0 lifts with 7 passes

5. CONCLUSIONS AND SUGGESTION

The addition of alkaline material to surface mine backfill can be an effective method of compensating for overburden that is naturally deficient in neutralizers and thus, reduce the potential for acid mine drainage. Surficial applications of alkaline material are less effective due to low solubility of calcite and limited contact with acid-producing materials deeper in the backfill. Most failed alkaline addition sites either had used application rates that were too low or employed ineffective placement of the alkaline material.

Special handling is often used in conjunction with management of ground water and alkaline addition. Special handling in the absence of alkaline materials cannot produce alkaline drainage. Special handling often involves both acid and alkaline materials and may also include clay materials for capping and lining pods of acidic materials. Special handling is not necessary on all mine sites. Special handling is most effective in conjunction with other best management practices such as alkaline addition. Monitoring during and after mining is necessary to evaluate special handling techniques.

Acid drainage is endemic in many Indonesian minings, associated not only with mining but also with any earthworks exposing pyritic materials. It is important to manage acid drainage because of its deleterious effects on water chemistry, animals and vegetation. In the mining context, perhaps the most significant impact is that acid-producing surfaces will not revegetate.

Table 1. Water monitoring program in PT. Nusa Halmahera Mining

Parameter	Units	Standard	Main Settlement Pond			Standard	Downstream Tobobo River		
			Operation	Post Operation			Operation	Post Operation	
			July 1999-	June 2002-May 2002	June 2003-May 2003		July 1999-May 2004	June 2002-May 2002	June 2003-May 2003
May 2004									
pH	-	6 - 9	4.6 – 7.8	6.4 - 8	6.4 – 7.8	6 - 9	6.7 – 7.6	7 – 8	7.2 - 8.1
Conductivity	-	NS	231 - 1866	178 - 2650	587 - 1408	NS	122 - 595	122 - 256	168 - 298
Acidity	-	-	1 - 85	4 - 26	J6 - 13	-	1 - 8	1 - 6	2 - 19
Alkalinity	-	-	20 - 260	102 - 233	92 - 191	-	9 - 40	18 - 49	21 - 39
Sulfate	mg/L	15	166 - 801	375 - 1220	475 - 742	400	26 - 206	38 - 169	58 - 75
Copper	mg/L	02-Mar	0.001- 0.076	0.001-0.057	0.001- 0.057	0.02	0.001-0.034	0.001-0.007	0.001-0.002
Manganese	mg/L	02-Mei	1.23 – 6.86	0.49 – 7.85	0.29 – 2.07	0.1	0.01 – 0.44	0.01 – 0.42	0.01 – 0.04

Content

In Indonesia with regular rainfall in tropical areas, it is possibleto construct a cover of clay, subsoil or waste rock that will retain some water throughout the year, and form an effective barrier to air diffusion. Given local conditions, which include high precipitation, physiographic characteristics and material availability mining in Indonesia decided to dump the overburden by using special handling method. However, research is required to determine whether the present isolation approaches provide the desired effect in the long term. There are measurements which suggest some isolation methods may not provide a long term solution, i.e. less than 100 years. More measurements are required to evaluate the long term effectiveness of present isolation design methods and provide better alternate management approaches.

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