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Review : Pollution due to Coal Mining Activity and its Impact on Environment

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Abstract

Utilization of natural resources in the form of coal mines has a positive impact on economic and energy development, in addition to coal mining activities have a negative impact on the environment that result in environmental pollution in soil, water, and air. Pollution begins when clearing land, taking exploitation, transporting, stockpile and when the coal is burned. When land clearing causes damage to forest ecosystems. At the time of exploitation impact on air pollution by coal dust particles, the erosion, siltation of the river, the pollution of heavy metals and the formation of acid mine drainage (AMD). The high acid conditions cause the faster heavy metals such as Hg, Cd, Pb, Cr, Cu, Zn and Ni present in the coal dissolved and carried to the waters. Coal stockpile activity also causes pollution in the air, soil, and water. At the time the coal is burned as an energy source causes the emission of hazardous materials into the air of Hg, As, Se and CO_2 gas, NOx, SO_2. This condition has an impact on the environment and ultimately on human health.

Keywords: coal, pollution, heavy metal, gas emission

Abstrak (Indonesian)

Pemanfaatan sumber daya alam berupa tambang batubara berdampak positif dalam pembangunan perekonomian dan energi, disamping itu aktivitas penambangan batubara berdampak negatif bagi lingkungan yang berakibat pencemaran lingkungan di tanah, air dan udara. Pencemaran dimulai ketika membuka lahan, pengambilan batubara (exploitasi), pengangkutan, penyimpanan sementara (stockpile) dan saat batubara tersebut dibakar. Ketika pembukaan lahan untuk penambangan batubara, hutan mulai di tebang sehingga menyebabkan kerusakan ekosisitem. Pada saat exploitasi berdampak pada tercemarnya udara oleh partikel debu batubara, terjadinya erosi, pendangkalan sungai, pencemaran logam-logam berat dan terbentuknya air asam tambang (AAT). kondisi asam yang tinggi menyebabkan semakin cepat logam-logam berat seperti Hg, Cd, Pb, Cr, Cu, Zn dan Ni yang ada pada batubara tersebut terlarut dan terbawa ke perairan. Aktivitas penyimpanan sementara (stockpile) batubara juga menyebabkan terjadinya pencemaran di udara, tanah dan air. Pada saat batubara tersebut dibakar sebagai sumber energi menyebabkan emisi bahan berbahaya ke udara berupa Hg, As, Se dan gas CO_2, NOx, SO_2. Kondisi ini yang berdampak pada lingkungan dan akhirnya pada kesehatan manusia.

Katakunci : batubara, polusi, logam berat, emisi gas.

1. Introduction

Energy demand is an essential requirement for successful economic and industrial development [1]. Coal demand is increasingly increasing as a source of energy for power generation and the need for the metal industry and other industries [2]. Utilization of the potential of natural resources as raw material and as an energy resource has a positive impact in improving the economy, but on the other hand, have a negative impact of pollution. The pollution is ultimately at risk for humans [3]; [4], one of the energy-producing resources namely coal.

Coal is one of the unrenewable fossil energies, formed from plant remains of 100 to 400 million years old [5]. The use of coal is still widely used by the world as a source of energy, nearly 36% of world energy needs still use coal. This proves that coal reserves are still quite large. point out that Indonesian is one of the largest coal producers, this is because the potential of coal mines is large enough to spread on the island of Sumatra and Kalimantan (figure 1) [6]

Coal mining activities have an impact on ecosystem damage [7], land degradation, disruption of aquatic ecosystems, higher water treatment costs [8] and air pollution releasing emissions into the atmosphere of Hg , As, Se [9] as well as CO_2 gas emissions, NOx, SO_2 [10] . The resulting pollution is triggered by an increase in population, technological advances and human activities [11]; [12]. The consequences of clearing land for coal mining activities is the occurrence of acid mine acid pollution [13] This pollution is influenced by the speed of rain flow, which results in runoff water entering the water, as well as heavy metals will be carried into the waters.

This paper presents the positive and negative impacts of coal mining activities on the environment, the impacts of acid mine water and its relation to heavy metal pollution and its impact on humans.

