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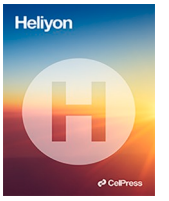

Research article

Economic valuation and characterization of heavy metal contamination in Dal Lake Srinagar, Kashmir, India

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ABSTRACT

Dal Lake, the world-famous tourist attraction has been polluted by allochthonous and autochthonous sources, as a result the heavy metal (HMs) concentrations within the water body has reached the toxic levels which is endangering the lives of the people. A study was carried out during the year 2021 (i) to determine the concentration of HMs (molybdenum: Mo, arsenic: Ar, cadmium: Cd, lead: Pb) at the four designated sites of Dal Lake, and (ii) a public survey (400 persons) involving economic valuation of water body in terms of recreational use and other benefits. The highest values of biological oxygen demand (BOD) and chemical oxygen demand (COD) within the Dal Lake were recorded at site A, which were 31 ± 1.10 mg/l and 76 ± 0.64, respectively. Similarly, maximum nitrate nitrogen was found at site A (865 ± 0.86 μg/l). The highest value of Pb was reported (6.828 ± 0.003 ppb) from site A whereas, the lowest from site B (2.492 ± 0.002 ppb). The mean values of Mo concentrations (in ppb) were found to be 2.538 ± 0.002, 1.703 ± 0.003, 3.627 ± 0.004 and 4.787 ± 0.002 at the four sites respectively. The observed values of HMs (in ppb) were much higher than the permissible values (WHO, 2006) and those reported earlier. A huge amount of money (Rs 16,18,66,000/) is being generated from the floating gardens of Dal Lake, calculated by TCM and CVM methods. During the survey, 68 % of people showed a willingness to pay (WTP) for the restoration of the Dal Lake and improved services (mean value: Rs 62,852.20/). Thus, the monitoring and assessment were done to find out how the Dal Lake contributes to the economy of the state by way of its different services and the major attraction for tourists besides the possible reasons for the deterioration of water quality, in order to find a long-lasting solution for the sustainable conservation of Dal Lake.

1. Introduction

The Kashmir valley is bestowed with a plenty of wetlands which provide a diverse set of products and services for human

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consumption and survival [1]. Many freshwater lakes in the Kashmir valley, including Dal, Manasbal, Wular, and Anchar lakes contribute to its regional biodiversity and are valuable resources for its socioeconomic activities, recreational opportunities and economic survival [2–4].

In the past few decades, a large number of studies related to monitoring and assessment have been accomplished on the hydro-biological features of Kashmir lakes [1,5]. Among these, Dal Lake has been an important tourist fascination in the heart of Srinagar city. Thus, Dal Lake was chosen for the study because of its scenic beauty and the different ecological and economic services derived from as it acts as a source of revenue generation (livelihood) to the localities.

The Dal Lake benefit the people who live in the nearby areas by supplying portable water (water extracted from Dal Lake: ~5.7 million gallons per day), water for agro-horticultural, industrial activities, and sustainable tourism [1,4]. Dal Lake act as the dwelling place for a number of aquatic organisms and primary sinks of pollutants. It has been reported that 50 % of the global wetland wealth has shown a drastic reduction during the last many decades [6]. The dominant macrophytes and the floating gardens of the Dal contribute to the economy of the state, besides the world-famous houseboats and Shikaras add to the income generation of the stakeholders. However, due to the increased human interference (due to the unplanned urbanization and industrial developments in the vicinity), Dal Lake is facing tremendous stress due to more rapid shift from oligotrophic to mesotrophic and to eutrophic states. As a result of this, it is constantly losing its charm and the chemical parameters of the water have changed due to which water quality has deteriorated. This in turn has affected the flora and fauna within the lake and has decreased its aesthetic appeal. Thus, immediate conservational measures need to be undertaken so as to prevent it from undergoing counterproductive [1].

