Heavy Metal Contamination in the Water of a Semi-Urban Lake – Bolgoda Lake, Sri Lanka

De Silva NJC, Malinda KMDRP, Elankeeran T, Dilshara RMP, Batapola BDNM, *Ratnayake NP, Premasiri HMR, and Abeysinghe AMKB

Department of Earth Resources Engineering, University of Moratuwa, Sri Lanka.

*Corresponding author – nalin@uom.lk

Abstract
Urbanisation and industrialisation have intensified the heavy metal contamination in inland water bodies. Therefore, this study investigates the recent status of heavy metal pollution in the water of the Bolgoda Lake in Sri Lanka, a semi-urban inland water body that receives both treated and untreated municipal and industrial discharge from the surrounding area. A total of 11 lake water samples were analysed by Inductively Coupled Plasma-Mass Spectrometer (ICP-MS) to determine the concentrations of As, Cd, Cr, Co, Cu, Ni, Pb, and V. Their mean concentrations in the Bolgoda Lake water were 0.661 ± 0.264 ppm, 0.010 ± 0.004 ppm, 0.090± 0.018 ppm, 0.007± 0.002 ppm, 0.043± 0.039 ppm, 0.002± 0.001 ppm, 0.662± 0.264 ppm, and 0.091 ± 0.018 ppm, respectively. However, the derived contamination factors of the analysed heavy metals revealed that Bolgoda Lake is highly polluted with Cd (22.0) and V (13.2), whereas moderately polluted with Pb (1.8). Compared to previous studies, heavy metal contents in Bolgoda Lake water have increased significantly, especially Cd and Pb. Therefore, Cd, V, and Pb can pose the greatest threat to the ecological environment of Bolgoda Lake, thus effective strategies such as treatment or recycling of wastewater and industrial discharges are needed to protect this lake from further contamination.

Keywords: Cadmium, Contamination factor, Waste disposal, Water pollution.

1 Introduction

Contamination of heavy metals in inland water bodies is increasingly menacing to the local ecosystem and human health and has become a major global issue that needs immediate attention. This is mainly due to the enrichment and persistence of heavy metals in the water column, sediments, and biota for a long time and their associated toxic effects [1]. Heavy metals enter inland water bodies through natural geochemical weathering of soil and rocks and anthropogenic activities, such as agricultural fertilization, mining & mineral processing, industrial production, urban development, and waste dumping. The most common heavy metals present in these waterbodies are arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), ferrous (Fe), manganese (Mn), nickel (Ni), lead (Pb), vanadium (V), and zinc (Zn) [2].

Heavy metals discharged into lakes can be distributed in both sediments and aqueous phases. However, heavy metal contamination in water can directly impact the ecological environment of lakes, thus evaluating the pollution status of the water column needs much attention [3]. The pollution of aquatic environments by heavy metals has become a global issue, which may be illustrated by countless examples originating from a variety of countries around the globe [1], [4].

The present study was carried out in Bolgoda Lake, a semi-closed coastal water body in Sri Lanka's southwest wet zone, which is heavily impacted by unsustainable development activities, inappropriate land use, and high population density. Despite the heavy metal pollution, locals rely on the lake's fishery supplies. Senarathne and Pathiratne [5], [6] conducted studies on the heavy metal pollution in Bolgoda Lake in 2007 and 2009, respectively. However, detailed research on heavy metal dispersion in water columns has been lacking in Bolgoda Lake since 2018. Therefore, this study evaluated the present heavy metal pollution levels in Bolgoda Lake and their spatial distribution.

The findings of this study are important to implement remedies for the pollution and ecological damages that are currently occurring in Bolgoda Lake. In addition, we need to find strategies to minimise the heavy metal pollution in the water body to ameliorate the ecological and environmental problems that have been occurring to date.

2 Methodology

2.1 Study area

The Bolgoda Lake is located within the Western Province of Sri Lanka (06.794927° N; 079.90475° E) Fig. 1 [7]. The lake has a 2 m maximum water depth of approximately. Its banks are characterized by steep slopes and just a small portion of the basin shows a water depth of <1 m [8] and a vast surface area measuring approximately 374 km² [7]. In addition, the aesthetic and ecological significance of the lake is being compromised as a result of the unregulated disposal of industrial byproducts, and household waste. As per the documentation of the Central Environmental Authority in Sri Lanka, a significant quantity of industrial establishments has been situated close to the lake [6].

