Cadmium concentration in water and sediment from lake Lau Kawar, North Sumatra

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Abstract. Heavy metals are easy to bind organic matter and settle to the bottom of the waters and unite with sediments, which is cadmium. Cadmium (Cd) is found from volcanic eruptions, from various human activities, and is carcinogenic. This study aims to analyze the concentration of cadmium in water and sediment in Lake Lau Kawar. Water samples were collected by purposive sampling at three stations using Horizontal Bottle samples. Sediment samples were collected compositely using an Eckmann grab then analyzed by the Atomic Absorption Spectrophotometer method. Descriptive data analysis used comparative quantitative methods, namely comparing the level of cadmium in water and sediment in Lau Kawar Lake with the quality standards set by WHO and IADC/CEDA. The water quality in Lake Lau Kawar is in good condition. The concentration of heavy metal Cd in water and sediment still meets the established water quality standard criteria. The source of Cd contamination in the lake, which comes from the volcanic ash of Mount Sinabung, is only carried in low quantities. The largest source of contamination comes from the activities of residents as fertilizers and pesticides used on agricultural land.

1. Introduction
Cadmium (Cd) is a heavy metal that is carcinogenic in both human and animal bodies. Cadmium is found in the earth's crust or as a result of volcanic eruptions. In addition, cadmium produce from various human activities, both intentional and unintentional. Examples are fuel, forest fires, industrial waste, and the use of fertilizers and pesticides. Cadmium widely uses in various industries including, metal plating, metal smelting, coloring, batteries, lubricating oils, fuels. Fuel and lubricating oil contain Cd up to 0.5 ppm. Coal contains Cd up to 2 ppm, superphosphate fertilizers also contain Cd, and some even reach 170 ppm. Liquid waste from industry and the disposal of used lubricating oil containing Cd enter the sea waters. The remnants of fuel combustion are released into the atmosphere and then fall into the sea (lake) [1].

Contamination of cadmium from mining and smelting operations poses crucial threats to aquatic environments because of its toxicity, persistence, bioaccumulation, and biomagnification in the food chain [2]. Under certain environmental conditions (e.g., water temperature, pH, hardness, and river flow) and biotic factors (e.g., organism life-history traits), they can accumulate to toxic concentrations and cause ecological damage [3].
Water quality is essential for the survival of an organism. Temperature, pH, light penetration, DO, and BOD play a vital role in the survival of an aquatic ecosystem. In addition, particles in water and sediment surfaces can accumulate heavy metals and pollute waters. The concentration of heavy metals in aquatic biota can form complex compounds with higher concentrations. Heavy metal complexes in sediments have high solubility in water and marine biota body organs. That causes heavy metals to infiltrate deep into the body tissues of aquatic biota. The concentration of heavy metals in sediments is highly dependent on the type of sediment, duration of contact, temperature, reduction, pH, salinity, and density of waters. Sediments exposed to heavy metals can be a source of heavy metals in water, even though the first source is lost. That happens because the remobilization and diffusion of heavy metals from the bottom sediment layer move to the surface through the flow of water in the sediment pores [4].

Lake Lau Kawar is one of the lakes in North Sumatra, precisely located at the foot of Deleting Puncak, Kuta Gugung Village, Simpang Empat District, and Karo Regency. Lake Lau Kawar is one of the lakes in the Leuser Ecosystem near Mount Sinabung. A small dam builds at the discharge point in 1954 for the irrigation system, and as a result, the water level rose by about 2 meters. Lake Lau Kawar is now around 116 ha, and this only increased slightly after the dam build due to the quite steep sides. The land to the north of the lake is undisturbed forest and to the south is agricultural land with low intensity [5]. We know that recently Mount Sinabung erupted and emitted volcanic ash. The area around the mountain is affected by pollution from volcanic ash, which is Lake Lau Kawar [6]. The characteristics of volcanic ash found on Mount Merapi have P content ranging from (8-232 ppm P$_2$O$_5$). CEC (1.77-7.10 me/100g) and Mg content (0.13-2.40 me/100g), which are relatively low, but the Ca content is quite high (2.13-15.47 me/100g). Sulfur (2-160 ppm), Fe (13-57 ppm), Mn (1.5-6.8 ppm), Pb (0.1-0.5 ppm), and Cd are lowest (0.01-0.03 ppm) [6]. Cadmium is one of the heavy metals contained in volcanic ash. When the lake pollutes for a long time, it can accumulate and cause death for the ecosystem that lives in it [7].

