Assessment of heavy metals concentration of Mapanuepe Lake, Zambales, Philippines

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ABSTRACT

Despite the absence of recent research, Mapanuepe Lake in the Philippines has been a significant environmental concern due to potential heavy metal contamination. Hence, the study assessed the heavy metal concentration of water and surface sediments and identified the other physicochemical properties of Mapanuepe Lake in San Marcelino, Zambales, Philippines. This descriptive research employed physical profiling and physicochemical characterization of water and surface sediments of the lake. Six sampling stations in the lake were selected based on their current land use and nearness to the point source of heavy metal pollution. The study found that the Mapanuepe Lake is a thriving place for algae and zooplankton. The heavy metal concentration of the lake water and sediment sample is within the standard limit. The water conductivity is considered to be within the standards. In terms of pH level, the sampling sites obtained a pH level within the acceptable limit. The concentration of heavy metals in the lake water and sediments is generally within the standard limit. Other physicochemical properties are also in the acceptable range. The community people and local government must collaborate to implement the crafted strategic environmental sustainability plan, which includes biodiversity conservation and ecotourism promotion. Likewise, the study provides updated and comprehensive data on the status of the lake's heavy metal concentration for policy formulation and further research.

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1. INTRODUCTION

Water, often termed the essence of life, sustains ecosystems and supports human civilization. For the Philippines, a Southeast Asian Island country sandwiched between the West Philippine Sea and the Pacific Ocean, water pollution has emerged as a persistent challenge. According to the Asian Development Bank as cited in Khalid [1], several pollutants have made water gradually a hazard to life. Water sources in the country suffer from a myriad of pollutants. Industrial water waste, containing heavy metals, can exist over long periods and is often called stock pollutants 2. Other detrimental wastes, such as decomposed plants, dead animals, livestock dung, and residue, are organic wastes that also contribute to the country's pollution problem [2].

The Environmental Management Bureau [3] stated that from 2001 to 2005, many water-related events happened, including spill incidents from chemicals and mine tailings, and illegal waste disposal. Such anthropogenic activities resulted in water contamination and the killing of fish and other aquatic resources.

Region III was included in the four regions that had unsatisfactory performance in terms of water quality. The risks associated with hazards and disasters, including pollution are further aggravated by industrial progress, disruptive technologies, and other human-made activities [4].

Heavy metals, ubiquitous in nature, pose significant threats due to their adverse effects on plants, animals, and human health. Due to anthropogenic activities, these heavy metals can affect plants, animals, and even human beings as these materials can interfere with the vital organs' functioning. Pollution, caused by heavy metals in lakes, rivers, and other water bodies, threatens public water supplies and affects the consumers of fishery and aquatic sources. Further, some heavy metals are metabolically required by species in minute amounts but are poisonous at larger concentrations [5].

The presence of heavy metals in nature originates from its many applications in manufacturing, agronomic, medical, and domestic areas [6] but is most noticeable in point source areas like mining and other metal-based manufacturing processes [7]. In recent years, concerns have been raised due to environmental and universal community health concerns due to heavy metal contamination in the environment. There are several reports about the effects of heavy metals polluting agricultural lands which cause a reduction in plant growth, performance and yield [8] and in water resources that pose a threat to public water supply and hazardous effects of consuming aquatic resources [9].

Mapanuepe Lake was formed after the catastrophic eruption of Mt. Pinatubo in 1991. It is considered a freshwater lake situated in the province of Zambales, Central Luzon, Philippines. Because of the lake's panoramic view, the government started to construct a structure to develop the lake as an ecotourism site. Despite its potential as an ecotourism destination, concerns persist regarding mercury contamination, purportedly leaking from nearby mine tailings [10]. The pollution of lakes caused by heavy metals has an extremely harmful effect on people and the other organisms that depend on the area. Heavy metals specifically enter aquatic ecosystems through river flow or atmospheric deposition and can be entered into the sediments instantly through the processes of absorption and sedimentation by suspended particles [11], [12].

