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Analysis of Heavy Metals in Sediment of Lapindo Mud, Sidoarjo, East Java

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Abstract: The existence of metals indicates pollution in environment and its toxicity is due to non-degradable substance which tends to accumulate in water, sediment and fish. The presence of heavy metals in water body (i.e. river, stream) is becoming a threat to aquatic animals thereby making them unfit for human consumption. Thus, this study was to investigate the concentration of heavy metal pollution status in sediments of Lapindo Mud, Sidoarjo, East Java in its current condition. Samples were taken from six different locations of Lapindo mud. Heavy metal concentration in mud sediments was analyzed from Lapindo mud in the month of March to June 2015. Physico-chemical analysis was carried out as per standard methods at Laboratory of Soil and Chemistry, University of Brawijaya. The results show that there are eight heavy metals were found. The heavy metal concentration in the sediments is in order B > Fe > Mn > Co > Mo > Cd > Cu > Zn. These results indicated that for the meantime there were no environmental effect of these heavy metals resulted of mud, unless when these metals are associated with other elements. However, the presence of elevated levels of Fe, Mn, and Cd in the sediments is a serious matter of concern and the potential for human exposure to heavy metals.
Keywords: concentration, health effect, heavy metals, Lapindo mud.

Introduction

Presence of metals are indication of pollution in environment and the toxicity of metals stems from the fact that they are biologically non-degradable and have the tendency to accumulate in water, sediment and fish[1]. Metal contamination of the environment results both from natural sources and industrial activities. Metals in soil and water may enter the food cycle with an additional contribution from air[2]. Trace elements and heavy metals into aquatic environments come through agriculture, industrialization and mining are ultimately absorbed by deposits and incorporated into the sediments[3].

Discharge of industrial effluents also constitute about 62% of total source of heavy metals such as lead, nickel, cadmium, chromium and manganese which are responsible not only for degrading the water quality of a river but also for killing a number of aquatic organisms[4]. These metals have been found to be toxic after large accumulation in the body of flora and fauna and later pass on through the food chain of plant and fish to human. The presence of heavy metals in water body (i.e. river, stream) is becoming a threat to aquatic animals thereby making them unfit for human consumption[5]. These toxic metals have been found to have accumulated mainly in the kidney and liver and high concentrations have also been found to lead to chronic kidney dysfunction. Steoppler has shown that when lead is ingested by man, it enters the blood stream and soon it begins to appear in the liver[6].

In addition, sediments are solid materials that settle at the bottom of water bodies. Sediments are important geochemical sinks which accumulate heavy metals rapidly and usually deplete them very slowly by leaching into ground water aquifers[7]. Physical effects such as in sediments which decreases light penetration, burg riverbed gravels used by spawning fish and clog gills, might cause the decomposition of organic matters which uses up oxygen otherwise available to aquatic organisms for example excess nutrient can cause excessive growth of plants and algae which then decompose and reduce available oxygen for the aquatic life due to the presence of some hazardous substances may distort water quality, adds colour and also hinders economic activities[8].

The Sidoarjo mud flow or Lapindo mud is the result of an erupting mud volcano[9] in the subdistrict of Porong, Sidoarjo in East Java, Indonesia that has been in eruption since May 2006. It is the biggest mud volcano in the world; responsibility for it was credited to the blowout of a natural gas well drilled by PT Lapindo Brantas, although some scientists and company officials contend it was caused by a distant earthquake. At its peak Lapindo mud spewed up to 180,000 m^3 of mud per day. Since the beginning of event until October 2008 it was predicted that the flowing rate of the mud was ranging from 100,000 to 180.000 m3 per day[10] and its keep flowing ever since. The mud vastly affected Sidoarja area which has buried houses, villages, schools, factories, and displaced thousands of people and continues to pose geo-hazard risks in a densely populated area with many activities and infrastructures[11]. Some scientists believed that Lapindo mud volcano is unnatural disaster and it was trigger by drilling. However, some geologist convinced that it was natural disaster which was trigger by earthquake that was occurred day before the eruption. Despite the occurrence of Lapindo mud volcano was debated, but maintaining the impact of the mud on social and environment is important. Not only evacuated around thousands people[10] but also monitoring water, land and air quality under permitable condition is urgently necessary. Steady population growth and industrialization in the area has led to an increase in metal pollutants in the sediments.