The level of water pollution can determine by analyzing the content of heavy metals that accumulate in water and sediments. Heavy metal content that is high and exceeds the quality standards can be used as data for analyzing pollution of an environment, especially when compared to water quality standards. It is important to have analytical data regarding the content of heavy metals in the waters of Lake Lau Kawar to maintain and preserve the surrounding ecosystem. Thus it will simply anticipate things that are not good in the future. This study aims to analyze the concentration of cadmium in water and sediment in Lake Lau Kawar.

2. Material and method
The study does in March - April 2020 at Lake Lau Kawar, North Sumatera. The samples were water and sediment, the water quality measurements on this research as supporting data. Water samples were collected by purposive sampling at three stations using a horizontal bottle sample. Sediment samples were collected by composites method using Eckmann grab. The measurement of cadmium concentration in water and sediment using the Atomic Absorption Spectrophotometer (AAS) method [8]. Water quality testing in this study used physical and chemical parameters measurements, namely: physical parameters including temperature, pH, brightness, and chemical parameters including DO and BOD. Water sampling was carried out under the requirements of the class II water quality parameter package in the Government Regulation of the Republic of Indonesia number 82 of 2001. The method of collecting and testing carries by referring to the provisions of SNI 03-7016-2004 for testing samples of water and waste. Samples take in three stations at Lake Lau Kawar. The research sites describe in Figure 1.

The research data were analyzed descriptively using quantitative methods in a comparative form. These data compare with the quality standard, namely water 0.0002 mg/L (WHO) and sediment 1000 mg/kg (IADC/CEDA).
3. Results and discussion

3.1. Water quality in lake lau kawar

Inspection of water quality in this study is very important to ensure the results obtained from each sample. The results of water quality inspections from Lake Lau Kawar are presented in Table 1.

| No. | Parameter           | Unit       | Station | Station | Station | Quality standards$^a$ |
|-----|---------------------|------------|---------|---------|---------|----------------------|
| 1   | Temperature         | $^0$C      | 22.6    | 22.9    | 23      | Deviasi 3           |
| 2   | pH                  | –          | 6.5     | 6.5     | 6.5     | 6 – 9               |
| 3   | Visibility          | m          | 1.9     | 1.82    | 1.64    | –                   |
| 4   | DO                  | mg/L       | 6.6     | 7.2     | 6.9     | >4                  |
| 5   | BOD                 | mg/L       | 0.4     | 0.3     | 0.5     | 3                   |

$^a$ Note are PP RI No. 82 of 2001 class II

The results show that the highest water temperature comes from station 3, which is 23$^0$C, the pH of each station is the same, and the highest visibility comes from station 2 of 1.82 m, and then the highest DO value comes from station 2 of 7.2 mg/L. The highest BOD came from station 3 of 0.5 mg/L. Overall, the water quality in the Lake Lau Kawar category is good for the ecosystem in it.
The temperature range in Lake Lau Kawar does not fluctuate or is relatively constant because it does not experience high-up changes. Temperature fluctuations in tropical waters, which are generally throughout the year, have air temperature fluctuations that are not too high, resulting in not too wide annual water temperature fluctuations [9]. In general, this temperature range is the normal range for aquatic organisms, including fish. High water temperatures can accelerate the formation of heavy ions, thereby increasing the metal content in the waters [10,11]. However, at low temperatures, heavy metal adsorption in the waters in the form of particulates increases and settles to the bottom of the water.

Based on the quality standard of PP RI No. 82 of 2001 Class II, water pH and visibility in Lake Lau Kawar are included in the standard criteria (Table 1.). Low brightness conditions result in less intensity of incoming sunlight and cause the photosynthesis in aquatic plants inhibited. Oxygen production by aquatic plants inhibited. Oxygen production by aquatic plants will be small at relatively short brightness conditions in these water bodies [12,13]. The DO value of the waters in Lake Lau Kawar is unpolluted compared to the quality standard of PP RI No. 82 of 2001 Class II. Oxygen demand is closely related to temperature. An increase in temperature will result in a decrease in the solubility of oxygen in the water.

The increasing concentration of heavy metal, the dissolved oxygen content will decrease, and CO₂ will increase. Low oxygen levels require an aquatic biota to pump water through its gills, thereby increasing respiratory flow and increasing dissolved CO₂, so more toxins absorb in the body through the gills [14]. The higher the level of water toxicity, the higher the respiratory flow will be [15].