Several studies have been done about the effects of mining in the province of Zambales, particularly in agricultural lands [13], [14] and riverine ecosystems [5], [15], [16]. Likewise, previous research in the province focused on assessing water quality in abandoned mine sites [17], stream sediment geochemical mapping of a mining site [18], and the identification of heavy metal accumulators [19]–[22]. However, scant attention has been paid to assessing heavy metal concentrations in Mapanuepe Lake over the past fifteen years [23]–[25]. Hence, the results can provide initial data about the lake's present condition with regard to the physicochemical characteristics of lake water, particularly the types and concentrations of heavy metal pollution in the area. These findings not only inform local policymakers for ecotourism development but also safeguard the lake's ecological integrity, ensuring a sustainable resource for local communities. Better condition of the lake means maximizing the benefits that can be utilized by the locals. While previous studies have explored environmental issues in the province, they have often lacked comprehensive analyses of the physicochemical properties of water bodies. The current research aims to conduct a thorough examination of the physicochemical characteristics of the lake, including heavy metal concentrations in both water and sediments, along with other relevant parameters. This comprehensive approach will offer a more holistic understanding of the lake's environmental health.

Hence, the study intended to assess the presence and concentration of some selected heavy metals. Specifically, it sought answers to the following research problems: i) what is the profile of Mapanuepe Lake in terms of water surface area, depth, and organisms present in the lake and ii) how do the Physicochemical characteristics of lake water be described in terms of concentration of selected heavy metals in lake water, the concentration of selected heavy metals in sediments; and other physicochemical parameters. Through these inquiries, the study aims to contribute valuable insights into the current state of Mapanuepe Lake and pave the way for informed conservation and management strategies.

2. RESEARCH METHOD

2.1. Research design

This study used a descriptive experimental design incorporating both quantitative and qualitative approaches to comprehensively assess the physical profiling and physicochemical characterization of Mapanuepe Lake. Through rigorous data collection and analysis, this research provides a holistic understanding of the lake's geological, ecological, and environmental dynamics. The design is crucial to facilitate informed conservation and management strategies for sustainable development.

2.2. Study areas

The site located at Mapanuepe Lake (14°59'0" N 120°17'30" E) is a result of the confluence of Marella and Mapanuepe Rivers, where they merge to form the Santo Tomas River (see Figure 1). Figure 1 also shows the different sampling stations used in the study which include Mapanuepe Lake, San Marcelino, Zambales, Philippines (Figure 1(a)), Aglao (Figure 1(b)), Camalca (Figure 1(c)), East of Aglao (Figure 1(d)), In between Camalca and Pili (Figure 1(e)), Lumibao (Figure 1(f)), and Pili (Figure 1(g)). Following the eruption of Mount Pinatubo in 1991, successive rains triggered lahars, depositing volcanic debris along the Marella River, a primary drainage of the mountain. This sedimentation led to the gradual buildup of the riverbed, eventually obstructing the flow of the Mapanuepe River. As a consequence, rising waters inundated the Mapanuepe valley, encompassing barangays Aglao, Buhawen, and Pili of San Marcelino, Zambales. Throughout the formation of the lake, the debris dam underwent breaches and subsequent reformations after each lahar event. At its peak, the lake spanned an area of 670 hectares (1,700 acres) with a catchment area of $75\times10\ m^2$ before stabilizing into its current dimensions [26].

