

Cadmium Pollution in Soil of Rice Fields Around Lapindo Mud Using The Geoaccumulation Index (I-Geo)

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Article Information	ABSTRACT
Article History Received : July 04, 2025 Revised : July 21, 2025 Published : July 31, 2025	The Lapindo Mud Disaster is a phenomenon of overflowing mud from the earth's crust that occurred in Sidoarjo. One of the impacts of the hot mud eruption on agricultural fields. This study aims to analyze the content of heavy metal cadmium in the soil of rice fields around the Lapindo Mud. The heavy metals analyzed include Cadmium (Cd), which is used in the Geoaccumulation Index (Igeo), with Class 7 of Igeo used to determine the level of heavy metal contamination due to a disaster that occurs. The results of this study indicate the largest Cadmium (Cd) metal content in the sample in Gempol Sari village, at 1.08 mg / L and 0.007 mg/L, respectively. This exceeds the threshold set by the Environment Protection Ministry of China (EPMC) and contaminates the rice field environment. Based on the Igeo calculation (geoaccumulation index) applied to the concentration of heavy metals in rice field soil not contaminated by Cadmium, with an index value of $0 < i_{geo} < 1$. Geoaccumulation Index figures in the research area, cadmium (Cd) content is within the normal range, so it is not included in the group of heavy metals that pollute the soil.
Keywords: <i>Cadmium; Geoaccumulation index; Heavy metal; Soil.</i>	

INTRODUCTION

The Lapindo mud disaster is a phenomenon of mud overflow from the mother's stomach that occurred in Sidoarjo. One of the impacts of the mudflow is the land in the rice fields. The rice field area has been inundated by Lapindo mud (Wijaya 2019). The results of preliminary tests of Cd metal content in 3 locations and 6 sampling points obtained an average of 0.99 mg/L and 0.003 mg/L, respectively.

Hazardous heavy metals such as Cadmium (Cd) and Mercury (Hg) are sources of environmental contamination. Some sources of Cd and Hg input into the soil include the use of agrochemicals, the application of organic fertilizers made from municipal waste and industrial waste. The presence of heavy metals in the soil can occur naturally or anthropogenically (Syachroni, 2017). According to research conducted by Purbalisa et al., (2017) if Cd in rice field soil is 2.58. This is because Cd is basically naturally present in the earth's crust, industrial waste disposal can also increase the Cd content in the soil, in addition. excessive use of inorganic fertilizers can also increase the cadmium content in the soil. One of the causes of heavy metal pollution comes from gold mining industry waste. Mapping the distribution of cadmium pollution in Sidoarjo has an impact on the pollution of rice fields, especially on the soil and water of rice fields. Some areas of Sidoarjo Regency have rice field pollution (Fitrianah,et.al, 2022)

This study focuses on the impacts caused by the agricultural sector aspect, researchers will identify and analyze the content of heavy metals in the soil of rice fields in Porong, Jabon, and

Tanggulangi Districts, Sidoarjo Regency. The location was chosen because it was close to the Lapindo mud and exposed to mudflows which caused a decrease in the quality of rice field soil in the area. The heavy metal to be analyzed Cadmium (Cd) is used the geoaccumulation index (Igeo) to determine the level of heavy metal contamination due to a disaster that occurred. (Wu et al., 2014).

The level of heavy metal contamination to determine the condition of an environment can be identified through the calculation of the contamination index. Poland (Skorobilowicz et al., 2024) using Geoaccumulation Index (Igeo), calculations can classify moderately, severely, and highly polluted areas based on the concentration of heavy metals originating from anthropogenic materials such as industrial, agricultural, and mining activities. This study aims to analyze the content of heavy metal cadmium in the soil of rice fields around the Lapindo Mud. The heavy metals analyzed include Cadmium (Cd), using the Geoaccumulation Index (Igeo). Due to the lack of research on heavy metal content and sediment pollution status, this study was conducted to determine the concentration and level of heavy metal pollution in sediment in Sidoarjo Regency based on the Geoaccumulation Index (Igeo). The results are expected to provide information to the public about the level of heavy metal sediment contamination that can impact environmental aspects.

RESEARCH METHODS

Location

This research was conducted in Gempolsari Village, Tanggulangin District, at a distance of 1.61 km from the center of the mudflow, Gelagah Village, Porong District, at a distance of 1.30 km from the center of the mudflow, and Besuki Village, Jabon District, at a distance of 1.41 km from the center of the lapindo mudflow, Sidoarjo Regency.

Population and Sampel

The population in this research is the Isawah land in the area around the Lapindo mudflats. iLand sampling was carried out at 3 locations by taking 6 land samples from each location with a total of 18 samples. The first location is in Gempolsari Village, Tanggulangin District (A1, A2, A3, A4, A5, A6), the second location is in Gelagah Village Porong District (B1, B2, B3, B4, B5, B6), and the third location is in Besuki Village, Jabon District (C1, C2, C3, C4, C5, C6).

