



Research paper

# Spatial Distribution and Ecological Risk Assessment of Heavy Metals in the Basins of Dal Lake, Jammu and Kashmir

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## ARTICLE INFO

## ABSTRACT

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Dal Lake, often referred to as the 'Jewel of Kashmir', is the second largest lake of Jammu and Kashmir and one of the most ecologically and economically important urban water bodies in the Himalayan region. Rapid urbanization, unregulated tourism, and the discharge of untreated domestic and religious-ceremony waste into its five distinct basins — Gagribal, Nigeen, Hazratbal, Bod Dal (Nishat) and Brari Nambal — have subjected the lake to sustained anthropogenic stress. This study evaluates the heavy metal load of Dal Lake across its five basins using Atomic Absorption Spectrophotometry (AAS) for seven metals: iron (Fe), nickel (Ni), lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu) and manganese (Mn). Concentrations were compared against the permissible limits prescribed by the World Health Organization (WHO, 2003). The results show that, with the exception of copper, the concentrations of most heavy metals exceeded WHO permissible limits in one or more basins, with nickel, cadmium, chromium and manganese consistently elevated across all five basins. The Hazratbal, Nishat and Brari Nambal basins, which receive concentrated inputs from religious congregations, horticultural runoff and dense residential settlements respectively, showed particularly high lead and cadmium loads. The findings indicate that anthropogenic activity and unchecked urban growth around the lake periphery are the principal drivers of heavy metal contamination, and underline the urgent need for basin-specific pollution control and catchment management measures.



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## 1. Introduction

Perched securely among the lofty, snow-sprinkled Himalayan mountain chain, with emerald blue skies peeping through the chinks of the clouds and tall chinar trees swaying to the rhythm of the wind, the state of Jammu and Kashmir occupies the northernmost part of India. It is strategically bordered by Tibet to the east, China to the north-east, Afghanistan to the north, and Pakistan to the west.

The state has a total area of about 2,22,236 sq. km, of which 78,114 sq. km remain under the illegal occupation of Pakistan and 37,555 sq. km under China. The Kashmir Valley, an ancient lake basin roughly 140 km long and 32 km wide, forms a significant part of the state. The valley lies at an average elevation of 5,300 feet above sea level and is enclosed by mountains rising to 16,000 feet, giving it a pleasant climate for most of the year.

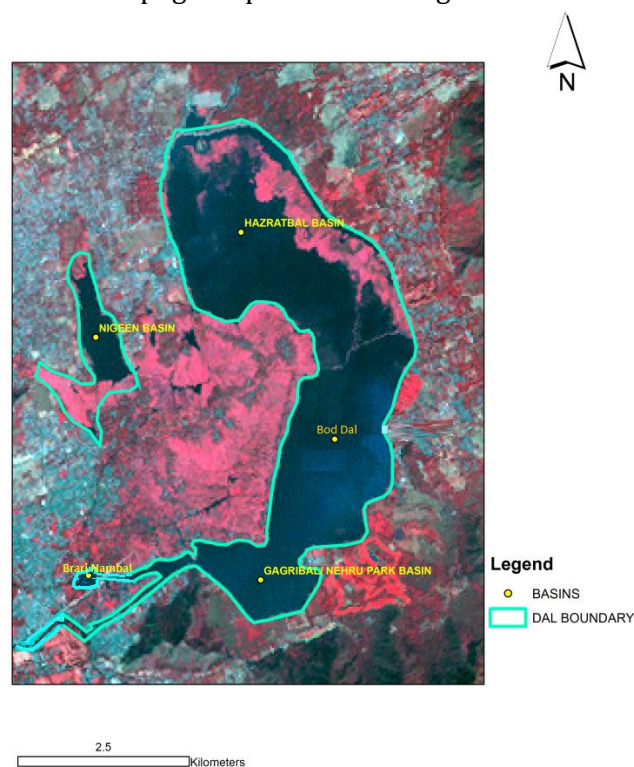
Aquatic ecosystems are among the most precious, dynamic and diverse ecosystems in the world, and Dal Lake is a prime example. Flanked on three sides by majestic mountains and lined with gardens and orchards along its shores, Dal Lake is widely known as the 'Jewel of Kashmir' and is the second largest lake in Jammu and Kashmir. Historical and scientific estimates of its area vary considerably: while some surveys place it at 20 km<sup>2</sup> and others at 12 km<sup>2</sup>, the lake's original area is reported to have been as large as 32 km<sup>2</sup>. The lake lies at the foot of the Nangaparbat–Shankaracharya hill range and is composed of several distinct basins — Lokat Dal (Gagribal), Bod Dal, Hazratbal, Nigeen and Brari Nambal.