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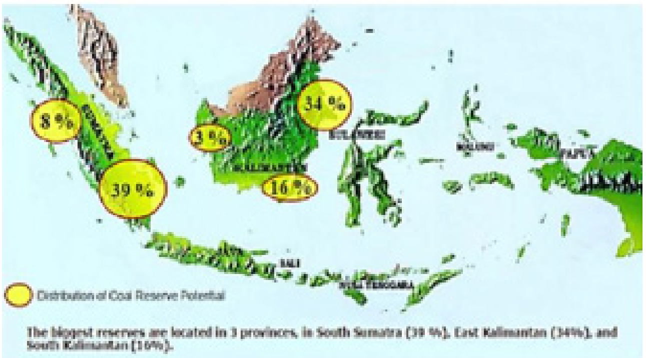

Figure 1 : Coal Distribution reserve potential Map ini Indonesia [6]

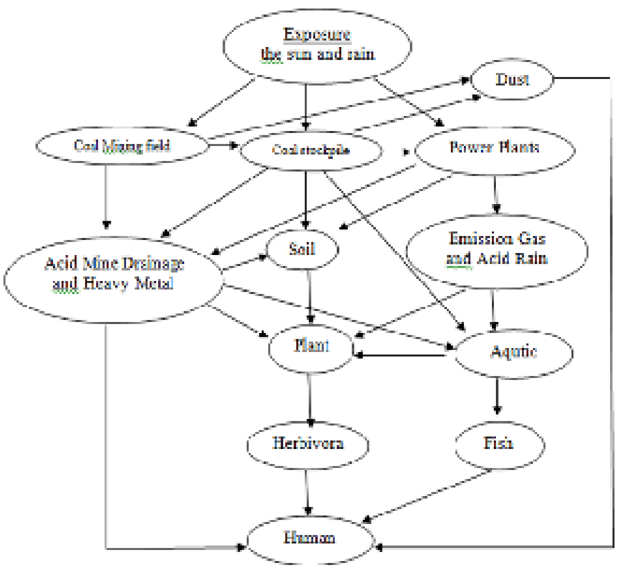

Figure 2. Diagram of the impact of coal mining activities (modified from [21])

2. Coal mining and environmental issues

Coal is one of the longest energy sources used by humans composed of organic materials and mineral fractions. Countries such as China in 2005 used coal as a source of energy at the top of 69.9%, followed by oil21%, natural gas 2.9%, and other energy 7.2% [14] As a result of these mining activities result in pollution in the environment [15]

The pollution may occur from the time of mining, haulage, stockpile and when used as an energy source [16]. Besides the phenomenon of pollution is also seen the phenomenon of coal fires in the stockpile. Several factors that affect the occurrence of fire spontaneously in the stockpile, including the environmental temperature . Coal mining activities have significant impacts on land, loss of biodiversity, degradation of agricultural land quality, degradation of quality and availability of water, air pollution in the form of dust during mining, collection, transportation, and solid waste in the form of organic matter and soil minerals [17].

When coal is burned as a fuel for a power plant, it produces a number of emissions that affect the environment, including CO, CO_2, NOx, and SOx. CO emissions cause ozone depletion (O_3) causing skin cancer, besides CO emissions if inhaled by humans causes the oxygen depleted blood flow that ultimately leads to death. CO_2 gas emissions [18]; [19]capture and storage of CO2 is required. Carbon capture and storage technologies that are currently the focus of research centres and industry include: pre-combustion capture, post-combustion capture, and oxy-fuel combustion. This review deals with the oxy-fuel coal combustion process, primarily focusing on pulverised coal (PC cause global warming to impact climate change. SOx and NOx gas emissions lead to acid rain. The impact of climate change and acid rain is bad for food security [20]. This mining activity is bad for the environment, the final impact of the journey of a pollutant from the coal (fate) is on human health (figure 2)

Table 1 Heavy Metal Sulfide Compound in Rocks [22]