Research Variables

The variable used in the research is a single variable, this variable includes the cadmium content (Cd) and pH of the rice fields around the Lapindo mud in Sidoarjo Regency.

Research Design

This research was an experimental laboratory study, specifically for cadmium (Cd) analysis. Samples were digested using a closed-reflux wet digestion method, varying the composition and total volume of the digester. Cadmium levels were then analyzed using atomic absorption spectroscopy (AAS) at a wavelength of 228.8 nm.

Data Analysis

The research began by taking samples of soil at each location point that had been determined, then after taking the samples, tests for the heavy metal content of Cd and Hg were carried out in the Research and Industrial Consultation Center. From these results, the contamination factor was analyzed using the Cf index and land pollution using the geoaccumulation index. The results of the index are then compared with the actual index

There are seven classes (ranging from 0-6) of Igeo usually used to assess the level of accumulated anthropogenic or geogenic pollutant load (Bhutiani et al., 2017). According to Guan et al. (2014), Igeo is suitable for assessing heavy metals in soil contaminated by industrial activities. This index classifies the level of soil pollution. Hoque, et al. (2023) explain class 7 of Igeo includes:

- a. Class 0 = $I_{geo} < 0$ (unpolluted)
- b. Class 1 = $0 < I_{geo} < 1$ (Not polluted medium)
- c. Class 2 = $1 < I_{geo} < 2$ (Medium polluted)
- d. Class 3 = $2 < I_{geo} < 3$ (Pollution Moderate to high)
- e. Class 4 = $3 < I_{geo} < 4$ (High pollution)
- f. Class 5 = $4 < I_{geo} < 5$ (Pollution is very high)
- g. Class 6 = $5 < I_{geo} < 6$ (very polluted)

The Igeo calculation formula is as follows based on the research Mohiuddin *et al.*, 2010.

$$I_{geo} = \log_2 (C_x / 1,5 B_n)$$

C_x = Concentration of metal x in the sample

B_n = normal concentration of metal x in nature (background)

RESULTS AND DISCUSSION

The results and discussion sections contain the results of data analysis content of cadmium in rice fields and Index of Pollution of Rice Field Soil by Cadmium Metal (Cd).

Content of Cadmium in Ricefields

Based on the results of the research that has been carried out in analyzing the content of heavy metals, namely Cadmium (Cd) in the soil around Lapindo mud in Sidoarjo Regency, the results obtained are as shown in Table 1.

Tabel 1. Content of Cadmium

Sampel	Content Cd (ppm)	Standard	pH
A1	1,08	above standard quality	5,68
A2	1,05	above standard quality	5,56
A3	1,06	above standard quality	5,6
A4	1,03	above standard quality	5,7
A5	1,04	above standard quality	5,62
A6	1,03	above standard quality	5,64
B1	1,02	above standard quality	6,01
B2	1,03	above standard quality	6,03
B3	1,01	above standard quality	6,1
B4	1,00	above standard quality	6,09
B5	1,01	above standard quality	6,11
B6	1,02	above standard quality	6,12
C1	0,98	above standard quality	6,26
C2	0,95	above standard quality	6,24
C3	0,86	above standard quality	6,15
C4	0,9	above standard quality	6,2
C5	0,92	above standard quality	6,21
C6	0,91	above standard quality	6,17

Information:

Quality standards is 0,6 ppm based Threshold refers to Environment Protection Ministry Of China (EPMC), 2015.

A: Location of ike-1 sample collection point in Gempolsari Village

B: Location of the second sample collection point in Gelagah Village

C: Location of the 3rd sample collection point in Besuki Village

Cadmium (Cd) is considered a serious pollutant because of its toxic properties, tendency to enter the food chain, and ability to stay in the environment for a long time (Ansari et al, 2004).

In the research location, samples detected through laboratory analysis had a concentration above 0.6 mg/L, above the threshold. The highest Cd is the A1 sample from Desa Gempol Sari with a concentration of 1.08 mg/L. According to Setyoningrum (2014), the influencing factors are pH and soil organic materials. Cadmium (Cd) in soil with low pH tends to be smaller when compared to soil with high pH. In soil conditions with a low pH, the element Cadmium (Cd) will dissolve in the soil water so that it is more easily leached into the lower layers of the soil if it rains or is absorbed by plant roots in the nutrient absorption process. In soil conditions with high pH, cadmium (Cd) will be bound by soil colloids and organic materials or precipitated in the form of hydroxide, so that it is avoided from the leaching process and absorption by plant roots. In research conducted by Serdani and Widiatmanta (2019), adding Lapindo mud to growing media at high concentrations can cause plant death due to the high heavy metal content. In plants, they can disrupt important physiological processes, causing reduced growth, chlorosis (yellowing of leaves), and nutritional imbalances that lead to plant death. Furthermore, heavy metals can also damage soil microorganisms that play a vital role in maintaining soil health. Heavy metals can disrupt microorganism populations and disrupt their metabolic processes, leading to an imbalance in nutrient availability and a decline in soil health.