Moreover, evidence is mounting that the mud has a harmful impact on river ecosystems and human health. Dried mud deposits could have adverse effects on river and marine environments and on the health of local residents[12]. The mud has been assessed as containing phenol in concentrations exceeding the maximum residue limit[13]. Phenol is toxic to fish, aquatic vegetation and humans. A recent report by the United States Geological Service has found that several elements, notably arsenic, are present in concentrations that exceed US government environmental guidelines for residential soil[12].

Many studies indicated that levels of metals were higher in sediment than in water. Studies conducted on metal accumulation in sediment showed increase in metal levels in sediment with addition of sewage, industrial effluents and agricultural wastes[14].

Therefore, the aim of this study is to determine the concentration of heavy metal pollution status in sediments of Lapindo Mud, Sidoarjo, East Java in its current condition. An attempt is also made in comparing the concentration between the samples and the standard sediment quality criteria of World Health Organization[15].

Materials and Method

Sediments from six sampling locations in the Lapindo mud area were collected and analyzed. Sample collection, preservation, Physico-chemical analysis was carried out as per standard methods at Laboratory of Soil and Chemistry, University of Brawijaya. Geographical Positioning System (GPS) was used to navigate the mud location within the area.

Six sediment samples were randomly collected during the short dry spell in the month of March to June 2015. The identifiable landmarks in adjoining land areas to the sampling points were also recorded. The sediments were drained of water and subsequently air-dried for few days under room temperature. The dried samples were disaggregated, sieved to remove materials such as wastes, animal shells and plant roots and later grinded into a homogenous mixture using a porcelain mortar and pestle, sieved through 2 mm sieve to achieve fine powder before they were analyzed for their elemental constituents.

The digestion of the sediment sample was carried out with each sample put into a digestion flask. The digesting acid [HCl] was measured in a fume cupboard and added to the sample in the digestion flask. Digestion was carried out on a hot plate in a fume chamber avoiding splattering. The beaker was removed and allowed to cool. The samples were cooled, filtered then diluted to HCl 0.1 N and stored in a sample bottle before they were analyzed for their elemental constituents.

Results and Discussion

According to the Geographical Positioning System (GPS) to navigate the mud location within the area, the mud is located close to Porong River. The mud will seriously affect the livelihoods and health of shrimp and fishing communities located adjacent to the Porong River and the Madura Strait, that is, communities in the districts of Sidoarjo, Madura, Pasuruan and Probolinggo (to the east of the map area), and the municipality of Surabaya (Fig. 1).

Lapindo mud is situated in the backarc area 10 km northeast from the Penanggungan volcano. Regional seismic profiles and field observations suggests the presence of a regional fault through the LUSI area although it is partly buried by alluvial sediments (Fig. 1). Several dormant mud volcanoes are located near Lapindo mud. The stratigraphy at the Sidoarjo locality consists of: 1) alluvial sediments; 2) Pleistocene alternating sandstone and shale of the Pucangan Formation, (up to 900 m depth), 3) Pleistocene bluish gray clay of the Upper Kalibeng Formation, to 1871 m depth and 4) volcaniclastic sand at least 962 m thick.