Heavy metals (HMs), such as iron (Fe), copper (Cu), manganese (Mn) and zinc (Zn) are required in traces (micronutrients) by animals and plants. Zinc (Zn), nickel (Ni), iron (Fe) and cobalt (Co) are important constituents of a variety of important enzymes, which makes them essential for basic plant metabolism [7], whereas, others such as mercury (Hg), chromium (Cr), lead (Pb) and cadmium (Cd) are detrimental to plant growth, even at minute concentrations [8]. They get accumulated in food chains due to geochemical weathering of rocks and variety of anthropogenic activities [1,9]. Increased concentrations of As in urban environment leads to increased risk of renal failure and skin cancer [10,11] while exposure to Cr increases the risk of respiratory and digestive system damage [12,13]. Unfortunately, the HMs and other pollutants in Dal Lake has changed the hydrochemistry of the water body and has decreased the aesthetic value in attracting tourists, which are the major drivers of the local economy [14,15]. The chemical poisoning of the Dal Lake has occurred in recent years and has culminated in the death of millions of fishes [16]. Dal Lake water which was once used for drinking purpose, has quickly deteriorated in quality in the recent decades, owing to anthropogenic interventions such as sewage from houseboats, hotels, and the surrounding population [17,18].

The travel cost method (TCM) and the contingent valuation method (CVM) are two methodologies for determining willingness to pay (WTP) for ecosystem services in the ecosystem valuation process [19]. It is in this backdrop that the monitoring process was undertaken to find out the economic valuation and HMs stress due to unregulated human interferences on the ecology of the Dal Lake and the flow of international, national and local tourists beyond the carrying capacity of the lake, which if not taken care in the due course of time can lead to serious ecological cum economic ramifications, and can have a drastic effect on the day to day earnings of the daily wagers and the Srinagar-state-economy as well.

The present study was undertaken with the objective to find out the valuation of different goods and services derived from the Dal Lake which include both direct and indirect benefits, heavy metal pollution of Dal Lake waters and the measures needed for conservation of the Lake. The information regarding the economic evaluation of the water body and the impact of tourist flow was collected. Generation of scientific information was done by using important techniques such travel cost method (TCM) and the contingent valuation method (CVM) to develop the possible adaptive management techniques for long lasting sustainability of Dal Lake. Economic value and recreational usage of water and its deteriorating impact on the national economy was accomplished via the use of data by survey method in conjunction with regression model to assess its value outside the market [20]. Untreated wastewater discharged by houseboats, oil spills from motorboats within the lake, as well as from motor garages and workshops, and substantial vehicular traffic in the vicinity of the lake are major contributors of hydrocarbons and heavy metals [21].

Though the lake has been the point of attraction for the researchers on various fronts but the timely heavy metal load and the economic valuation has not been undertaken on the priority. As such, the current study attempted to find out the causes of deteriorating water quality by increased pollution load and the necessary measures needed to be taken on urgent basis to make this lake lively and to increase the economy of the state by attracting more tourists on yearly basis.

2. Methodology

2.1. Study area

The study was carried out in Dal Lake (area of about 11.4 km^2 with a depth of approx. 5.4 m) located between 34°05′–34°N latitude and 74°50″–75°05″ E at 1580 m (a.s.l) to assess the concentration of HMs (Mo, Ar, Cd and Pb) at the four sites: site A (Hazratbal), site B (Habak), site C (Laam), site D (Brarinambal), during Dec. 2020 to Nov. 2021 and economic valuation of water body in terms of recreational use and other benefits, through survey (involving 400 persons).

2.2. Water analysis

The pH and conductivity of the water from the four sites was measured using a pH meter and conductivity meter respectively [22]. The calibration was done using 0.01 M KCl solution.

2.3. Biological oxygen demand

It involved the estimation of the oxygen content of a 20 ml water sample taken from the four different sites of Dal Lake four times during the year with an incubation step for five days. 1 ml of phosphate buffer, $CaCl_2$, ferric chloride and magnesium sulphate were added to each liter of diluted water. One normal H_2SO_4 or NaOH was used to neutralize the sample. Dissolved oxygen (DO) of one bottle was determined immediately and that of the other after five days of storage at 20 °C [22]. The calculations were done as shown below.