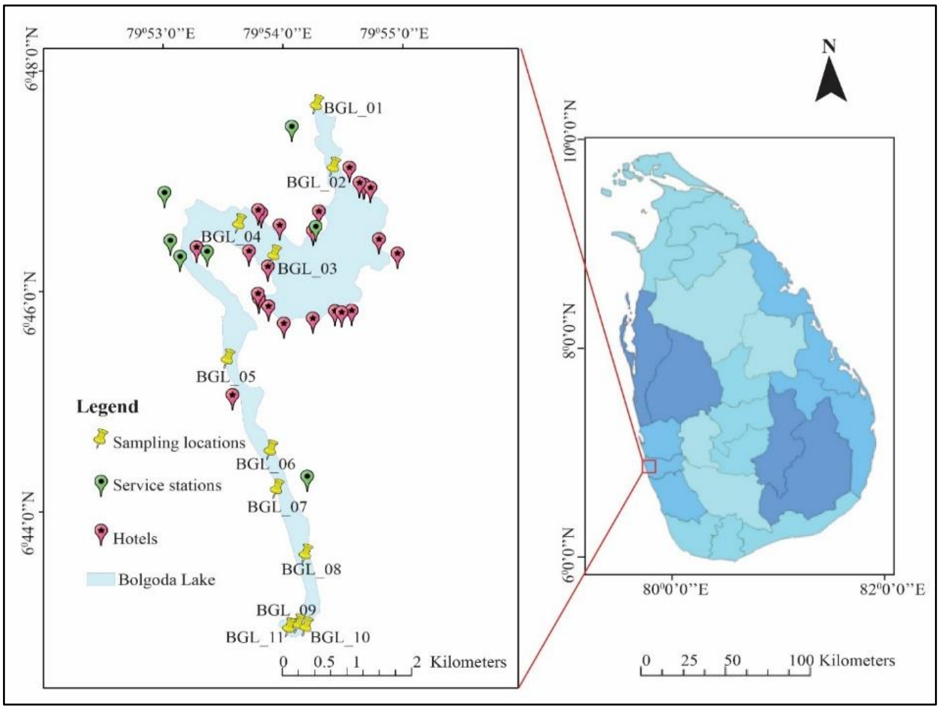

Figure 1: Study area and sampling locations in Bolgoda Lake

2.2 Sample collection

Samples (n=11) were collected from Bolgoda Lake in March 2023 by utilising the judgmental sampling technique (Fig. 1). The focus of the study was on heavy metals as the analyte, and the data were obtained through a comprehensive review of significant literature by identifying certain special locations where the heavy metal discharging points are available nearby [5], [6].

Samples were collected 1 m below the surface using a Ruttner water sampler and transported to the laboratory in plastic bottles. 1 ml of HNO_3 was added to the sample bottles to preserve all the metals below pH 2. During sample collection, physical properties such as colour, and odour were identified and recorded during the field study locations where the heavy metal discharging points are available nearby the Lake.

2.3 Sample preparation for heavy metal analysis

Water samples were analysed from the Inductively Coupled Plasma-Mass Spectrometer (ICP-MS) considering their sources of contamination. From each sample, 10 ml was filtered by using 0.45 µm Nylon filters and subjected to ICP-MS.

During the analysis, three replicates of each sample and a blank sample were analysed to maintain the quality of the analysis. In addition, the quality of the analysis was further improved by analysing certified international reference samples for ICP-MS (San Joaquin NIST SRM 2709a from Sigma-Aldrich, Germany).

2.4 Calculation of contamination factor

According to [10], the contamination factor and degree of contamination were introduced to evaluate water contamination in Bolgoda Lake. As in Equation 1, M_e Sample is the obtained value from the sample, and M_e baseline is the pre-industrial reference value for the element. The pre-industrial reference values were obtained from the Sri Lankan Gazette in 2019, [11].

$$Contamination\ Factor = \frac{M_e Sample}{M_e Baseline} \qquad (1)$$

Contamination factors of the trace elements can be categorized into 4 classes [10], as in Table 1.