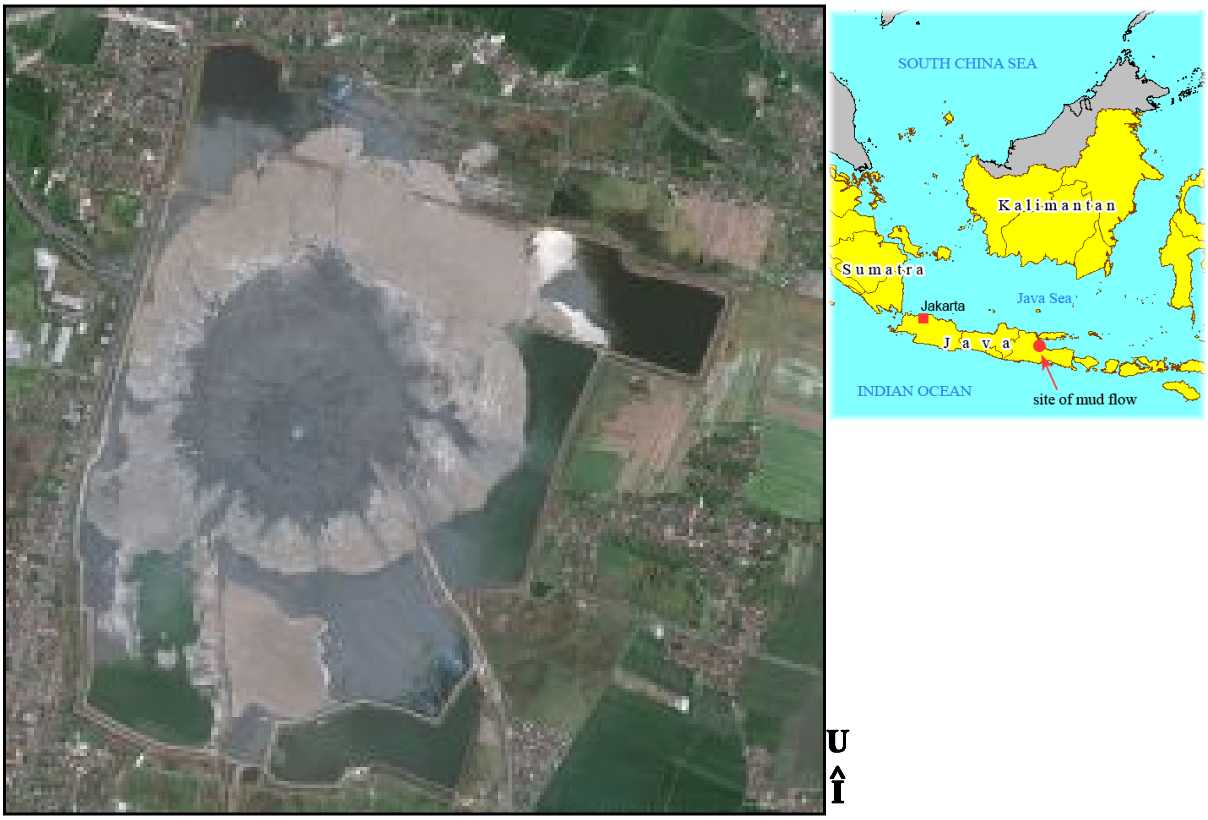

Figure 1. Mudflow Area and Surrounding Regions

The metals detected in the sediments include copper (Cu), iron (Fe), mangan (Mn), cobalt (Co), zinc (Zn), cadmium (Cd), molybdenum (Mo) and boron (Bo). Pb and Hg were not detected in Lapindo mud sample

(Table 1). The table indicates that the heavy metal concentration in the sediments in order B > Fe > Mn > Co > Mo > Cd > Cu > Zn.

Among those heavy metals found in the Lapindo sediments, copper, cobalt, molybdenum, manganese, iron and zinc are not harmful in normal level. They are nutritionally essential metals to maintain the metabolism of the human body (Table 2). The absorption of copper is necessary because copper is a trace element that is essential for human health. However, at higher concentration they can lead to poisoning. Long-term exposure to copper can cause irritation of the nose, mouth, and eyes which can lead to headaches, stomachaches, dizziness, vomiting, and diarrhea. Intentionally high uptake of copper may cause liver and kidney damage.

Table 1. Metal Contaminants of Lapindo Sediments

Transition Metal	Samples in HCl 0.1N (%)						Average
	A	B	C	D	E	F	
Fe	4.86	4.69	4.99	50.80	55.20	55.90	29.40667
Cu	1.46	1.24	1.70	1.59	1.96	1.81	1.626667
Zn	0.85	0.76	0.60	0.62	0.60	0.89	0.72
Mn	5.62	5.91	7.19	7.28	7.22	10.03	7.208333
Pb	nd	nd	nd	nd	nd	nd	nd
Hg	nd	nd	nd	nd	nd	nd	nd
Cd	0.45	3.88	4.60	0.57	0.60	0.68	1.796667
Co	10.00	6.70	5.60	7.80	4.40	5.60	6.683333
Mo	4.80	6.40	2.40	4.00	5.60	3.20	4.4
B	164.80	137.40	155.70	7.30	109.90	91.60	111.1167

*) nd = not detected

Table 2. Classification of Metals Based on Characteristics of Health Effects

Nutritionally Essential Metals	Metals with Possible Beneficial Effects	Metals with No Known Beneficial Effects
Cobalt	Boron	Aluminum
Chromium III	Nickel	Antimony
Copper	Silicon	Barium
Iron	Vanadium	Beryllium
Manganese	Iodine	Cadmium
Molybdenum		Lead
Selenium		Mercury
Zinc		Silver
		Strontium
		Thallium

Source: Geiger and Cooper[16]

On the other hand, although the concentration of boron (B) is high in the sediments, it is not dangerous as it is a trace mineral essential to human health. It helps the bone use calcium. The increased level of boron in the soil has been associated with a lower risk of osteoarthritis. Similarly, molybdenum has the same potential effect on the plantation. The most important role of molybdenum in living organisms is as a metal heteroatom at the active site in certain enzymes. In nitrogen fixation in certain bacteria, the nitrogen enzyme usually contains molybdenum in the active site. This is necessary for eukaryotic life.