This is in line with research showing that as much as 90% of heavy metals found in the aquatic environment will be deposited in sediment. (Amin, et al., 2011). In addition, heavy metals have properties that bind organic materials and settle to the bottom of the ocean and unite in sediment so that heavy metal levels will become higher than the levels of heavy metals in the air.

Mud pollution in water bodies can impact biodiversity and ecosystems in the long term. Water contaminated with mud containing metals can damage ecosystems, including the death of plants, biota, animals, and microorganisms. Mud pollution in water bodies can also inhibit growth and development processes, impacting productivity and the services provided by ecosystems (Ngabekti et al., 2019). Furthermore, water pollution due to mud can damage genetic resources, accelerating the erosion of genetic diversity or the loss of genetic resources.

Heavy metals found in water around rice fields cannot decompose in water, resulting in water pollution, and metals accumulate. Heavy metals in the water are absorbed and accumulated by plants (Syafriiliansah et al., 2022). Soil contaminated with metal waste can cause plant stunting and damage the ecosystem, due to the physical and chemical properties of the soil. Another impact of heavy metal pollution on human health is when plants grown in contaminated areas are accidentally consumed by humans (Putri et al., 2023).

Index of Pollution of Rice Field Soil by Cadmium Metal (Cd)

Based on the results of the research that has been carried out in analyzing index pollution in Table 2.

Tabel 2. Index of Pollution

Number	Indeks Geoakumulasi (Igeo)		
	Point A	Point B	Point C
1	0,36	0,34	0,32
2	0,35	0,34	0,31
3	0,35	0,33	0,28
4	0,34	0,33	0,3
5	0,34	0,33	0,30
6	0,34	0,34	0,30

Source: Results Analys, 2022

Based on the research data above, the meaning of the Igeo index is obtained. Based on Table 2, it shows the Geoaccumulation Index figures in the fish research area, the content of cadmium (Cd) is in the normal range, so it is not included in the group of heavy metals that pollute the soil. However, in the calculation of the fish contamination factor, the cadmium content is classified as highly polluted because in the calculation of the Geoaccumulation Index, the 1.5 million factor is used to take into account possible variations in the threshold data due to lithology. Based on research by Suganda et al., (2006), the land contains the heavy metal Cd, not as a result of pollution but as a derivative of the parent material of the land. The results of metal analysis on the land are still classified as very low or it can be said that the land is not yet polluted.

The study site had a pH value ranging from 6.9 to 8.2 pH units. The soil at a depth of 15 cm (center) showed different results than previously. The craft site in the east showed a high pH value, while the one in the west showed a lower pH value. For the soil at the lowest depth (25 cm), the pH value showed similar results to the soil in the center. This is because pH plays a crucial role in determining heavy metal mobility in soil (Kicińska et al., 2022).

This is consistent with research on cadmium contamination in rice paddy soil. A study in Kermanshah Province, Iran, found several trace elements in agricultural soil (Ahmadi et al., 2019). The Igeo order for trace elements was Ni>Cu>Cr>Mn>Zn>Fe. The high Igeo values for Ni and Cu in agricultural soil indicate significant Ni and Cu contamination in the soil in this area. In Moroccan agricultural soil, the average Igeo levels were -0.79, -1.06, 0.62, -1.97, and 0.90 for cadmium, chromium, copper, lead, and zinc, respectively. The average Igeo values for cadmium, chromium, and lead were below 0 (Igeo < 0), indicating that the studied soil was not contaminated by these metals (Ennaji et.al., 2020)

In a study of Saudi Arabian agricultural soil, calculated Igeo values for elements, including Pb and Cd, indicated that all analyzed samples were uncontaminated. The variations in contamination factor and Igeo for metals observed in the soil in this study may be due to both natural processes and various human-made sources. The causes of these high metal(loid) levels could be the soil itself, the use of manure, chemical fertilizers, pesticides, and increased soil salinity due to sprayed water. Therefore, it is important to inform farmers and the government about this issue so that appropriate measures can be implemented to prevent further soil degradation in pistachio orchards (Al Bagawi et.al., 2021).

CONCLUSION

Based on the research that has been conducted, it can be concluded that the largest content of Cadmium (Cd) metal in sample A1 in Gempol Sari Village is 1.08 mg/L and 0.007 mg/L, respectively, which means it exceeds the threshold according to EPMC and contaminates the rice field environment. The results of the geoaccumulation index of the rice field soil location at the sampling location point are not contaminated with cadmium metal. Mitigation measures or the need for regular monitoring in the affected areas include Soil Monitoring using regular testing of

cadmium content in the soil, irrigation water monitoring using analyzing heavy metal content in water sources, agricultural product Monitoring by testing Cd content in rice or other food crops and public health monitoring by conducting surveys and health education for the surrounding community.

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