2.4. Calculation

Biological Oxygen Demand mg/L = $(D_0 - D_5) \times$ dilution factor

Where DO = Initial dissolved oxygen of the sample.
D_5 = Dissolved oxygen after five days.

2.5. Chemical oxygen demand (COD)

The water samples taken from four different sites of Dal Lake at four times during the year, were titrated with 0.1 N ferrous ammonium sulphate after addition of few drops of ferroin indicator (Ferroin is a redox indicator used in cerimetry). The amount of potassium dichromate used is proportional to the oxidizable organic matter in the sample [22].

2.6. Ammonical nitrogen

Ammonical nitrogen was estimated using the protocol of Mackerth et al. [23]. 20 mL of water sample from the four sites of Dal Lake were collected during four different seasons of the year. Samples were collected in 50 mL graduated flask and 8 mL of sodium phenate was added. After shaking, 4 mL of hypochlorite was added and the volume was made up to 50 mL. The tightly packed flask was heated at 70 °C for 45 min and the absorbance was read at 625 nm using a spectrophotometer (Systronics, India).

2.7. Nitrate nitrogen

The nitrate nitrogen content was determined by phenol disulphonic acid method [22]. In a 200 mL pyrax flask, 100 mL of water sample each from four different sites of Dal Lake were taken, during the four seasons of the year, and 2 mL of phenol disulphonic acid was added and the solution was allowed to stand for 10 min. Later, 80 mL of distilled water and 2 mL of magnesium sulphate was added, followed by the addition of sodium hydroxide (drop by drop) until the formation of magnesium hydroxide precipitate, which was removed by using Whatman filter paper and the absorbance of the yellow colour solution was read at 410 nm against a reagent blank.

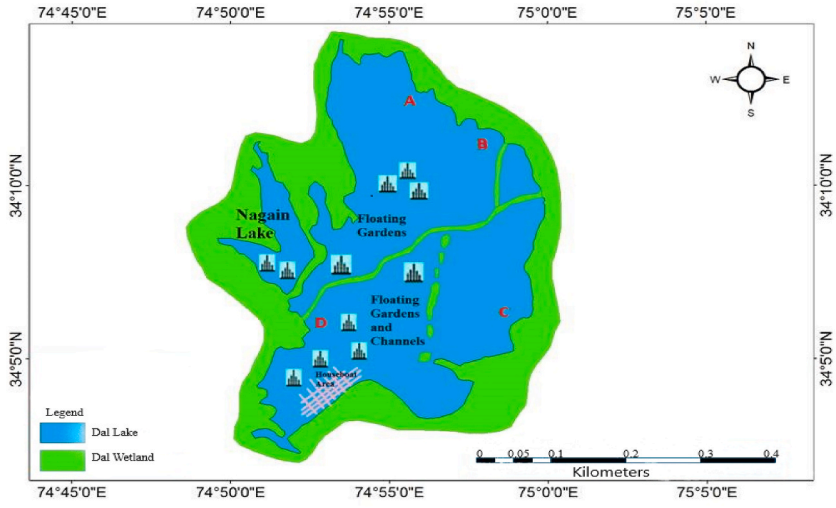

Fig. 1. Map depicting the sampling sites within the Dal Lake: (A)Hazratbal (B) Habbak (C) Laam, and (D) Brarinambal.

2.8. Orthophosphate

Orthophosphate was determined by the stannous chloride-reduced phosphomolybdate method [22]. To the 25 mL of water sample, 1 mL of ammonium molybdate was added, and 2–3 drops of stannous chloride were also added. The absorbance of the resulting blue colour was read at 690 nm using a spectrophotometer.

2.9. Estimation of heavy metals (HMs)

Four sampling sites were chosen within the Dal Lake, which were designated as site A (Hazratbal), site B (Habak), site C (Laam), site D (Brarinambal) as shown in Fig. 1. Water Samples were collected from four times from the four locations during the year 2021 and were analyzed at Punjab university Chandigarh using ICP-MS (Icap RQ November 2, 2021 10 ppm, Thermo Fischer Scientific, USA) technique. ICP-MS is a technology that uses a mass analyzer to separate and detect ions created in inductively coupled plasma. The sample is then evaporated, dissociated, and ionized to different degrees in the plasma. The mass analyzer extracts the generated positive ions. A channel electron multiplier is used to separate the ions based on their mass to charge ratio (m/z) [24,25]. HMs such as Mo, Ar, Cr, Cd and Pb were estimated by using this technology.