In contrast, Cadmium was found to have average of 1.8% in the sediments. This is high concentration regarding the effect of Cadmium for the environment. In human, long-term exposure of cadmium is associated with renal disfunction. Cadmium may also produce bone defects in humans and animals. In addition, the metal can be linked to increased blood pressure.

Moreover, as oxygen is produced by plants and algae, there is further drop in dissolved oxygen levels. Some investigations have suggested that pyrite oxidation and siderite dissolution were among the possible As sources in the groundwater of many areas. The arsenic enrichment has also been known well associated with mud volcanoes and geothermal fields[17]. Arsenic is well known to be adsorbed on Fe or Mn oxide/hydroxide minerals in subsurface sediments[18]. As-rich minerals may therefore release arsenic as a result of weathering of alluvial sediments[19], and arsenic may subsequently be released into the groundwater through reductive dissolution of Fe (III) oxyhydroxides under reducing conditions[17,20]. Thus, as locations D, E, and F contain high Fe and Mn, the production of arsenic is possible and this can be harmful to organism. In many part of the world it was reported that arsenic enrichment and its mobilization in subsurface environments causes health concerns[18,21].

These results indicated that for the meantime there were no environmental effect of these heavy metals resulted of mud, unless when these metals are associated with other elements. For example, among the other metals, mercury has high similarity for suspended particles, which can lead to its extraction from the water column and its accumulation in the sediments, resulting that sediments functioning as a deposit and also mercury source to pore waters and biota[22,23]. Furthermore, water that is resulting from settling mud deposits potentially affect the quality of surface or ground-water sources for drinking water, trough the effect of several constituents such as fluoride, nitrate, iron, manganese, aluminium, sulfate, chloride, and total dissolved solids.

Even though the level of Total Dissolved Solid (TDS) was higher than standard, but the TDS is not an indicator of health hazard, due to TDS indicates an anion, cation or some small amount of organic matter that are dissolved in water.

Conclusion

All the metals studied did not appear to pose any threat. The levels of the elemental concentrations are very low compared with the values obtained from other studies from other parts of the country and also within acceptable limits and not considered to be a cause for toxicology concern. The level of heavy metals on Lapindo mud was below environmental soil quality guidelines. Besides, among those heavy metals found in the Lapindo sediments, copper, cobalt, molybdenum, manganese, iron and zinc are not harmful in normal level. They are nutritionally essential metals to maintain the metabolism of the human body. These results indicated that for the meantime there were no environmental effect of these heavy metals resulted of mud, unless when these metals are associated with other elements. On the other hand, at higher concentration they can lead to poisoning. All locations except D had high concentration of boron which is beneficial for plant growth. However, D, E, F locations where manganese and iron are high are harmful for organism as the production of arsenic is possible in these locations. Moreover, a higher concentration of cadmium and iron in the sediments indicates potential threat of ground water pollution and soil pollution which can be dangerous for surround organisms. Therefore, regular monitoring is necessary to protect human health and further environmental disaster.

References

1. Gale NL, Adams CD, Wixson BG, Loftin KA, Huang Y. Lead, Zinc, Copper and Cadmium in fish and sediments from the River and Flat River Creek of Missour's Old Lead Belt. Environ. Geochem. Health, 2004, 26: 37-49.
2. Gül A, Yilmaz M, Isilak Z. Acute toxicity of Zinc Sulphate (ZnSO .H2O) (*Poecilia reticulata* P., 1859). G.U. J. Sci., 2009, 22(2): 59-65.
3. Olajire AA, Ayodele ET, Onyedirdan GO, Olugbemi EA. Levels and specification of heavy metals in soils of industrial southern Nigerian. Environ. Monit. Assess., 2003, 85(2):135-155.
4. Garba S, Abubakar M. Level of heavy metals in terrestrial crabs. Best J. 2006, 3(4): 77-80.
5. Sunday AD, Augustina DO, Zebedee B, Olajide OO. Analyses of heavy metals in water and sediment of Bindare Stream, Chikaji Industrial Area Sabon Gari. Int. J. Sci. Res. Environ. Sci. 2013, 1(6): 115-121.
6. Stoeppler M Techniques and instrumentation in analytical chemistry, Vol. 12. Hazardous metals in the environments. In: Powell RE. Trace element in fish over subaqueous tailing in the Tropical West Pacific. Water, Air, Soil Poll., 1992, 125: 81-104.
7. Enguix AG, Tenanzo RJ, Fernadez JE, Naranga Dala Rosa FJ. Assessment of metals in sediments in a tributary of Guadaloquiver River (Spain): Heavy metals partitioning and relation between the Water Sediments system. Water, Air, Soil Poll., 2000, 12: 11-19.