Successive surveys over the past century and a half have documented a consistent shrinkage of the lake. Drew (1875) recorded the lake as measuring five miles from north to south and two miles from east to west. Hussan (1833) described it as roughly three miles long from Gagribal to Telbal and nearly two miles wide from Khawjayarbal to Nishat Bagh, with a circumference of about ten miles. Lawrence (1895) estimated its length at four miles and width at two-and-a-half miles, and noted that the lake was becoming progressively shallower — an observation confirmed by Stein (1899), who recorded a maximum depth of thirty feet. By 1931, Mukerjee reported the deepest point of the lake at only about twenty feet. The Enx Consortium of New Zealand (1978) placed the total lake area at twenty-one square kilometres, of which 12.1 km<sup>2</sup> was open water, while Vass and Zutshi (1979) reported an open water area of 11.75 km<sup>2</sup> and a total basin volume of  $9.83 \times 10^6$  m<sup>3</sup>, with Nigeen identified as the deepest basin at 6 metres. Kango and Fotedar (1982) found that the lake's area had shrunk from 23.4 km<sup>2</sup> to 13.82 km<sup>2</sup> over 118 years, and Zutshi and Kundangar (1983), comparing Montgomerie's survey maps of 1856–60 with contemporary data, reported an open water area of 10.56 km<sup>2</sup>. According to the latest survey by the J&K Revenue Department, the combined area of Dal and Nigeen lakes is estimated at 50,432 kanals, of which only 3,922 kanals are open water and 10,206 kanals are land mass.

Continuous ecological monitoring of the lake reveals far-reaching changes in its environment. Ecological stress is reflected in deteriorating water quality, excessive weed growth, frequent algal blooms and loss of biodiversity. Rapidly expanding human populations and fast urbanization around the lake, compounded by natural siltation, are increasingly threatening the lake ecosystem and the natural resources it supports.

Among the pollutants of greatest concern are heavy metals, which are non-biodegradable and persist indefinitely in the environment once introduced through natural or anthropogenic sources.

Considerable scientific attention has therefore been directed at the potential health hazards posed by heavy metals in aquatic systems. The term 'heavy metal' refers to any metallic chemical element with a relatively high density, conventionally greater than 5.0 g/cm<sup>3</sup>. Common examples include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), lead (Pb), copper (Cu), zinc (Zn), cobalt (Co), nickel (Ni) and iron (Fe). Heavy metals are broadly classified into three categories: toxic metals (e.g. Hg, Cr, Pb, Zn, Cu, Ni, Cd, As, Co, Sn), precious metals (e.g. Pd, Pt, Ag, Au, Ru) and radionuclides (e.g. U, Th, Ra, Am). This study was undertaken to assess the extent of heavy metal contamination across the five major basins of Dal Lake and to relate the observed pattern to the anthropogenic pressures acting on each basin.



**Fig. 1** Map of Dal Lake showing its major basins

## 2. Study Area

Dal Lake is divisible into five distinct basins, each with its own hydrological character and pollution profile, described below.

### 2.1 Gagribal Basin

The Dal lock gate is situated in the shallowest of the basins, Gagribal. Lake water drains out through Nallah Amir Khan into a tributary of the River Jhelum towards the south-west, and also through a weir-and-lock system at Dal Gate. A stone-lined canal running parallel to this exit connects the lake to the tributary; it is used for the movement of boats in and out of the lake and helps prevent inundation of the floating gardens during high floods.

## 2.2 Nigeen Basin

Known as the 'Jewel in the Ring', Nigeen Basin forms the western part of Dal Lake and is considered one of its principal basins. It is an important source of vegetables and fish, supports an active water-transport system, and is a popular venue for aquatic sports and tourism. Over the years, however, it has become increasingly vulnerable to biotic and abiotic interference. It is the deepest basin of the lake, with a maximum depth of 6 m, and is connected to Anchar Lake by Nallah Amir Khan via Khushalsar Lake. A large part of this basin is occupied by floating islands.