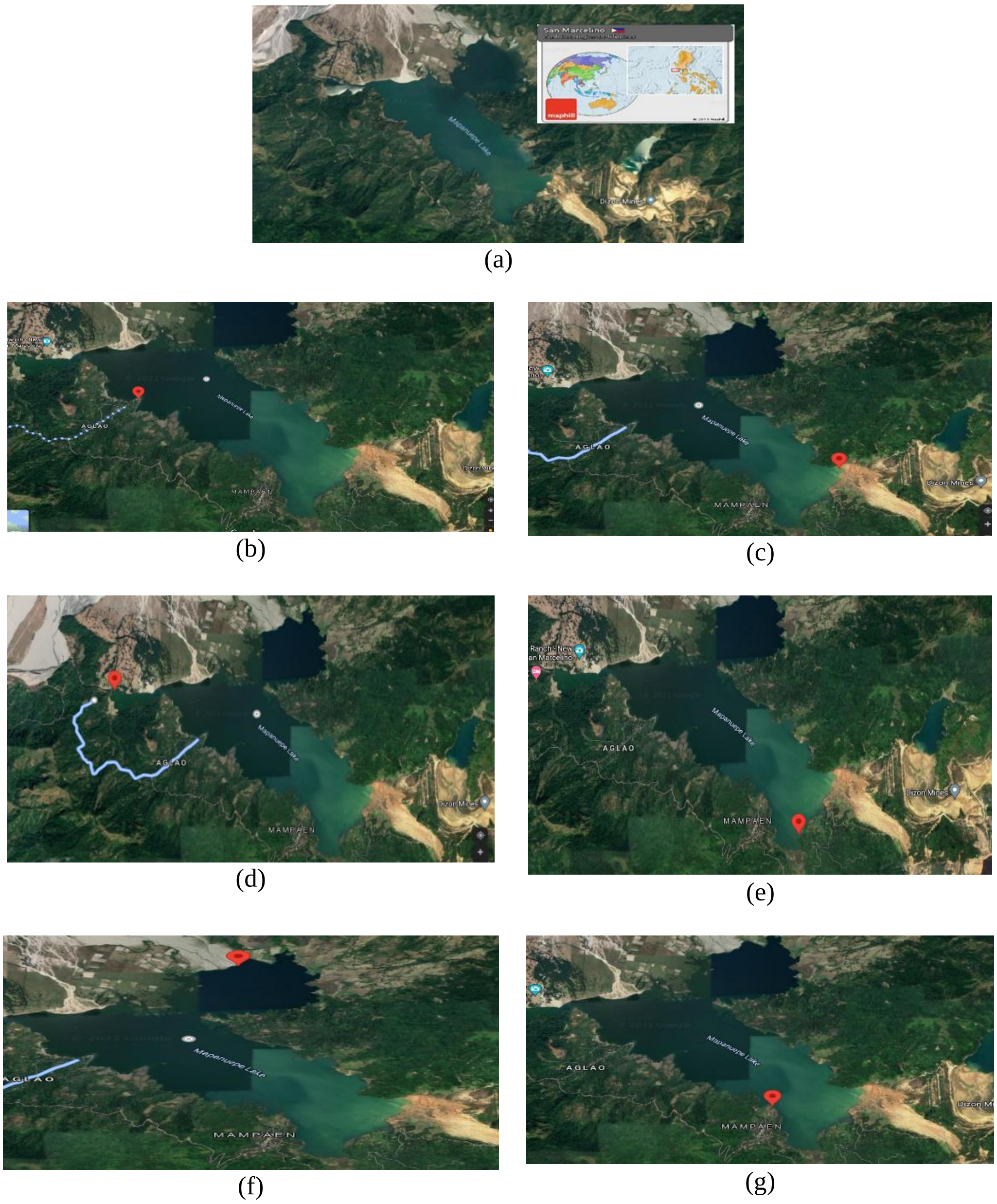

Figure 1. Map of the study area and the different sampling stations in the study which include (a) Mapanuepe Lake, San Marcelino, Zambales, Philippines, (b) Aglao sampling station is found near Mapanuepe view deck (14°58'51.7" N 120°17'10.8" E), (c) Camalca sampling station (14°58'23.6" N 120°18'44.1" E), (d) East of Aglao station found near Rodriquez ranch (14°59'15.5" N 120°16'19.5" E), (e) In between Camalca and Pili sampling station (14°57'53.8" N 120°18'27.3" E), (f) Lumibao sampling station (14°59'50.2" N 120°17'55.3" E), and (g) Pili sampling station (14°58'13.1" N 120°18'08.8" E)

2.3. Instrument

The researchers used the water and sediment analysis sheets and the guidelines set by the Department of Environment and Natural Resources Administrative Order (DAO) 34 [27] and DAO 35 [28]. Enabling the laboratory instrument to be precise and accurate, we followed the standard laboratory procedure as per ISO 9001, standard parameters were set up, the instruments with the standards with a known value, standard reagents, and blank sample to determine the accuracy of the analysis before the experimental procedure of the water and surface sediment samples.