8. Asonye CC, Okolie NP, Iwuanyanwu UG. Some physico-chemical characteristics and heavy metal profiles of Nigeria rivers, streams and water ways. Afr. J. Biotech., 2007, 6(5): 617-625.
9. van Noorden R. Mud volcano floods Java. Available at: http://www.nature.com/news/2006/060828/full/news060828-1.html. 2006, Retrieved on October 18th 2006.
10. Mazzini A, Svensen H, Akhmanov GG, Aloisi GG, Planke S, Malthe-Sørenssen A, Istadi B. Triggering and dynamic evolution of the LUSI mud volcano, Indonesia. Earth Planet. Sc. Lett., 2007, 261: 375–388.
11. Istiadi BP, Promono GH, Sumintadireja P, Alam S. Modeling study of growth and potential geohazard for LUSI mud volcano: East Java, Indonesia. Mar. Petrol. Geol., 2009, 26: 1724-1739.
12. Plumlee GS, Casadevall TJ, Wibowo HT, Rosenbauer RJ, Johnson CA, Breit GN, Lowers HA, Wolf RE, Hageman PL, Goldstein H., Anthony MW, Berry CJ, Fey DL, Meeker GP, Morman SA. Preliminary analytical results for a mud sample collected from the LUSI mud volcano, Sidoarjo, East Java, Indonesia. Reston VA: US Geological Survey Open-File Report, 2008, 1019.
13. Friends of the Earth International. Lapindo Brantas and the mud volcano, Sidoarjo, Indonesia. Paper Introduction. Available at: http://www.foeeurope.org/publications /2007/LB_mud_volcano_Indonesia.pdf, 2007, Retrieved on June 20th 2015).
14. Wang L, Chen J, Hong S. The new advances of sediment quality criteria for heavy metals, the biological effect database based approach. Environ. Sci. Technol., 2001, 2: 4-8.
15. World Health Organization. Standard sediment quality criteria. 2007.
16. Geiger A, Cooper J. Overview of airborne metals regulations, exposure limits, health effects, and contemporary research: draft. Portland: Cooper Environmental Services LLC, 2010.
17. Nath B, Berner Z, Chatterjee D, Basu-Mallik S, Stueben D. Mobility of arsenic in West Bengal aquifers conducting low and high groundwater arsenic. Part II. Comparative geochemical profile and leaching study. Appl. Geochem., 2008, 23: 996–1011.
18. Smedley PL, Kinniburgh DG. A review of the source, behavior and distribution of As in natural waters. Appl. Geochem, 2002, 17: 517–568.
19. Saunders JA, Lee MK, Uddin A, Mohammad S, Wilkin RT, Fayek M, Korte NE. Natural arsenic contamination of Holocene alluvial aquifers by linked tectonic, weathering, and microbial processes. Geochem., Geophys., Geosyst., 2005, 6.
20. Polizzotto L, Kocar BD, Benner SG, Sampson M, Fendorf S. Near-surface wetland sediments as a source of arsenic release to ground water in Asia. Nature, 2008, 454: 505-508.
21. Kar S, Maity JP, Jean JS, Liu CC, Nath B, Yang HJ, Bundschuh J. Arsenicenriched aquifers: Occurrences and mobilization of arsenic in groundwater of Ganges Delta Plain, Barasat, West Bengal, India. Appl. Geochem., 2010, 25 (12): 1805-1814.
22. Ram A, Rokade MA, Borole DV, Zingde MD. Mercury in sediments of Ulhas estuary. Mar. Pollut. Bull., 2003, 46: 846–857.
23. Ramalhosa E, Pato P, Monterroso P, Pereira E, Vale C, Duarte AC. Accumulation versus remobilization of mercury in sediments of a contaminated lagoon. Mar. Pollut. Bull., 2006, 52: 332–356.

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