Impact of anthropogenic activity and lusi-mud volcano on fish biodiversity at the Brantas Delta, Indonesia

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Abstract. Investigation to examine the impact of anthropogenic activity and unstoppable hot mudflow by the “LUSI” mud on the environment and fish biodiversity has been carried out. Water quality analyses including heavy metal and phenol concentration from the site were determined using AAS and spectrophotometer. Physico-chemical analyses at the location showed high levels of pollutants: including a high level of phenol and heavy metal such as lead, cadmium and mercury. The discharge of these pollutants into the river body, estuaries and coastal environment influenced fish biodiversity. Data on fish diversity taken by comparing fish data from reports after the eruption in 2006 with the data before the eruption from the previous study shows a decrease of diversity. Seven years after the eruption, there were nine important economic species consumed by local people of the deltas need to be taken seriously.

1. Introduction
The Brantas with long of 320 km from the spring river at the mountainous area to the estuaries of Madura Strait, is the longest river in East Java. The width of the river flow stream basin is about 12,000 km² or 25% the width of East Java. The Brantas River flows through several big cities, which becomes the prominent zones in East Java. For the people of East Java, the Brantas has a very important role in the socio-economic aspects for supplying freshwater necessities, whether domestic or industry, irrigation, electricity energy, recreation infrastructure, transportation, and other necessities. The Brantas is facing many problems since the last time, such as the flood in the rainy season, the dryness in the dry season, its sediment, the conflict of human necessity, water pollution, and other problems. Many industrial companies operate around the Brantas catchment zone that may add the problem in the area.

The problems of the Brantas at the deltas and estuaries in the Northern Java coast increased by the occurrence of volcanic mud named “Lumpur Sidoarjo” or “LUSI” since May 29, 2006. Davies et al. has provided the history of the LUSI site and eruption [1,2,3,4,5]. It led to detrimental effects on the environment and ecosystem at the Brantas Deltas and its surroundings in the East Java area. High sedimentation was smothering aquatic and marine life, as indicated by a high level of suspended solids and dissolved solid mentioned by Bapedal of East Java in 2006. Water Quality analyses showed high
levels of heavy metal such as lead, cadmium and mercury and phenol. The pollution from anthropogenic activities and other environmental changes may impact on the decrease of fish species number. This paper reported about ecological impacts descriptively at the studied areas, including chemical analysis and impact on fish biodiversity.

2. Material and methods
2.1. Study area and water quality sampling
Sampling was carried out at the Brantas Deltas are in Sidoarjo, East Java, Indonesia. The sampling was including water from the deltas to analyses its chemical parameter. The water samples were brought directly to the laboratory of Chemistry at the University of Brawijaya to be analyzed for water quality. Heavy metals (Pb, Hg, Cd, Zn) concentration were measured using Atomic Absorption Spectrometer (AAS method). Phenol concentration was determined using a spectrophotometer on 500 nm of wavelength.

2.2. Fishes data
Fishes data were taken from the East Java Fisheries Office (Dinas Perikanan Jawa Timur) for cultured fish. Wild fishes were taken directly from rivers at the Brantas Delta and wetland near the LUSI mud eruption, in detail at Surabaya, Kalimas, Porong and Aloo Rivers by a gill net, and were identified of each species. The data reported as the percentage of species of the total caught. Other sources present data were taken into the discussion from the census reported by Ecoton previously and from other studies [6,7]. The present status of fish biodiversity is compared to the past status as historical data as overviewed previously by Risjani et al., and Weber and de Beaufort [8,9]. The overall study used descriptive analyses.

3. Results and discussion
3.1. Chemical pollution in the area
The Brantas Deltas included several branches of the river bodies: the Porong and Aloo rivers. Volcanic mud in Sidoarjo District at the deltas that erupted in 2006 caused the change of ecosystem. As studied by PSLS in 2007, the composition of mud is a fluid mixture of salt water (30%) and solids (70%) in the form of coarse sand, fine sand, silt containing hydrocarbons, steam, and gas (H2S). The mud eruption that overflow 160,000 m3 per day has changed the temperature and salinity of the area, from lower to higher, from freshwater to brackish water. It also caused an increase in total suspended solids (TSS) and total dissolved solids (TDS). At the center of eruption, Total Suspended Solid (TSS) reached 252 mg/L and Total Dissolved Solids (TDS) reached 226,000 mg./L (Data from BAPEDAL East Java, 2006). The last data showed TSS attained 86 ppm and BOD was 40 ppm in the Porong River at the site after the Lusi-mud outflow pipe [10]. Water Quality analyses on sites closed to the eruption area showed a higher level of heavy metals and phenol concentration. The level was also high on the Porong river (Tables 1 and 2), where the volcanic mud flowed via this river to the sea. Heavy metal concentration at this river was over the limit standard permitted by the Indonesian Government (PP No 82/2001) [11].