2.4. Water quality assessment

Six sampling stations in the lake were selected based on their existing land use and nearness to the point source of heavy metal pollution. For pH determination, the pH level was measured using Eutech instruments. The conductivity was measured using dakton conductivity meter. Water samples were homogenized. The researcher prepared the pH meter for measurement and cleaned the probe using deionized water and tissue paper. Then, measured a buffer standard with a known value. Dipped the probe into water samples and recorded the reading after the meter had stabilized. The total soluble solids (TSS) were measured using the Buchner funnel, filter membrane from the Nikasan procedure. Water samples were homogenized, weighed 20 g into 400 ml beaker, filter the samples using Buchner funnel/ filter membrane, washed the filter paper and the residue with deionized water several times until the coloration was removed, filter papers were oven-dried at 500 C, cooled inside a desiccator and weighed for computation using (1) whereas W1 (weight of sample and filter paper) and W2 (weight of dried sample) and Ws (weight of sample).

$$\% \, Insol. = \frac{W1-W2}{Ws} \times 100 \tag{1}$$

For total dissolved solids (TDS), water samples were homogenized using agitation, filtered with ordinary filter paper, the filtrate was collected. Each sample was aliquoted 25 ml and transferred in a clean previously tared 50 ml beaker. (Weight of the tared beakers was recorded A). Samples were evaporated and the beaker was covered with a watch glass to avoid losses due to spattering after the breakers were dried in an oven at 1,050 C. After cooling inside the desiccator weighted and recorded weight as B. Computations were done as % TDS (2).

$$\% TDS_{25g}^{B-A} = \times 100 \tag{2}$$

2.5. Heavy metal determination

Water samples were collected at mid-depth using an improvised water sampler, samples were filtered with #42 Whatman filter paper and were sent to the Umicore specialty chemicals laboratory to analyze impurities using ICP-OES 5110. Trace elements/heavy metal concentrations, particularly cadmium, lead, copper, and zinc, were measured using atomic absorption spectrometry (AAS) (AA 7000 Shimadzu). Two replicate samples per sampling station were collected and analyzed. The measured parameters were compared against the prescribed standard limits set by the DAO 34 and DAO 35.

2.6. Lake surface sediment sample

At each designated station, sediments were collected at a depth of 0-10 cm using a fabricated Van Veen grab sampler. A total of 10 sediment samples were collected in five sediment sampling stations weighing 1 kg each. The collected sediment sample was placed in a sterile ziploc. The soil samples were initially subjected to x-ray fluorescence spectroscopy (XRF) to determine the types and levels of metals in the lake and to serve as a guide for the prioritization of metals to be studied based on their concentration and toxicity levels. The samples were dried, pounded, and sieved to mesh 40 and were put in a labeled sample container. The dried sediment samples were mixed thoroughly and then digested 1 g each with Agua Regia with blank samples, the digested sediment samples were transferred to a 100 ml volumetric flask, volume to 100 ml using DDI, shaken, and filtered using 42 Whatman filter paper, dilution 20 of digested sediments sample were used for ICP-OES 5110 analysis, parameters were set up using different standard concentration at Umicore specialty chemicals laboratory. AAS specifically analyzed the metals that are not within the prescribed limits for inorganics in sediments and those that can potentially cause harm to the aquatic biota.

2.7. Data analysis

The data were treated using simple statistical tools like average or weighted mean. Qualitative data were analyzed thematically based on the existing literature. The researchers used SPSS v25 for the data processing.