BOD is an organic matter level, namely the amount of oxygen need from aerobic microbes to oxidize organic matter into carbon dioxide and water. The presence of heavy metals will interfere with the ability of microbes to oxidize organic matter. BOD levels indicate the amount of DO levels required by aquatic organisms in the process of decomposition of organic matter [13]. The results showed that the levels of BOD in the waters of Lake Lau Kawar at all stations were still categorized as optimum levels for the life of aquatic organisms because when compared with the PP RI No. 82 of 2001 Class II, the water BOD level is still at a value of < 3 mg/L. The water quality in Lau Kawar Lake classifies as ordinary for living organisms. The results of this study are in line with the opinion of [16,17] that the level of water pollution in Lake Lau Kawar is between 1-3 with moderate water quality.

3.2. Analysis of cadmium (Cd) concentration in water and Sediment

The results analysis of water samples at three stations in Lake Lau Kawar showed that the concentration of heavy metal Cd in the lake was relatively the same. The concentration of Cd in lake water is <0.0001 mg/L. Base on PP RI No. 82 of 2001 concerning quality standards for water quality control and pollution class II, the water quality criteria applied to metal parameters means maximum Cd is 0.01 mg/L. The data obtained show the concentration of Cd in all stations is still below the water quality standard criteria. The low concentration of Cd in Lake Lau Kawar occurs due to the dilution of heavy metals by the strong influence of lake currents. The opinion is following the research of [18] that the low levels of cadmium (Cd) in the water are more due to the ability of these waters to dilute contaminants which is high.

The results of the analysis of the Cd concentration in the sediment in Lake Lau Kawar were 0.1 ppm (mg/kg). It is still in the lowest concentration compared to the International Association of Drilling Contractor (IADC) quality standard of 1000 mg/kg. The sources of heavy metal Cd in the waters come from natural sources from the earth's crust, such as input from coastal areas originating from rivers and coastal abrasion due to wave activity, current from the deep sea emanate from marine activity, the geology of deep-sea volcanoes, and airborne inputs from the atmosphere as dust particles [11]. Cd can also come from human activities, such as market waste, plantations, and fertilizers. The increase in cadmium sedimentation can affect by natural factors such as rock weathering and anthropogenic [19]. Examples of anthropogenic sources are the use of fertilizers and agricultural waste [20]. In this research, the largest source of Cd contamination came from the activities of residents, such as fertilizers, pesticides used on agricultural land.

Based on data, cadmium concentration in sediments is much higher than in water. The low concentration of Cd in water compared to sediments is due to most of the heavy metal Cd originating from the environment generally being deposited in sediments because sediments are very representative
for recording heavy metal accumulation in waters. [21] Said that 90% of heavy metals that contaminate the aquatic environment deposit in sediments. Heavy metals have properties that easily bind organic matter and settle to the bottom of the water and unite with sediments, hence the levels of heavy metals in sediments are higher than in water [22].

The higher levels of heavy metal content in sediments can affect the metabolic processes of biota that eat organisms that live on the bottom of waters and sediments. The high up accumulation of heavy metals in the body of the biota causes the biota to be unable to tolerate (towards heavy metals in the body) in the end, can cause death [23]. If the lake biota contaminates with heavy metals is consumed, it can damage the biochemical system and is an extreme threat to human and animal health [24]. When Cd enters the human body, it can accumulate in body tissues and cannot be excreted again outside the body. At high levels in the human body, it will cause negative impacts, namely: (1) inhibiting enzyme activity so that metabolic processes disruption, (2) causing chromosomal (gene) abnormalities, (3) inhibiting fetal development, (4) decreasing female fertility, (5) inhibits spermatogenesis, (6) reduces peripheral nerve conduction, (7) inhibits hemoglobin formation, (8) causes kidney damage, (9) causes blood loss or (anemia), (10) swelling of the head (encephalopathy), and (11) cause emotional and behavioral disturbances [25].

4. Conclusion
We conclude that the water quality in Lake Lau Kawar is in good condition for the life of the ecosystem in it. The cadmium concentration in sediments is higher than in water but still in standard criteria specified. The source of Cd contamination in the lake from the volcanic ash of Mount Sinabung carried in low quantities. The largest source of Cd contamination came from the activities of residents, such as fertilizers and pesticides used on agricultural land.

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