No	Compound Sulfide	Compound Name
1	FeS_2	Pirit
2	FeS_3	Marcasite
3	$Fe_{(1-x)}S_x$	Pyrrhotite
4	ZnS	Sphalerite
5	PbS	Galena
6	ZnS	Sphalerite
7	SbS	Stibnite
8	NiS	Millerite

3. Acid Mine Drainage and Heavy Metal

The presence of minerals in coal includes quartz, pyrite, sulfide, calcite, dolomite, siderite, carbonate and choline and other clay minerals such as phosphorus, sulfate alumina and zeolite interacting and associated with organic compounds [22]. When the coal mine is peeled, rocks containing sulfide metal compounds react with oxygen and water, causing water to become acidic or known as AMD. This condition also facilitates the solubility of heavy metals are carried into the waters so that the soil and water content of heavy metals is relatively high. The sulfide compounds can be seen in (Table 1).

AMD derives from mining activities including underground mining and open pit mining, when mineral sulfide eg pyrite associated with coal and in contact with water and oxygen [23], reaction accur [24]

$$2FeS_{2(s)} + 7O_{2(g)} + 2H_2O_{(l)} \rightleftharpoons 2Fe^{2+}_{(aq)} + 4SO_4^{2-}_{(aq)} + 4H^+_{(aq)} \quad (1)$$

$$4Fe^{3+}_{(aq)} + O_{2(g)} + 4H^+_{(aq)} \rightleftharpoons 4Fe^{2+}_{(aq)} + 2H_2O \quad (2)$$

This AMD condition facilitates the solubility of sulfide minerals containing heavy metals, one of which for example the Sphalerite (ZnS) mineral dissolved in acidic conditions forming Zn^{2+} metal ions is shown in the following equation of 3 [25] :

$$ZnS_{(s)} + 2H^+_{(aq)} \longrightarrow n^{2+} + H_2S \quad (3)$$

High AMD content makes it easier for heavy metals contained in the coal to dissolve and enter the soil [23]; [26] resulting in heavy metal content in high soil compared to the source of coal. AMD and heavy metals carried by waterways threaten life in the waters, thus increasing the cost of water treatment. The inclusion of acid mine water and heavy metals that ultimately affect the aquatic environment. These events run continuously resulting in accumulated increasingly longer

4. Chemical Aspect of Heavy Metal

Heavy metal is a chemical element having an atomic period equal to or greater than 200. The exposure of these heavy metals in humans has toxic effects. Specific gravity over 5 gr/cm^3 with an atomic number over 20[27] and a molecular weight above 40 . Elements of heavy metals may have more than one oxidation number, depending on the state of the environmental conditions. The metals interact with other components, this interaction can be modeled on the equilibrium state in the aquatic system. These interactions undergo oxidation changes forming complex solutions, can also form oxide deposits, carbonates, and sulfides [28]. The presence of heavy metals such as Hg, Cr, Pb, Cd, Cu, Zn, and Ni is increasing in line with industrial and agricultural progress [29]. The heavy metals can be dissolved in the waters, deposited in the sediments and can accumulate in fish, thus threatening living creatures in the waters and humans, therefore it is necessary to analyze the heavy metal content and controlled sources of the contamination [30]. The elements of the metal can also be grouped by weight based on the elements required by the living organism (essential), for example : As, Cu, Zn, Fe, Mn, Mo, Ni, and Se. These metallic elements are required by the body in small amounts to function as enzymes and pigments, but if excessive can result as toxins in the body [31].

Heavy metals can enter in aquatic organisms through 3 paths [32] :

1. Free metal ions are absorbed through the surface of organ organisms, such as gills in fish which are then distributed throughout the bloodstream.
2. The free ions are absorbed by the body of water which then newly absorbed by the bloodstream.
3. Metals are absorbed by food and absorbed by digestion

Chemicals as pollutants in aquatic environments may undergo several chemical reactions [33]including: Photolysis, this reaction occurs where the molecules absorb solar radiation, so it can break the chemical bonds to form a new compound. Most occur in nature in the form of organic compounds. Compression, this reaction occurs in the element of metal ions that bind to molecules that have a pair of free electrons (ligands) form a complex compound. Examples of molecules having these free electrons are hydroxy, carbonate, carboxylate, phosphate and cyanide. Acid-base, this reaction occurs what happens when the displacement of H^+ ions into the environment. Reduction-oxidation (Redok), this reaction occurs due to electron displacement or changes in oxidation number. The reaction of hydrolysis and hydration, reactions in chemical compounds bind or react with water or hydroxyl ions. Deposition reaction, this reaction occurs when 2 or more elements react to form an insoluble compound.