| Heavy metals | Ppm (Mg/L) | Standard [11] |
|--------------|------------|--------------|
| Pb           | 0.355-0.552| 0.03         |
| Cd           | 0.33-0.067 | 0.01         |
| Hg           | 0.039-0.079| 0.002        |
| Zn           | 0.305-0.450| 0.05         |
Phenol concentration from the different sites at the deltas showed very high, and above the standard permitted by the Indonesian Government (KEP No 51/MENLH/10/1995 and PP No 82/2001 3rd class) [11], the level is varied between 2.84 - 4.98 mg/L (Table 2). Phenol or 4-1,1,3,3-tetramethyl butyl- is a monosubstituted aromatic hydrocarbon, combustible, soluble in water and evaporates more slowly than water. It has other synonyms: Benzenol, hydroxybenzene, monophenol, oxybenzene, phenyl alcohol, phenyl hydrate, phenyl hydroxide. It produces through both natural and anthropogenic processes (EPA, 2002) [12]. Another study conducted in 2006 by Herawati [13] also showed that the Phenol level is between 3 and 5.9 mg/L measured near the eruption area. Gad and Saad reported fish physiological effects by phenol [14].

Table 2. Phenol concentration from the different sites at the Brantas Deltas (the data was taken seven years after the Lusi eruption).

| Sites           | Position                  | Phenol (mg/L) | Standard and Regulation                      |
|-----------------|---------------------------|---------------|---------------------------------------------|
| Gempol sari     | 7°32'41.83"S ; 112°43'36.79"E | 3.53          | 0.5-1.0 mg/L (KEP No 51/MENLH/10/1995)       |
| Kaliporong      | 7°32'23.97"S ; 112°46'37.01"E | 4.14          |                                              |
| Kalidawir       | 7°31'10.87"S ; 112°48'50.80"E | 2.84          | 0.001mg/L                                    |
| Penatarsewu     | 7°33'24.97"S ; 112°52'19.74"E | 4.98          | (PP 82/2001 3rd class)                      |

3.2. Ecotoxicological impact on aquatic biodiversity

Data on Table 3. shows the economically important species caught from the Brantas Delta. Nine consumable species have been identified at the Deltas. Among fishes caught, Oreochromis mossambicus (local name: mujaer) and Barbonymus gonionotus (tawes) were important in number at the sites of anthropogenic activity like Surabaya and Kalimas River, while Mystus gulio or Keting occupied Porong River, the sites that received an impact from the LUSI mud volcano.

Natural changes and anthropogenic activities caused physical and chemical pollution, and these problems influenced aquatic biodiversity in the studied areas, for example, the indigenous fishes of the Brantas. The past fishes data from 1916 to 1962, there were 87 species on the Brantas River [9]. Another study reported by Risjani et al. [8] collected 50 species, included 18 species of indigenous fishes. In 2009, a fish census by Ecoton found 17 species between the middle to downstream of the Brantas and only 11 species in 2011. The last study by Hayati et al. [7] in Karangkates and Surabaya River found 25 species. This observation showed that pollution from anthropogenic activities and other environmental changes have an impact on the decrease in fish species.

The census on sex ratio by Ecoton in 2011 showed a balance between males and females in the majority of the deltas, except in the most populated area on Kali Surabaya (Kali Mas), where more than 84% of total species were female. It seems, probably, the imposex and feminization of males have occurred for fishes inhabited this area. The change of sex ratio can be caused by estrogenic hormonal existed on the river [14]. A future deeper study needs to be done for this issue.

Table 3. The number of individual consumable fishes caught from the Brantas Delta seven years after LUSI eruption.

| Site       | Local name | Species          | The number caught by a gill |
|------------|------------|------------------|----------------------------|
Volcanic mud that erupted in 2006 in Sidoarjo, has impacted on fisheries production, particularly of milkfish and shrimps cultured on brackish water ponds or tambak near the mudflow. These species were economic importance in the region. Fishermen only have half of fisheries production compared to the time before the eruption occurred but the Office of Marine and fisheries of East Java Province has given the new supply for the loss of fisheries production of this district. Nine species were found in the areas closed to the eruption and around the deltas (Figure 1). Those important economic fishes were originated from four different sites, namely, Porong and Aloo Rivers that received an impact from the Lusi-mud in Sidoarjo and from Surabaya and Kalimas Rivers that related to anthropogenic activities. The study data limit only from consumable species (Table 3).

