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Research Article

Characteristics of Lusi mud volcano and its impacts on the Porong River

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Abstract: Since the first gas and mud volcano spewed from well at Sidoarjo, East Java, Indonesia (called Lusi or Lapindo mud) in 2006, its keep flowing ever since. Despite the occurrence of Lusi mud volcano was debated. Either it was natural or unnatural disaster, but maintaining the impact of the mud on social and environment is important. In addition, monitoring water, land and air quality under permitable condition is urgently necessary, due to some scientist stated that the eruption of mud volcano might be impossible to stop. The Lusi's mud was analyzed in 2009 and showed that the concentration of heavy metals were below environmental soil quality guidelines. There were no environmental effect of heavy metals (Mn, Zn, Cu, Cr, Cd, Pb, Co, Ni, Hg, and As) resulted of mud, unless when these metals are associated with other elements. In contrast, the physical and chemical of mud-water was above the environmental standard. Continues monitoring on mud and mud-water was required to protect the environment, thus human health.

Keywords: *environment, heavy metals, Lusi mud, Porong river*

Introduction

It was started at 26 May 2006 when the first gas and mud volcano spewed from well at Sidoarjo, East Java and its named Lusi or Lapindo mud. 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 m^3 per day (Plumlee et al., 2008; Jalil et al., 2010; Manzzini et al., 2012) 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 geohazard risks in a densely populated area with many activities and infrastructures (Istiadi et al, 2009). Some scientists believed that the Lusi 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 Lusi mud volcano was debated, but maintaining the impact of the mud on social and environment is important. Not only evacuated around thousands people (Manzzini et al., 2012), but also monitoring water, land and air quality under permit able condition is urgently necessary, due to some scientist stated that the eruption may be a mud volcano forming, and may be impossible to stop. Indonesia Government which is represented by BPLS (Badan Pelaksana Lumpur Sidoarjo) decided that the only way to discharge the mud volcano is through Porong River . The Porong river is classified as level III where the purpose is for fresh water farming, cattle farm, agriculture irigation according to Indonesian Government Regulation No 82/2001.

In the environment, the present of nature contaminants can range from toxic heavy metal (loid)s to present organic pollutants. Its depend on the interaction of intrinsic properties contaminants with soil properties. The existency of Metal(loid)s either as cations (heavy metal such as Cd, Cu, Zn and Pb) or anions (metalloids such as Cr, As) in the soil environment is significantly affects metals sorption, mobility and solubility in soils (Naidu and Bolan, 2008). When contaminants enter the freshwater system transformation processes will occur along with additional processes due to aqueous environment, such as mercury, and arsenic. It was stated that each source of possible contamination content on mud has its own damaging effects to plants, animals and ultimately to human health, but those that add heavy metals to soils and waters are of serious concern due to their persistence in the environment and carcinogenicity to human beings. They cannot be destroyed biologically but are only transformed from one oxidation state or organic complex to another (Garbisu and Alkorta, 2001). Therefore, heavy metal pollution poses a great potential threat to the environment and human health. Once released to the environment, metals can remain for decades or centuries, increasing the likelihood of human exposure. Thus, identified Lusi's hazardous metals which can affect environment, particularly Porong river where people at Surabaya City are depending their life there and using the river as daily base activity is required to be monitored.

Methods and Materials

The samples of mud and mud-water were collected from different site which were crater, big hole, pond, over flow and spillway. The mud samples were taken from the surface site. The wet samples were analyzed by using Standard Methods Ed 21 2005 bag 3500, US EPA SW-846-3050 B 1996 at Laboratory of Environmental Quality Test- Environmental Agency of West Java Province.

Results and Discussion

The metals concentration on Lusi's mud in 2009 showed that the concentrations of metals spill from the crater were lower than the threshold of environmental concern (Table 1), along with the concentration of metals on big hole, pond and overflow area. 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, resulted that sediments functioning as a deposit and also mercury source to pore waters and biota (Ram et al., 2003; Ramalhosa et al., 2006).

Table 1. The sediment properties of LUSI's mud volcano on July-August 2009 sampling.

Parameter *)	Environmental Soil Quality guidelines*) (ppm)	Crater (22 July) (ppb)	Big hole (5 August) (ppb)	Pond Reno (22 July) (ppb)	Over flow (24 July) (ppb)	Pond Reno ½ (22 July) (ppb)
Fe		31.0156	36.5274	30.4624	35.2873	32.3306
Mn	500	0.8768	0.9309	0.8769	0.8869	0.8476
Zn	200	0.1338	0.0879	0.147	0.0967	0.1607
Cu	60	0.0184	0.0158	0.0176	0.0209	0.0172
Cr	50	0.0186	0.0141	0.0186	0.0092	0.0147
Cd	3	nd	nd	nd	nd	nd
Pb	300	0.023	0.0143	0.0169	0.0154	0.014
Co	170	0.0167	0.0127	0.0242	0.0127	0.0131
Ni	60	0.0148	0.0093	0.0143	0.0186	0.0122
Hg	1	0.0023	0.000659	0.0015	0.0028	0.0011
As	20	nd	nd	nd	nd	nd