Table 1: Contamination factor and levels

Class interval	Level
0-1	Low contamination
1-3	Moderately contamination
3-6	Considerable contamination
>6	Very high contamination

3 Results

The present study investigated the presence of heavy metal contamination in bottom water samples collected from Bolgoda Lake. The results revealed that the order of heavy metal contamination in the samples was Cd > V > Pb > Ni > Cr > Co > As. The average dissolved values of heavy metals are mentioned in Table 2. As Table 2 indicates, sampling locations, such as BGL_01 and BGL_09 showed high V, Cr, Co, As, and Cd levels while BGL_05 showed the highest Ni level in water. These values were above the permissible level mentioned in the Sri Lankan Gazette in 2019, for heavy metal contamination [11].

The ecological risk in the area according to the degree of contamination is tabulated in Table 3. The contamination factor of V, Cr, Ni, Co, Cu, As, Cd, and Pb in Bolgoda Lake varied as 0.661, 0.010, 0.090, 0.007, 0.043, 0.002, 0.662, and 0.091 mg/L, respectively in Table 3. However, according to the gazette, the acceptable concentrations of heavy metals in inland water bodies are in mg/L as, 0.05, 0.05, 0.20, 0.10, 0.05, 0.05, 0.03, and 0.05 for the aforementioned heavy elements.

Table 2: Heavy metal concentration (ppm) in water samples

Sample Location	V	Cr	Ni	Co	Cu	As	Cd	Pb
BGL_01	**0.0177**	**0.001**	0.093	**0.002**	0.029	**0.0008**	**0.0181**	0.095
BGL_02	0.4960	0.008	0.073	0.006	0.006	0.0008	0.4964	0.075
BGL_03	0.5501	0.009	0.088	0.006	0.010	0.0022	0.5506	0.090
BGL_04	0.5439	0.009	**0.070**	0.006	**0.005**	0.0025	0.5444	**0.071**
BGL_05	0.6764	0.011	**0.135**	0.007	0.027	**0.0034**	0.6768	**0.137**
BGL_06	0.7452	0.011	0.078	0.007	0.015	0.0027	0.7456	0.079
BGL_07	0.7555	0.011	0.086	0.008	0.028	0.0025	0.7559	0.088
BGL_08	0.7681	0.011	0.086	0.008	0.052	0.0022	0.7685	0.088
BGL_09	**1.0046**	**0.015**	0.099	**0.010**	0.094	0.0030	**1.0050**	0.100
BGL_10	0.9088	0.013	0.099	0.009	**0.111**	0.0024	0.9094	0.100
BGL_11	0.8074	0.012	0.078	0.008	0.091	0.0022	0.8077	0.079

Table 3: Contamination factors for the heavy metals analysed

Sampling Locations	V	Cr	Ni	Co	Cu	As	Cd	Pb
BGL_01	0.354	0.025	0.467	0.025	0.583	0.017	0.598	1.900
BGL_02	9.920	0.161	0.365	0.056	0.125	0.015	16.542	1.492
BGL_03	11.002	0.173	0.441	0.059	0.203	0.044	18.345	1.795
BGL_04	10.879	0.179	0.348	0.061	0.094	0.049	18.140	1.423
BGL_05	13.527	0.215	**0.677**	0.073	0.544	**0.067**	22.553	**2.741**
BGL_06	14.904	0.230	0.388	0.073	0.295	0.054	24.848	1.583
BGL_07	15.109	0.228	0.431	0.084	0.551	0.050	25.191	1.758
BGL_08	15.362	0.229	0.432	0.077	1.041	0.043	25.611	1.760
BGL_09	**20.092**	**0.293**	0.494	**0.097**	1.888	0.061	**33.495**	2.007
BGL_10	18.176	0.259	0.494	0.090	**2.222**	0.048	30.302	2.007
BGL_11	16.147	0.232	0.389	0.081	1.828	0.043	26.921	1.589