![Figure 1](image_url)

**Figure 1.** Percentage of the number of economically important species consumed by local people caught from the Brantas Delta by a gill net. The data was based on the number of each species caught at all sites per total number of species multiplied by 100.
Another study shows there were nine species found where 7 of them are common species consumed by local people. *Oreochromis mossambicus* was found more than 40% of the total species naturally at the areas around the center of eruption, but the content of heavy metals in the fish tissue was relatively high. Cadmium was 0.62 mg/L and lead (Pb) was 1.36 mg/L [6]. We noted an interesting phenomenon that an invertebrate species, *kupang* increased and dominated more than 75% of total masses after mud eruption at the estuary of the Brantas Deltas. Fish morphology also changed as seen on several individual fish, particularly of important economic fishes, for example, *Channa striata* from Aloo river (Risjani, unpublished report).

As fish morphologically changed, the pollution may also affect aquatic organisms physiologically [5,15]. This pollution may alter several responses of aquatic organisms such as physiological processes, reproduction, immune system, and development. More studies need to be done to get endocrinological data on fishes that occupy this area.

4. Conclusion

The anthropogenic and environmental impacts at the Brantas are increasing from year to year. The environmental impacts and hazards due to the unstoppable hot mudflow at the delta have changed the ecosystem in the area. Seven years after the eruption, there were nine important economic species consumed by local people of the deltas need to be taken seriously. Since the eruption in 2006, the Indonesian government has made many attempts to stem the flow of mud from the sources and to carry social treatments in the area. Strategies are needed to minimize environmental impacts and to manage the ecological -social impact. Analyses and studies should be undertaken not only to examine its impact on the environment but also to examine its impacts on living organisms and including human health. Further studies on physiological changes in aquatic organisms and health assessment are needed to be conducted.

References

[1] Davies R J, Brumm M, Manga M, Rubiandini R, Swarbrick R, and Tingay M. 2008. *Earth. and Planet. Sci. Lett.* 272 627–38
[2] Mazzini A, Svensen H, Akhmanov GG, Aloisi G, Planke S, Malthe-Srenssen A and Istadi B 2007 *Earth. and Planet. Sci. Lett.* 261 375–88
[3] Cyranoski D 2007. Muddy Waters *Nature* 445 812-815
[4] United Nations Final Technical Report 2006 *United Nations Disaster Assessment and Coordination mission* (Switzerland by the Joint: UNEP/OCHA Environment Unit) p 53 http://rovicky.wordpress.com/files/2006/09/environment_assessment_report_final.pdf.
[5] Risjani Y, Yunianta, Couteau J and Minier C 2014 *Marin. Environ. Res.* 96 73-80
[6] Purnomo T, Marsoedi, Sukoso and Yenny R 2009 *Int. Conf. on Bio. Sci.*
[7] Hayati A, Tiantono N, Fadhil M M, Dary S P I, Abdizen M M, Seta A R and Solikha B M 2017 *J. of Bio. Res.* 22 43-4
[8] Risjani Y, Sudaryanti S, Batorio D, Herawati E Y and Musa M 1998 *Biodiversity of the Brantas River Basin* (Indonesia: Fac of Fisheries and Marine Sciences Universitas Brawijaya) p 107
[9] Weber M and de Beaufort L F 1962 *The fishes of the Indo-Australia Archipelago I-XI* (New Delhi: A7 Reprints Agency )
[10] Safii I, Risjani Y and Widjanarko P 2017 *J. of FLS* 1 43-48
[11] Government Regulation Number 82 year 2001 regarding Management of Water Quality and Water Pollution Control (in Indonesia)
[12] EPA, 2002. Toxicological Review of Phenol. IRIS. EPA/635/R-02/006.
[13] Herawati N 2007 *Lapindo Mudflow Water Flow Environmental Risk Analysis to the Water Agency* (Case Study of Porong River and Aloo River - Sidoarjo Regency) (Semarang: Master Thesis Universitas Diponegoro Semarang) (in Indonesia)
[14] Gad N S and Saad S A 2008 *Global Veterinaria* 2 312-319
[15] Shobikhuliatul J J, Andayani S, Couteau J, Risjani Y and Minier C 2013 *J. of Bio. and Life Sci.*
[16] Risjani Y, Musliha S, Hermawati A, Couteau J and Minier C 2012 *Comp Biochem Physiol Part A* S42