2.10. Economic valuation

During the study an economic survey was carried out with a sample size of four hundred individuals in the vicinity of Dal Lake, using 'Travel cost method (TCM)' and Contingent valuation method (CVM)' in order to build the scenario as to how the educational qualification, family strength, environmental awareness and economic status of a person or family play a role in the conservation of Dal Lake. The survey sheet for TCM is shown in Supplementary Fig. 1a whereas Fig. 1b shows the survey sheet for CVM. Many direct benefits are provided by the lake, such as drinking water, vegetables (from floating gardens) and recreational activities like boating and rafting.

The monetary value of the key advantages and the money generated through these activities has been assessed by taking into account the number of individuals who live there and the average annual income they earn. Boatmen, tea stalls-owners, lakeside merchants, hawkers, food and cold drink dealers, dhabawallahs (temporary restaurant-owners), fruit sellers, and visitors were among those covered. Besides that, the cost of providing water to the people and the water tax levied on them have been taken into account. In addition, the revenue generated by hotels, houseboats, shikara riders has been taken into consideration. The 'vegetable gardens' in the Dal Lake provide vegetables on daily basis and contribute significantly to the economy of the union territory [26]. This information was collected by direct interaction with the localites, tourists and other stake holders, besides secondary source information.

2.11. Statistical analysis

The data of the water analysis was subjected to two-way ANOVA and Levene's test for equality of variances and to check the significant difference between the different parameters of water. For economic valuation, 'Travel Cost method' and 'Contingent valuation method' was used in the survey in order to build the scenario regarding the principal factors which contribute to the economy of the state.

3. Results and discussion

3.1. Water analysis

During our study on the Dal Lake, the average water pH values from the different sites were, site A: 7.4 ± 0.11, site B: 7.3 ± 0.11, site C: 7.2 ± 0.14 and site D: 7.3 ± 0.13. The lower pH values were found to be due to macrophytic phosphate absorption [27]. The conductivity values recorded were site A:196 ± 1.55, site B:162 ± 3.52, site C:215 ± 2.12, and site D:242 ± 2.21. The highest and lowest conductivity values were at the site D and site B respectively. The BOD and COD values for all the sites are site A: 31 ± 1.10 and 76 ± 0.64, site B: 29 ± 1.49 and 65 ± 0.85, site C: 24 ± 1.08 and 52 ± 0.86 and site D: 26 ± 0.64 and 54 ± 0.65 mg/l. The highest BOD and COD values were recorded at the site A. The values of nitrate nitrogen at the four sites were, site A: 865 ± 0.86, site B: 787 ± 1.04, site C: 428 ± 1.37, and site D:466 ± 1.55 μg/l. Nitrate nitrogen content value showed a peak at the site A which was possibly due to sewage disposal. The values of orthophosphate content at the four sites were, site A: 28.5 ± 0.12, site B: 67.6 ± 0.11, site C: 39.3 ± 0.18, and site D: 43 ± 0.86 μg/l. A high orthophosphate content was recorded at site B. It was found that the values of these parameters are significantly dependent on each other due to low p-value ($p < 0.0001$) [1,28]. Due to the increasing nutrient content of Dal Lake, certain members of phytoplanktons (members of cyanophyceae and certain members of rhodophyceae) are increasing causing the algal blooms (Supplementary Table 1).