3. RESULTS AND DISCUSSION

3.1. Profile of Mapanuepe Lake

Mapanuepe Lake's profile is described in terms of water surface area; depth; and organisms present in the lake. Mapanuepe lake (14°59'0" N 120°17'3" E) is located in Zambales, Central Luzon, Philippines. The lake's governing body is not specified, its protective status is not protected, and its class is not classified [29]. Water surface area. Before the infamous volcanic eruption of 1991, the Mapanuepe River drained an area of 88 km^2 in a rocky watershed located south of Mount Pinatubo. Converging with the Marella River, which descended the southwest flank of Pinatubo, the Mapanuepe River formed the Santo Tomas River, tracing the northern edge of its expansive 235 km^2 alluvial plain on its journey to the West Philippine Sea [30]. The eruption of Mount Pinatubo generated significant lahars that descended along the Marella River, obstructing the flow of the Mapanuepe River and giving rise to the lake that now shares its name [30]. The evolution of Mapanuepe Lake has been studied since its inception [26]–[31]. At its peak, the lake covered an area of 6.7 km^2 with a volume of approximately 7.5×107 m^3 [27]. Based on Brillo's [32] meta-analysis study, Mapanuepe Lake is considered a big lake in the Philippines since the lake has a surface area of 646.06 hectares. Lakes are considered big with above 200 hectares of surface area.

Depth the swift buildup of sediment along the Bucao and Santo Tomas Rivers has blocked the entrances of tributaries not associated with Mount Pinatubo and has led to the formation of ponds and lakes [30]. Among these lahar-dammed lakes, the largest is currently Mapanuepe Lake, situated in the southwestern region of the volcano, at the junction of the Marella and Mapanuepe rivers. By the end of the 1992 monsoon season, the lake had an average depth of 25 m (82 feet) and covered an area of about 8 km^2 [33]. Sedimentary fill and geomorphology specify that similar lahar-dammed lakes inhabited the area during at least two preceding volcanic eruptions of Mt. Pinatubo [30], [34]. Several terraces border the Mapanuepe catchment area and the contiguous valley of the Santo Tomas River. One terrace, 15 m higher than the pre-eruption floor of the Santo Tomas river at Sitio (hamlet) Dalanaoan is composed of “pyroclastic-flow deposits overlain by lahar deposits” [31]. Organisms present in the lake. Mapanuepe Lake is a thriving place of different organisms as shown in Table 1.

Zafaralla and Orozco [35] conducted a study to examine the characteristics of the phytoplankton community in Mapanuepe Lake, which was formed by lahars, about certain limnological factors. The study identified five groups of algae: Cyanophyceae, Chlorophyceae, Baccilariophyceae, Dinophyceae, and Chloromonadaceae. Among these, Baccilariophytes were the most prevalent among the blue-green algae (BGA), followed by the Cyanophyceae, with BGA representatives comprising less than 50% of this group. The biological analysis of Buhawen, a site directly impacted by mine tailings, suggested that these pollutants likely contribute to the reduced species diversity compared to other areas within the lake. In contrast to lakes such as Taal, Sapang, Cauayan, and Looc Lake, Mapanuepe Lake exhibits a lower diversity of algal species, with euglenaceae and dinophyceae being the least abundant groups.

Cladocerans are one of the biggest zooplankton groups that serve as food for fish and as a metric of marine ecosystem health. Its diversity and distribution in freshwater ecosystems, like the Mapanuepe lake, are also evident [36]. Several species from families Moinidae, Bosminidae, Sididae, and Chydoridae were likewise seen flourishing in the lake [36]. Family Sididae and Chydoridae are considered the most diverse and well-distributed inhabiting different islands in the country. In 2002, mine waste from two compromised tailings dams and spillways was discharged into Mapanuepe Lake, eventually reaching the Santo Tomas River. Authorities determined that heavy rainfall accumulated water on the Bayarong and Camalca dams and spillways, causing erosion and ultimately leading to the leakage of mine waste into the lake [37]. The dam's catchment area spans 50 hectares each.

In terms of the human population, about 2,000 families live near the mining area, located in an upland site some 30 km. east of the San Marcelino town proper. The lake, including the river, is still being used as a fishing ground and source of irrigation for several Zambales Towns [38]. Further, Sazon 16 revealed that the “number of taxa, density, and abundance of plankton and benthic macroinvertebrates were relatively low and the identified species could indicate the oligotrophic status of the river and metal pollution” (p.1). The profile of Mapanuepe Lake provides valuable insights into its geological history, ecological diversity, and environmental challenges. Understanding these aspects is crucial for effective conservation and management strategies to ensure the lake's sustainability and the well-being of surrounding communities.