## 2.3 Hazratbal Basin

Located on the western shores of Dal Lake (Bod Dal), the Hazratbal Basin also receives water from the Doubkoul, Harishkoul and Boutkoul channels. It is one of the most heavily polluted basins, largely as a result of human anthropogenic activity. The Hazratbal shrine, located just 50 metres from the study site, draws thousands of pilgrims during religious ceremonies and rituals; the pollutants generated during these events ultimately reach the water body and indirectly disturb its natural water quality.

## 2.4 Bod Dal near Nishat Garden

Nishat, on the eastern side of Dal Lake, forms part of Bod Dal and lies about 11 kilometres (6.8 miles) from the city centre, at the foot of the Zabarwan mountains. The renowned Nishat Bagh, a major tourist attraction, lies only a short distance from the study site. Large volumes of sewage and wastewater are discharged into this part of the lake, resulting in persistent bad odour.

## 2.5 Brari Nambal

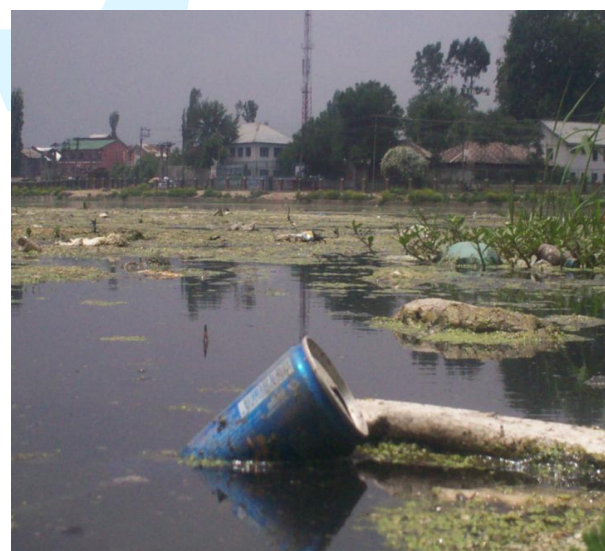
Brari Nambal is one of the most polluted basins of Dal Lake, covering an area of about 0.7 km<sup>2</sup>. It is saucer-shaped, with a maximum depth of 1.77 m, and is connected to the Gagribal basin through the Chinar-Bagh Nallah, which passes through Nowpora. In addition, numerous ephemeral channels and drains carry large quantities of wastewater into the basin from surrounding human settlements. The catchment of Brari Nambal is composed of the densely populated parts of Srinagar city, and following the closure of Nallah Mar, the basin has become an ecologically sick lagoon with no natural flushing of water. The surrounding topography channels sewage from numerous drains directly into the lagoon, effectively turning it into a cesspool.



**Fig. 2** Iron metal plate present at the Dal Lock Gate



**Fig. 3** Metallic walling at a floating garden near the Dal Lock Gate



**Fig. 4** Discarded metallic cold-drink tin in the lake, indicative of direct anthropogenic metal input

## 3. Materials and Methods

Water samples were collected from the five major basins of Dal Lake — Gagribal, Nigeen, Hazratbal, Nishat and Brari Nambal — each basin representing a distinct sampling site with a characteristic pattern of anthropogenic input. Samples were collected in acid-washed polyethylene bottles, preserved with a few

drops of concentrated nitric acid to prevent adsorption of metal ions onto the walls of the container, and transported to the laboratory for analysis.

The heavy metal content of the water samples was determined using Atomic Absorption Spectrophotometry (AAS), a technique introduced by Dr. A. Walsh of Australia in 1955 and now among the most widely used methods for the quantitative estimation of trace and heavy metals in environmental samples. Prior to analysis, samples were digested with concentrated nitric acid to bring the metals into solution and eliminate organic interference. The concentrations of seven metals — iron (Fe), nickel (Ni), lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu) and manganese (Mn) — were determined in mg/L for each basin. The mean values obtained for each basin were then compared against the permissible limits for drinking and surface water prescribed by the World Health Organization (WHO, 2003) in order to assess the pollution status of each basin.

#### 4. Results and Discussion

The mean heavy metal concentrations recorded across the five basins of Dal Lake are summarised in Table 1. For reference, the corresponding WHO (2003) permissible limits for each metal are presented in Table 2.