3.2. Heavy metals (HMs)

The concentration of HMs in water at the different sites within the Dal Lake was analyzed and the mean values of the same are depicted in Fig. 2 and Supplementary Table 2. Perusal and analysis of the results showed significant variation between the sites A to D (from Hazratbal to Brarinambal). The Mo content (in ppb) content at sites A, B, C and D were found to be 2.538 ± 0.002, 1.703 ±

0.003, 3.627 ± 0.004, and 4.787 ± 0.002 respectively. It is clear that the highest concentration of Mo was recorded at site D (Brarinambal) whereas, lowest was recorded from site B (Habbak). On the contrary, the site B showed the highest values of Ar 3.098 ± 0.0008 ppb whereas, lowest was found in site C (Laam) 0.006 ± 0.0007 ppb. The mean values of Cd showed a peak at the site D (Brarinambal) 0.989 ± 0.002 and a low value at the site A (Hazratbal) 0.099 ± 0.001. An increase in Cd concentration was possibly due to increased suspended solids. Similarly, the mean values of Pb showed a peak at the site A (Hazratbal) 6.828 ± 0.003 (Supplementary Table 2) and lowest concentration at the site B (Habbak) 2.492 ± 0.002. Similar results were reported by Shafi et al. [29] and have shown concern towards increased human interference and dumping of municipal and sewage wastes in the waterbody. Chromium, which is highly toxic and carcinogenic, was not detected in any of the samples examined during the study period. The general decreasing order of occurrence and concentration of HMs recorded during the study was Pb > Mo > As > Cd. Our results are in consonance to those reported by Shah et al. [15]. The observed values of HMs (in ppb) were much higher than the permissible values [30] which are, 0.01 for Mo, 0.005 for Cr, 0.01 for As, 0.003 for Cd and 0.01 for Pb. The high significant values ($p < 0.00001$) for all HMs indicated that there is a single contamination source for all the four sampling sites within the Dal Lake. The mean value of Molybdenum was found to be 2.54(0.01) mg/l, 1.71(0.01) mg/l, 3.62(0.02) mg/l and 4.76(0.04) mg/l at the sampling site I, II, III and IV, respectively with $p < 0.0001$ between the samples analyzed. Mo is extensively utilised in electronics, missiles, metallurgy, and many other significant fields (11–13). It can also be found in commonplace goods like apparel, toys, and household and plant care supplies. Humans mostly obtain Mo through their diet and water intake. Foods high in molecular sulphur (Mo) include milk, cheese, beans, wheat, oats, asparagus, and soil and water in the area where the product was grown (15). The amount of Mo in food varies according to these levels. Mo is mostly found in the kidneys, liver, and bones after absorption; very little of it crosses the placental barrier (16–18). Given their ultra trace incidence, molecular shortages are rare, but overconsumption can lead to health problems such as joint discomfort, hyperuricuria, seizures, and hallucinations.

The mean value of Arsenic was found to be 2.76 (0.03) mg/l, 3.10 (0.01) mg/l, 0.01(0.01) mg/l and 2.32 (0.01) mg/l at the sampling site A, B, C and D, respectively with $p < 0.0001$ between the samples analyzed. The Environmental Protection Agency (EPA) federal drinking water standard for arsenic in drinking water is 10 μg per liter (μg/L). Arsenic species can be present in all types of environments and can originate from natural and anthropogenic sources. Long-term consumption of arsenic-contaminated food and water can result in skin sores and cancer. Diabetes and cardiovascular disease have also been linked to it. Exposure during pregnancy and early infancy has been associated with poor effects on cognitive development as well as an increase in young adult fatalities. The mean value of Cadmium was found to be **0.10**(0.01) mg/l, **0.38** (0.022) mg/l, 0.38(0.**22**) mg/l and **0.96** (0.05) mg/l at the sampling sites A, B, C and D, respectively with $p < 0.0001$ between the samples analyzed. Poisoning with cadmium compounds affects many organs and systems. It is regarded as a possible global hazard to both the environment and people. It travels by soil, water, air, food chains, etc. The mean value of **Lead** was found to be **6.82**(0.01) mg/l, **2.49** (0.01) mg/l, 5.37(0.**01**) mg/l and **6.28** (0.01) mg/l at the sampling site A, B, C and D, respectively with $p < 0.0001$ between the samples analyzed. Hearing loss, anemia, hypertension, kidney damage, immune system malfunction, and toxicity to the reproductive organs are among the health impacts. Low exposure levels can impair cognitive function, reduce IQ in kids, and lead to behavioral and attention issues, all of which have an impact on lifetime learning. The presence of heavy metals in Dal Lake can be attributed to the natural weathering of the geology and different human activities, such as the usage of pesticides and fertilizers in neighboring horticulture and agricultural sectors, as well as urban waste disposal [31]. Untreated wastewater discharged by houseboats, oil spills from motorboats within the lake, as well as from motor garages and workshops, and substantial vehicular traffic in the vicinity of the lake are major contributors of heavy metals. The contamination is further exacerbated by the discharge of effluents from the sewage treatment facility located on the shore of Nigeen Lake, as well as the application of fertilizers and cow manure to the floating gardens within the lake [21].