Table 1. Organisms present in the lake

Classification	Representative family/species	Study source
Algae	Cyanophyceae, Chlorophyceae, Baccilariophyceae, Dinophyceae, Chloromonadaceae	Zafaralla and Orozco [35]
Zooplanktons	Moina micrura, Diaphanosoma excisum, Diaphanosoma sarsi,	Lopez *et al*. [29] and Pascual *et al*. [36]

3.2. Physicochemical characteristics of lake water

The physicochemical characteristics of water in Mapanuepe lake were described in terms of the concentration levels of selected heavy metals in lake water and sediments. By comparing the water quality of the lake to the standards outlined by the Philippine Department of Natural Resources (DENR) in DENR Administrative Order 34 for surface waters, it becomes possible to assess the potential uses of these surface waters. Surface waters are typically categorized based on their intended beneficial uses, including as a source of drinking water (class AA and A), for recreational activities (class B), for the propagation and growth of fish and other aquatic life (class C), and for agricultural purposes such as irrigation and livestock watering (class D) [27], [28]. To determine the most suitable utilization of surface waters affected by lahars, criteria for classes C and D are particularly relevant. Additionally, to complement DENR Administrative Order 34-90, certain guidelines for understanding water quality for irrigation were also consulted [39]. Heavy metal concentration of lake water, Table 2 shows the concentration level of selected heavy metals in Mapanuepe Lake water.

Table 2. Concentration level of selected heavy metals of Mapanuepe lake water

Heavy metals	Concentration (mg/L)							
	Aglao	East aglao	Lumibao	Camalca	In between camalca	Pili	Ave	Std
Al (396.152)	0.45	0.34	0.12	0.09	1.01	0.72	0.46	---
As (188.980)	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.02
Ba (455.403)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	3.00
Ca (396.847)	63.79	55.76	52.08	49.66	57.49	56.16	55.82	---
Cd (214.439)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.005
Co (238.892)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	---
Cr (267.716)	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Cu (324.754)	0.21 [a]	0.19	0.14	0.14	0.28 [a]	0.25 [a]	0.20	0.20
Fe (259.940)	0.00	0.00	0.01	0.02	0.00	0.00	0.01	1.50
K (766.491)	3.46	3.50	3.41	3.30	3.28	3.35	3.38	---
Mg (285.213)	18.41 [a]	18.53 [a]	18.16 [a]	17.74 [a]	19.40 [a]	18.82 [a]	18.51 [a]	0.05
Mn (257.610)	2.66 [a]	2.66 [a]	2.68 [a]	2.64 [a]	2.84 [a]	2.70 [a]	2.70 [a]	0.20
Na (589.592)	8.02	7.95	7.37	6.93	6.73	7.55	7.43	---
Pb (283.305)	0.61 [a]	0.59 [a]	0.62 [a]	0.58 [a]	0.59 [a]	0.61 [a]	0.60 [a]	0.05
S (181.972)	121.24	125.92	126.21	126.91	144.14	147.82	132.04	---
Sb (206.834)	0.01	0.02	0.00	0.01	0.00	0.00	0.01	---
Si (251.611)	20.53	20.73	20.71	20.27	20.48	20.69	20.57	---
Sn (189.925)	0.00	0.01	0.01	0.01	0.01	0.01	0.01	---
Zn (206.200)	0.23	0.22	0.21	0.20	0.25	0.24	0.23	---
Ni (232.138)	0.18	0.23	0.15	0.11	0.13	0.11	0.15	---

[a] above the standard limit

As shown in Table 2, the water's heavy metal concentration is generally within the standards limit, which connotes that the water is safe for agricultural and recreational purposes. However, it can be noted that copper concentration in some sampling sites is above the standard limit of 0.20 for DENR class D. These include the areas of Aglao (0.21 mg/L), in between Camalca (0.28 mg/L), and Pili (0.25 mg/L). However, the average copper concentration (0.20 mg/L) is within the acceptable limit. The manganese concentration is likewise above the standard limit of 0.2 mg/L for class D. All the sampling sites obtained an average manganese concentration of 2.70 mg/L, which is above the standard.