**Table 1** Basin-wise mean heavy metal concentrations (mg/L) in Dal Lake

Metal (mg/L)	Gagribal Basin	Nigeen Basin	Hazratbal Basin	Nishat Basin	Brari Nambal
Iron (Fe)	0.503	0.9206	0.11452	0.085	0.1698
Nickel (Ni)	0.466	0.346	0.316	0.316	0.16
Lead (Pb)	0.0248	0.0332	0.082	0.0624	0.1952
Cadmium (Cd)	0.332	0.316	0.238	0.376	0.156
Chromium (Cr)	0.13	0.148	0.156	0.144	0.138
Copper (Cu)	0.064	0.058	0.052	0.068	0.064
Manganese (Mn)	0.184	0.204	0.156	0.188	0.192

**Table 2** WHO (2003) permissible limits for the heavy metals under study

Heavy Metal	WHO (2003) Permissible Limit (mg/L)
Iron (Fe)	0.3
Nickel (Ni)	0.02
Lead (Pb)	0.05
Cadmium (Cd)	0.01
Chromium (Cr)	0.05
Copper (Cu)	1.0
Manganese (Mn)	0.05

##### 4.1 Iron (Fe)

The mean Fe concentration was 0.503 mg/L at Gagribal, 0.9206 mg/L at Nigeen, 0.11452 mg/L at

Hazratbal, 0.085 mg/L at Nishat and 0.1698 mg/L at Brari Nambal, giving the order Nigeen > Gagribal > Brari Nambal > Hazratbal > Nishat. Against the WHO (2003) permissible limit of 0.3 mg/L, Fe concentrations at Gagribal and Nigeen exceeded the standard, while Hazratbal, Nishat and Brari Nambal remained within limits. The elevated Fe levels at Gagribal and Nigeen are likely attributable to anthropogenic activity in and around these basins.

##### 4.2 Nickel (Ni)

Mean Ni concentrations were 0.466 mg/L at Gagribal, 0.346 mg/L at Nigeen, 0.316 mg/L at Hazratbal, 0.316 mg/L at Nishat and 0.16 mg/L at Brari Nambal, following the order Gagribal > Nigeen and Hazratbal > Nishat > Brari Nambal. Against the WHO (2003) permissible limit of 0.02 mg/L, Ni concentrations at Gagribal, Nigeen, Hazratbal and Nishat all exceeded the standard, while only Brari Nambal remained within permissible limits. The elevated nickel levels at the other basins may be attributed to anthropogenic pressure, particularly vehicle washing along the lake shores.

##### 4.3 Lead (Pb)

Mean Pb concentrations were 0.0248 mg/L at Gagribal, 0.0332 mg/L at Nigeen, 0.082 mg/L at Hazratbal, 0.0624 mg/L at Nishat and 0.1952 mg/L at Brari Nambal, giving the order Brari Nambal > Hazratbal > Nishat > Nigeen > Gagribal. Against the WHO (2003) permissible limit of 0.05 mg/L, Pb concentrations at Hazratbal, Nishat and Brari Nambal exceeded the standard, while Gagribal and Nigeen remained within limits. The elevated lead concentrations at these basins are likely linked to vehicular pollution in their catchments.

##### 4.4 Cadmium (Cd)

Mean Cd concentrations were 0.332 mg/L at Gagribal, 0.316 mg/L at Nigeen, 0.238 mg/L at Hazratbal, 0.376 mg/L at Nishat and 0.156 mg/L at Brari Nambal, giving the order Nishat > Gagribal > Nigeen > Hazratbal > Brari Nambal. All five basins exceeded the WHO (2003) permissible limit of 0.01 mg/L for cadmium, with the elevated values across all sites attributable to sustained anthropogenic pressure.

##### 4.5 Chromium (Cr)

Mean Cr concentrations were 0.130 mg/L at Gagribal, 0.148 mg/L at Nigeen, 0.156 mg/L at Hazratbal, 0.144 mg/L at Nishat and 0.138 mg/L at Brari Nambal, giving the order Hazratbal > Nigeen > Nishat > Brari Nambal > Gagribal. All five basins exceeded the WHO (2003) permissible limit of 0.05 mg/L for chromium, with elevated concentrations likely associated with paint residues and other anthropogenic inputs.