5. Impact on life

The entry of waste from mining activities has an impact on the aquatic environment biotics (fish, shellfish, worms and aquatic plants) and abiotic (water and sediment). Invertebrate living beings can accumulate heavy metallic elemental elements both essential and non-essential in the body of the living creature so that it is toxic in the body. This relates to the concentration of the heavy metal exceeding the threshold value [34].

Contamination of heavy metals in Tianjin China consisting of Cu, Zn, Pb, Cd, Hg and Cr on vegetable and fish foods. Exposure to heavy metals is measured risk level based on target hazard quotients (THQs). The results show that Pb metal exposure suggests a great potential risk for children who consume vegetables and fish exposed to these heavy metals [34] . The dynamics of heavy metals such as Fe, Mn, Zn, Cr, Cu, Co, Ni, Pb and Cd at surface waters of Mahanadi river at 31 different stations. The results show that most of the heavy metals are of high concentration. Fe heavy metal concentration is higher than Cd. The existence of heavy metals is caused by human activity (anthropogenic). High Ni, Pb and Cd concentrations exceed the allowed limit value. This degrades the water quality and impacts health risks [35].

Exposure to heavy metals into the human body causes diseases such as disorders of organ function, kidney damage, cancer, miscarriage for pregnant women, lowering behavior and intelligence even at high concentrations of exposure causing death [36]. The body contains various enzymes, with the entry of foreign substances will inhibit the action of enzymes (inhibitors). Among them are foreign substances in the form of heavy metal Pb^{2+} ions, where they will be strongly bonded with sulfur groups present in the enzyme, in particular, -SS-, -SH and $-S-CH_3$ [37]

Exposure to heavy metals in the environment leads to various diseases in humans, namely kidney damage, cancer, behavioral decline and intelligence to cause death. Exposure to these heavy metals into the human body through the food chain [38]. Heavy metals cause poisoning and triggering cancer since it generally reacts with oxygen and nitrogen. The metals form free radicals due to the modification of DNA bases, increased lipid peroxide [39].

6. Conclusions

Mining activities in addition to a positive impact on the economy, on the other hand, a negative impact of pollution in water, air, and land. This pollution starts from land clearing, mining, transportation, temporary storage and when used as fuel in power generation industry and metal processing industry. Such pollution problems can be heavy metal and AMD that can contaminate water and soil. At the time the coal is burned as a source of energy produces CO, CO_2, NOx, SOx emissions which can lead to depletion of the ozone layer, global warming and acid rain that can interfere with food security.

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References

[1] D. Mamurekli, "Environmental impacts of coal mining and coal utilization in the UK," *Acta Montan. Slovaca Ročník*, vol.

15, pp. 134–144, 2010.

[2] A. K. Sahu, H.B. Dash, and S. Swar, "Environmental Impact of Coal Beneficiation and its Mitigation Measures.pdf," *Indian J. Environ. Prot.*, vol. 31, no. 8, pp. 691–698, 2011.

[3] J. Neustadt and S. Pieczenik, "Heavy-Metal Toxicity—With Emphasis on Mercury," *Integr. Med.*, vol. 6, no. 2, pp. 26–32, 2007.

[4] M. Izquierdo and X. Querol, "International Journal of Coal Geology Leaching behaviour of elements from coal combustion fl y ash : An overview," *Int. J. Coal Geol.*, vol. 94, pp. 54–66, 2012.

[5] D. Katoria, D. Sehgal, and S. Kumar, "Environment Impact Assessment of Coal Mining," *Int. J. Environ. Eng. Manag.*, vol. 4, no. 3, pp. 245–250, 2013.