This finding corroborates the study of the Japan International Cooperation Agency (JICA) [40] on the water quality of Mapanuepe during the dry season when water flow is negligible. The study found that among the 20 inorganic substances assessed, only copper and manganese exceeded the minimum standards [40]. Although no standards were set for both copper and manganese under DAO 34, their concentrations exceeded the acceptable limit of 0.2 mg/L for irrigation water [39].

The result negates Philippine Star's [41] news report that the water release coming from the uninhibited open pit and the tailings pond showed a large concentration of heavy metals such as cadmium, copper, lead, and zinc. The news report further stated that the heavy metals contaminate the lake, which serves as a source of aquatic food for the residents. By presenting empirical data that contradicts sensationalized media claims, the study provides a more accurate and scientifically grounded assessment of the lake's environmental health, dispelling potential misconceptions. Heavy metal concentration in the sediments, Table 3 shows the concentration level of selected heavy metals in the sediments.

As gleaned from Table 3, the heavy metal concentration of sediment samples from the five sampling sites is generally within the standard limit. It suggests that the sediments are good for propagating and growing fish and other aquatic resources (class C), agriculture, irrigation, and livestock watering (class D).

The finding conforms to the study of Decena *et al.* [42] which found that much of the sampling sites in the Mangonbangon River, Iloilo were generally uncontaminated with the assessed heavy metals.

However, the quantity of dissolved heavy metals such as chromium and lead exceeds the standard Philippine value [43], [44]. In Aglao, the mean concentration of available chromium is 0.38 mg/kg, 0.21 mg/kg in East Aglao, 0.31 mg/kg in Lumibao, and 0.24 mg/kg in Camalca, with an average mean concentration of 0.31 mg/kg which exceeds the standard limit of 0.01 mg/kg. On the other hand, the mean concentration of available lead in Aglao is 1.15 mg/kg, 0.61 mg/kg in East Aglao, 1.05 mg/kg in Lumibao, 2.61 mg/kg in Camalca, and 2.18 mg/kg in Pili with an average mean concentration of 1.52 mg/kg which is above the standard limit of 0.01. It implies that the chromium and lead content is slightly higher than the standard limit.

Sarinas *et al.* [43] obtained the same results in their study wherein they found out that the available chromium and lead in the river of Iloilo Batiano, Philippines surpasses the standard limit. This shows that the river is polluted with heavy metals. They further stated that if the sediment is disturbed, the metals will spread on the water's surface and endanger humans and other organisms' health.

Heavy metals also threaten the sectors of agriculture and health because of their destructive impacts on the food quality and marketability of the agricultural produce and consequently, the consumers' well-being [13]. The study highlights the potential threats posed by heavy metal contamination to agriculture and public health. Elevated levels of chromium and lead in sediment samples raise concerns about food quality, marketability of agricultural produce, and overall consumer well-being. This underscores the importance of addressing environmental pollution to safeguard agricultural productivity and human health.

Other physicochemical parameters, Table 4 shows the mean values of each physicochemical parameter for each sampling area matched to the standards set by DENR for surface waters in terms of conductivity, pH level, TSS, and TDS. The water conductivity from the different sampling sites ranges from 498 to 543, which is considered to be within the standards. It implies that the lake water is generally good for agricultural use such as irrigation and suitable for all livestock. The same results were obtained by the study conducted by JICA [40].

In terms of pH level, the sampling sites obtained a pH level range of 3.93 to 4.81 which is considered to be acidic but within the standard. TSS of samples ranged from 29 to 633 mg/L. Camalca has the highest TSS (633 mg/L) while Camalca has the lowest (29 mg/L). The higher the TSS value, the lower the water's capacity to sustain aquatic life due to reduced light penetration disturbing plant photosynthesis [3]. Since the obtained TSS is within the standard, the lake's marine life is in great condition. The low TSS value also coincides with the high transparency values in all sampling sites. TDS of the sampling areas ranges from 0.07 to 0.15%. This suggests that the TDS of Mapanuepe Lake water is within the standard. The study results support the findings of Angagao *et al.* [45] which assessed the water quality of Lanao Lake, Philippines. Several studies also reported that the physico-chemical parameters of some of the Philippine bodies of water are within the acceptable range [46]–[49].