#### 4.6 Copper (Cu)

Mean Cu concentrations were 0.064 mg/L at Gagribal, 0.058 mg/L at Nigeen, 0.052 mg/L at Hazratbal, 0.068 mg/L at Nishat and 0.064 mg/L at Brari Nambal, giving the order Nishat > Gagribal and Brari Nambal > Nigeen > Hazratbal. All values remained well within the WHO (2003) permissible limit of 1.0 mg/L, making copper the only metal in the study whose concentration did not exceed the standard at any basin.

#### 4.7 Manganese (Mn)

Mean Mn concentrations were 0.184 mg/L at Gagribal, 0.204 mg/L at Nigeen, 0.156 mg/L at Hazratbal, 0.188 mg/L at Nishat and 0.192 mg/L at Brari Nambal, giving the order Nigeen > Brari Nambal > Nishat > Gagribal > Hazratbal. All five basins exceeded the WHO (2003) permissible limit of 0.05 mg/L for manganese, with the elevated levels likely linked to the corrosion of steel tools and disposal of used batteries in the catchment.

Taken together, these results show that, of the seven metals studied, only copper remained consistently within WHO permissible limits across all basins. Nickel, cadmium, chromium and manganese exceeded permissible limits in every basin sampled, while iron and lead exceeded limits in a subset of basins closely tied to specific anthropogenic pressures — vehicular traffic, religious congregation, horticultural runoff, and dense residential settlement, respectively. This pattern strongly suggests that basin-specific land-use pressures, rather than a single uniform source, are driving the heavy metal load of Dal Lake.

### 5. Conclusion

The concentrations of most heavy metals in Dal Lake exceeded the permissible limits prescribed by the WHO (2003), with copper being the sole exception. Nickel, cadmium, chromium and manganese were found above permissible limits in all five basins studied, while iron and lead exceeded limits in specific basins associated with concentrated anthropogenic activity. The elevated heavy metal load is most likely a consequence of intensifying anthropogenic activity and unchecked urbanization around the lake periphery, including vehicular pollution, religious and tourist congregation, horticultural runoff and untreated sewage discharge from surrounding settlements. Given that heavy metals are non-biodegradable and persist indefinitely once introduced into the aquatic environment, continued contamination poses a serious long-term threat to the ecological integrity of Dal Lake and to the health of the communities that depend on it. Sustained basin-wise monitoring, stricter regulation

of waste discharge, and targeted catchment management are essential to safeguard the lake's water quality and its status as one of the most valuable aquatic ecosystems of the Kashmir Himalaya.

### References

1. Drew, F. (1875). *The Jummoo and Kashmir Territories: A Geographical Account*. London: Edward Stanford.
2. Enx Consortium New Zealand. (1978). *Master Plan for the Preservation and Development of Dal and Nagin Lakes and Environs, Srinagar, Jammu and Kashmir*. Report prepared for the Government of Jammu and Kashmir.
3. Hussan (1833). Cited in early geographical accounts of the Kashmir Valley and Dal Lake.
4. Kango, N., & Fotedar, D. N. (1982). Studies on the shrinkage of Dal Lake, Kashmir. *Proceedings of the National Academy of Sciences, India*.
5. Lawrence, W. R. (1895). *The Valley of Kashmir*. London: Henry Frowde, Oxford University Press.
6. Mukerjee, R. N. (1931). *Report on the Dal Lake, Srinagar*. Government of Jammu and Kashmir.
7. Stein, M. A. (1899). *Kalhana's Rajatarangini: A Chronicle of the Kings of Kaśmīr (translation with introduction, commentary and appendices)*. Westminster: Archibald Constable.
8. Vass, K. K., & Zutshi, D. P. (1979). Limnological studies on Dal Lake: Morphometry and physical features. *Journal of the Inland Fisheries Society of India*, 11, 11–20.
9. Walsh, A. (1955). The application of atomic absorption spectra to chemical analysis. *Spectrochimica Acta*, 7, 108–117.
10. World Health Organization (WHO). (2003). *Guidelines for Drinking-water Quality (3rd ed.)*. Geneva: World Health Organization.
11. Zutshi, D. P., & Kundangar, M. R. D. (1983). Comparative limnology of nine lakes of Jammu and Kashmir Himalayas. *Hydrobiologia*, 99, 107–112.