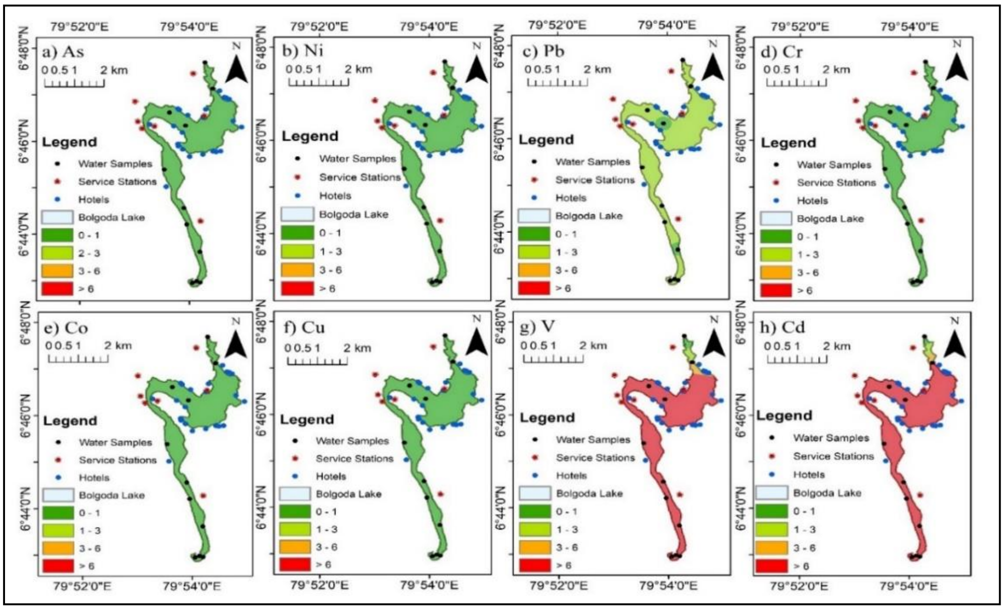

Figure 2: Spatial distribution for contamination factor of heavy metals As, Ni, Pb, Cr, Co, Cu, V, and Cd in water sample

4 Discussion

The findings indicate that the contamination factor decreased in the order of Cd > V > Pb > Cu > Ni > Cr > Co > As, with respective factors of 33.4, 20.1, 2.7, 2.2, 0.67, 0.29, 0.09, and 0.66 (Table 3). Furthermore, it can be observed that the water samples collected from Bolgoda Lake indicated a high concentration of V, which surpasses the permissible limit by a contamination factor of more than 10. According to global studies, volatile organic compounds are released into the environment as a result of emissions from various sources such as refineries, power stations, shipping, stainless steel production, ceramic tile manufacturing, and brick-making [12]. Since Bolgoda Lake is linked to the sea at Pandura estuary, where that area is close to the fishing harbour. The high V contamination may result from the Fossil fuels used in shipping operations. Tidal movements can also facilitate the transportation of V concentration from the shore to the off-shore or vice versa[13].

Furthermore, moderate contamination of Pb can be resulted, due to paints, plumbing, and batteries dumped with the solid waste[14]. When referring to the field observation and previous literature, the lake is surrounded by service stations, hotels, and carpentries from which the wastewater and solid waste are discharged into the lake water. These sources could be the possible reason for the high Pb contamination in Bolgoda Lake.

Compared to the studies done by Senarathna in 2007, Pathirathna in 2009, and Wijeyaratne in 2016, lake heavy metal concentration has increased in Pb from 44 ppm to 253 ppm in sediments and Cd has increased from 0.8 ppm to 243.43 ppm in sediments. Due to the pH variation and other factors heavy metal dissolving can be happened. Therefore, that could be a reason to increase heavy metals in the water column as seen in Fig. 2 [5], [6], [15].

5 Conclusion

The findings of the experiments and the information that is currently available indicate that the water in Bolgoda Lake is heavily polluted with Cd and V, whereas moderately contaminated with Pb. According to the filed observations and findings of the previous literature, discharge of service stations and improper waste disposal practices from hotels may have contributed to the heavy metal pollution in the lake. In addition, industrial discharges, agricultural runoff, and improper waste disposal practices in the upper stream area may be the reason for the high heavy metal contamination in the water column. These metals accumulate in the sea mouth and inland sites, posing a risk to human well-being when consumed from contaminated water sources.

To effectively mitigate the problem of heavy metal contamination in Bolgoda Lake, it is crucial to promptly and efficiently implement appropriate interventions. These measures could include the enforcement of stringent regulations regarding the disposal of industrial waste, the encouragement of sustainable agricultural practices, and the provision of public education on proper waste management and the associated risks of heavy metal exposure.

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