*) nd = not detected

In addition, through methylation processes which is mediated by bacteria in sediments, its convert mercury into methyl mercury, the most toxic lipophilic form (Heyes et al., 2006; Kim et al., 2006). The methylmercury which is in organic form is bio-available, accumulating along food chains due to bio-concentration and bio-magnification (Baeyens et al., 2003; Gochfeld, 2003; Tchounwou et al., 2003). It is indicated that 25-60% of Hg (II) and methyl mercury organic complexes are particle-bound in the water column, and the rest is dissolved and DOC-bound phase (Bloom et al., 1991). Therefore, mercury is now acknowledged as a global, diffuse and chronic problem (SEC, 2005) due to its high toxicity to humans, ecosystems and wildlife. Hein et al. (2006) stated that the present of mercury in Gulf of Cadiz mud volcanoes, reached a maximum of seven times the mean concentration in reference cores. It was pointed out that the high metal content in mud volcano sediments from offshore southern California is a result of leaching of basement rocks by fluid circulating along an underlying fault, which also allows for a high flux of fossil methane. It was indicated that the high levels of mercury found in the sediments from the Gulf of Cadiz mud volcanoes.

In many part of the world it was reported that arsenic enrichment and its mobilization in subsurface environments causes health concerns (Smedley and Kinniburgh, 2002; Kar et al., 2010). The arsenic enrichment has also been known well associated with mud volcanoes and geothermal fields (Nath et al., 2008).

Some investigations have suggested that pyrite oxidation and siderite dissolution were among the possible As sources in the groundwater of many areas such as the Chianan plain and the Choushui River alluvial fan in Southern Taiwan (Lu et al., 2010). Arsenic is well known to be adsorbed on Fe or Mn oxide/hydroxide minerals in subsurface sediments (Smedley and Kinniburgh, 2002). As-rich minerals may therefore release arsenic as a result of weathering of alluvial sediments (Saunders et al., 2005), and arsenic may subsequently be released into the groundwater through reductive dissolution of Fe(III) oxyhydroxides under reducing conditions (Nath et al., 2008; Polizzotto et al., 2008). 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. Of these, fluoride and nitrate are perhaps of the greatest potential concern due to their elevated concentration in the waters (Plumlee et al., 2008).

The physical and chemical of mud-water showed that the level of some elements on mud-water were high, above the environmental standard (Table 2). The level of Total Suspended Solid (TSS) was doubled the environmental standard. As levels of TSS increase, a water body begins to lose its ability to support a diversity of aquatic life. Suspended solids absorb heat from sunlight, which increase water temperature and subsequently decrease levels of dissolved oxygen.

Table 2. The physical and chemical properties of LUSI's mud volcano on July-August 2009 sampling

No	Parameter	Unit mg/L	Threshold value for river class III*)	Crater (22 July)	Big hole (5 August)	Pond Reno (22 July)	Over flow (24 July)	Pond Reno ½ (22 July)	Spillway	Estuary	Porong"s upstream
1	Physical										
2	Temperatur	oC	40	62	83	40	32.7	43	33.6	33	31
3	Total Suspended Solid (TSS)	mg/L	400	418,100	241,000	219,000	265,000	573,350	120.5	61.4	19.4
4	Total Dissolved Solid (TDS)	mg/L	1000	28,720	59,500	32,550	49,000	27,220	285	17880	385
	Chemical										
1	pH			7.54	7.48	7.66	7.4	7.15	7.8	7.9	8.5
2	Sulfide (H_2S)	mg/L	0.002	0.12	0.1	0.16	0.02	0.1	0.01	0.01	0.01
3	Fluoride (Fl)	mg/L	1.5	n.d	0.46	n.d	0.39	0.56	n.d	0.59	n.d
4	Free ammonium (NH3-N)	mg/L	=0.02	7.68	28.19	0.39	0.57	1.15	0.01	0.09	0.04
5	Nitrate (NO_3-N)	mg/L	20	0.08	0.05	0.09	0.09	0.08	1.41	0.05	0.04
6	Nitrit (NO_2-N)	mg/L	0.06	0.02	0.0002	0.003	0.01	0.01	0.09	0.03	0.01
7	BOD	mg/L	6	1055	256	362	825	564	6	37	7
8	COD	mg/L	50	2600	640	968	1952	1408	12	79	17
9	Phenol	µg/L	1	0.06	3.39	0.03	0.09	0.02	-	-	-

*) Under regulation of Republic Indonesia No. 82/2001: n.d = not detected

As less oxygen is produced by plants and algae, there is further drop in dissolved oxygen levels. 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. In addition, the level of BOD and COD were high. Accumulation of NH_3-N and Cl occurred in estuary where the Porong' river is end. This was not caused by the Lusi's mud only, but also the occurrence of these materials on Porong's upstream where the amount of NH_3-N and Cl were higher at upstream than spillway, due to many factories in Surabaya city discharged their waste water to Porong river. In addition, Surabaya City is well known as an industrial city, and the second largest city in Indonesia.

Conclusion

The level of heavy metals on Lusi's mud was below environmental soil quality guidelines. The level of physical and chemical on Lusi's mud-water were above environmental water quality guidelines. Regular monitoring of Porong River is necessary to protect human health and further environmental disaster.

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