[6] M. H. Hasan, T. M. I. Mahlia, and H. Nur, "A review on energy scenario and sustainable energy in Indonesia," *Renew. Sustain. Energy Rev.*, vol. 16, no. 4, pp. 2316–2328, 2012.

[7] R. K. Tiwary, "Environmental impact of coal mining on water regime and its management," *Water, Air, Soil Pollut. 132*, vol. 132, pp. 185–199, 2001.

[8] G. Tozsin, "Hazardous elements in soil and coal from the Oltu coal mine district, Turkey Gulsen," *Int. J. Coal Geol.*, no. accepted manuscript, 2014.

[9] J. M. Tian, H. Z., Wang, Y., Xue, Z. G., Cheng, K., Qu, Y. P., Chai, F. H. and Hao, "Trend and characteristics of atmospheric emissions of Hg , As , and Se from coal combustion in China , 1980 – 2007," *Atmos. Chem. Phys.*, vol. 10, pp. 11905–11919, 2010.

[10]B. J. P. Buhre, L. K. Elliott, C. D. Sheng, R. P. Gupta, and T. F. Wall, "Oxy-fuel combustion technology for coal-fired power generation," *Prog. Energy Combust. Sci. 31*, vol. 31, pp. 283–307, 2005.

[11]A. R. Karbassi, S. M. Monavari, G. R. Nabi Bidhendi, J. Nouri, and K. Nematpour, "Metal pollution assessment of sediment and water in the Shur River," *Environ. Monit. Assess.*, vol. 147, no. 1–3, pp. 107–116, 2008.

[12]K. Ozseker, C. Eruz, and S. Ciliz, "Determination of Copper Pollution and Associated Ecological Risk in Coastal Sediments of Southeastern Black Sea Region ," *Bull Env. Contam Toxicol*, no. 91, pp. 661–666, 2013.

[13]C. J. B. Gomes, C. A. B. Mendes, and J. F. C. L. Costa, "The Environmental Impact of Coal Mining : A Case Study ˜ o Watershed in Brazil ' s Sanga," *Mine Water Env.*, no. 30, pp. 159–168, 2011.

[14] C. F. You and X. C. Xu, "Coal combustion and its pollution control in China," *Energy*, vol. 35, no. 11, pp. 4467–4472, 2010.

[15]M. J. Ahrens and D. J. Morrisey, "Biological Effect of unburnt coal in the marine environment," *Oceanogr. Mar. Biol. An Annu. Rev.*, vol. 43, pp. 69–122, 2005.

[16]L. Pan, P. Liu, L. Ma, and Z. Li, "A supply chain based assessment of water issues in the coal industry in China," *Energy Policy*, vol. 48, pp. 93–102, 2012.

[17]C. Sensogut and A. H. Ozdeniz, "Statistical modelling of stockpile behaviour under different atmospheric conditions — western lignite corporation (WLC) case," *Fuel*, vol. 84, pp. 1858–1863, 2005.

[18]S. P. Raghuvanshi, A. Chandra, and A. K. Raghav, "Carbon dioxide emissions from coal based power generation in India," *Energy Convers. Manag.*, vol. 47, pp. 427–441, 2006.

[19]G. Scheffknecht, L. Al-Makhadmeh, U. Schnell, and J. Maier, "Oxy-fuel coal combustion-A review of the current state-of-the-art," *Int. J. Greenh. Gas Control*, vol. 5, no. SUPPL. 1, pp. 16–35, 2011.

[20]G. R. Carmichael *et al.*, "Changing trends in sulfur emissions in Asia: Implications for acid deposition, air pollution, and climate," *Environ. Sci. Technol.*, vol. 36, no. 22, pp. 4707–4713, 2002.

[21]V. C. Pandey, J. S. Singh, R. P. Singh, N. Singh, and M. Yunus, "Arsenic hazards in coal fly ash and its fate in Indian scenario," *"Resources, Conserv. Recycl.*, 2011.

[22]C. R. Ward, "Analysis and significance of mineral matter in coal seams," *Int. J. Coal Geol.*, vol. 50, pp. 135–168, 2002.