Table 3. Concentration level of selected heavy metals in sediments

Heavy Metals	Concentration (mg/kg) *					Ave	Std
	Aglao	East Aglao	Lumibao	Camalca	Pili		
Al (396.152)	46.13	39.76	84.19	74.33	148.77	78.64	---
As (188.980)	0.01	0.17	0.01	0.74	0.34	0.25	---
Ba (455.403)	0.07	0.16	0.27	0.25	0.66	0.28	---
Ca (396.847)	13.34	28.78	25.87	7.30	23.56	19.77	---
Cd (214.439)	0.00	0.00	0.01	0.01	0.01	0.01	---
Co (238.892)	0.00	0.00	0.06	0.02	0.04	0.02	---
Cr (267.716)	0.38 [a]	0.21 [a]	0.31 [a]	0.24 [a]	0.42 [a]	0.31 [a]	0.01
Cu (324.754)	0.92	0.42	1.80	1.67	2.26	1.41	---
Fe (259.940)	230.34	126.15	217.14	501.58	326.73	280.39	---
K (766.491)	1.24	2.79	3.88	3.51	3.38	2.96	---
Mg (285.213)	8.87	17.66	26.38	38.14	27.88	23.79	---
Mn (257.610)	5.28	1.35	1.96	1.72	2.00	2.46	---
Na (589.592)	4.02	5.21	6.27	4.32	5.41	5.05	---
Pb (283.305)	1.15 [a]	0.61 [a]	1.05 [a]	2.61 [a]	2.18 [a]	1.52 [a]	0.01
S (181.972)	3.04	3.57	7.80	22.22	8.43	9.01	---
Sb (206.834)	0.08	0.05	0.04	0.14	0.05	0.07	---
Si (251.611)	9.65	9.25	10.01	8.16	8.11	9.04	---
Sn (189.925)	0.02	0.02	0.02	0.02	0.02	0.02	---
Zn (206.200)	0.45	0.24	1.95	0.60	1.55	0.96	---
Ni (232.138)	0.81	1.12	0.80	1.00	0.73	0.89	---

*Results are an average of two replications

[a] above the standard limit

Table 4. Other physicochemical parameters of the lake water

Sampling area	Conductivity (μs)	pH	TSS (mg/l)	TDS (%)
Aglao	512	4.44	521	0.21
West aglao	510	4.53	528	0.21
Lumibao	505	4.81	488	0.07
Camalca	498	4.90	633	0.18
In between Camalca	543	3.93	29	0.18
Pili	524	4.30	80	0.15
Standard set by DENR-EMB for class C	---	6.5-9.0	Not more than 30 mg/L increase	---
Standard set by DENR-EMB for class D	300	6.5-8.5	Not more than 60 mg/L increase	1,000
Interpretation of Data	Within the standard	Within the standard	Within the standard	Within the standard

4. CONCLUSION

Mapanuepe Lake emerges as a significant body of water in the Philippines and a thriving place for diverse organisms and microorganisms. Importantly, the concentration of heavy metals in both the lake water and sediments generally adheres to regulatory standards, signaling overall environmental health. Moreover, key physicochemical parameters exhibit values within acceptable ranges, further affirming the lake's ecological integrity. Future studies may assess the biodiversity distribution and taxonomical classification of the lake's flora and fauna. Additionally, there is a pressing need for comprehensive evaluation and ongoing monitoring of the lake's water condition. This proactive approach would ensure the continuous assessment of water quality and support informed decision-making regarding its use as an alternative water resource, particularly in light of the community's escalating water demand. Collaborative efforts between the Department of Environment and Natural Resources, local community members, and the San Marcelino local government unit are imperative for the successful implementation of a strategic environmental sustainability plan for the lake. This plan should prioritize biodiversity conservation initiatives and promote ecotourism opportunities, harnessing the lake's natural beauty to benefit both the environment and the local economy.

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