[23]W. M. Gitari, "Passive neutralisation of acid mine drainage by fly ash and its derivatives : A column leaching study," *Fuel*, vol. 87, pp. 1637–1650, 2008.

[24]D. Banerjee, "Acid drainage potential from coal mine wastes : environmental assessment through static and kinetic tests," *Int. J. Environ. Sci. Technol*, vol. 11, pp. 1365–1378, 2014.

[25]M. A. H. Bhuiyan, M. A. Islam, S. B. Dampare, L. Parvez, and S. Suzuki, "Evaluation of hazardous metal pollution in irrigation and drinking water systems in the vicinity of a coal mine area of northwestern Bangladesh," *J. Hazard. Mater.*, vol. 179, no. 1–3, pp. 1065–1077, 2010.

[26]C. D. Williams and C. L. Roberts, "Removal of heavy metals from acid mine drainage (AMD) using coal fly ash , natural clinker and synthetic zeolites," *J. Hazard. Mater.*, vol. 156, pp. 23–35, 2008.

[27] T. Sherene, "Mobility and transport of heavy metals in polluted soil environment," *Biol. Forum*, vol. 2, no. 2, pp. 112–121, 2010.

[28]E. U. Tipping, S. Lofts, and A. J. Lawlor, "Modelling the chemical speciation of trace metals in the surface waters of the Humber system," *Sci. Total Environ.*, vol. 210/211, 1998.

[29]Q. Zhou, J. Zhang, J. Fu, J. Shi, and G. Jiang, "Biomonitoring: An appealing tool for assessment of metal pollution in the aquatic ecosystem," *Anal. Chim. Acta*, vol. 606, no. 2, pp. 135–150, 2008.

[30]Y. Yi, Z. Yang, and S. Zhang, "Ecological risk assessment of heavy metals in sediment and human health risk assessment of heavy metals in fi shes in the middle and lower reaches of the Yangtze River basin," *Environ. Pollut.*, vol. 159, no. 10, pp. 2575–2585, 2011.

[31]M. Nikinmaa, *An introduction to aquatic toxicology*, vol. 53, no. 9. 2014.

[32]S. Pintilie, L. Brânz, C. Be, L. V. Pavel, F. Ungureanu, and M. Gavrilescu, "Modelling and simulation of heavy metals transport in water and sediments," *Environ. Eng. Manag. J.*, vol. 6, no. 2, pp. 153–161, 2007.

[33]E. R. Weiner, *Applications of Environmental Aquatic Chemistry: A Practical Guide, Second Edition (Google eBook)*. 2010.

[34]X. Wang, T. Sato, B. Xing, and S. Tao, "Health risks of heavy metals to the general public in Tianjin , China via consumption of vegetables and fish," *Sci. Total Environ. 350*, vol. 350, pp. 28–37, 2005.

[35]S. K. Sundaray, B. B. Nayak, T. K. Kanungo, and D. Bhatta, "Dynamics and quantification of dissolved heavy metals in the Mahanadi River estuarine system, India," *Environ. Monit. Assess.*, vol. 184, no. 2, pp. 1157–1179, 2012.

[36]Z. Banu, S. A. Chowdhury, D. Hossain, and K. Nakagami, "Contamination and Ecological Risk Assessment of Heavy Metal in the Sediment of Turag River , Bangladesh : An Index Analysis Approach," *J. Water Resour. Prot.*, vol. 2013, no. February, pp. 239–248, 2013.

[37]S. E. Manahan, "Environmental Chemistry," pp. 3–876, 2000.
[38]A. Mashiatullah, M. Z. Chaudhary, N. Ahmad, T. Javed, and A. Ghaffar, "Metal pollution and ecological risk assessment in marine sediments of Karachi Coast , Pakistan," pp. 1555–1565, 2013.
[39]M. Valko, H. Morris, and M. T. D. Cronin, "Metals , Toxicity and Oxidative Stress," *Curr. Med. Chem.*, vol. 12, pp. 1161–1208, 2005.