3.3. Economic valuation

As aforementioned, the economic valuation survey was conducted using TCM and CVM. The Supplementary Table 3 indicates an increase in revenue from Rs 6,30,00000 in 2020 to Rs 6,89,41200 in 2021 due to increase in number of water connections. The revenue collected however, is low because of the inability of the people to pay the water tariff regularly. As a result, instead of the actual money recovered, the department projects to collect nearly 45 crores annually, this deficit is expected to be overcome by the installation of

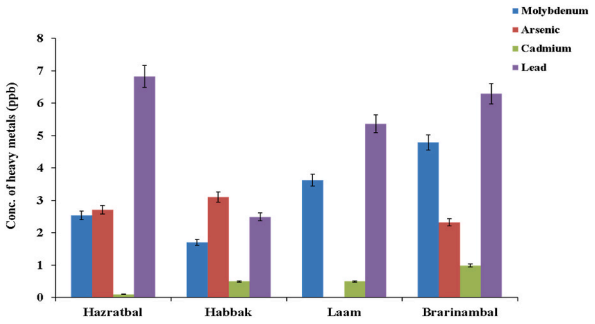

Fig. 2. Graph showing heavy metal content (ppb) within the Dal Lake: (A) Hazratbal (B) Habbak (C) Laam, and (D) Brarinambal.

pre-paid meters which the department is mulling to install soon and the process has already started. The Supplementary Tables 4 and 5 indicates that a considerable amount of revenue was generated by hotels and house boats during the study period, however the amounts generated could have been much higher if the COVID restrictions would not have been implemented throughout the country, which negatively affected the revenue generation. The 'shikara' and 'boat riders' also earn significantly good amount of money during the peak tourist seasons however, due to lock down this sector also faced a problem to earn their livelihood (Supplementary Table 6). The information gathered through TCM and CVM is mentioned below.

3.4. Travel cost method (TCM)

The analysis of the survey under 'Travel cost method' reveals that education level, and total gross income were more or less the more dominant factors to visit the Dal Lake and most of the tourists were visiting the lake for recreational rather than the religious purposes. The results of the analysis are as follows: (i) of all the respondents interviewed during the survey, most of the people were found to be self-employed (60.6 %), followed by private sector (20.3 %) and Govt. sector (12.3 %) employee; (ii) as far as education was concerned, majority of the people were graduates (35.2 %), followed by intermediate pass (33.0 %); (iii) the main income group was found to be in the range of 3–5 lakh (86.7 %) followed by less than 25 thousand (13.3 %); (iv) the family structure of the respondents showed that 50.7 % were below the age of 18 years and 28.4 % were above the age of 18 years; (v) regarding the frequency of visit by the tourists, 86.8 % (majority) of the respondents visited once in 1–2 years and 13.2 % respondents visited once in a week, who were localites; (vi) although, the Dal Lake has many religious places located on its banks which are very sacred for Hindu population such as Shankaracharya Mandir, Hazratbal shrine (Muslims) and Chattipadshahi Gurduwara (Sikhs) but as per the survey, most of the people (86.8 %) visited for recreational purposes and (13.2 %) people visited for religious purposes. However, local people visit for recreational purposes mainly in the evening hours; (vii) most of the people who visited Dal Lake, travelled through private car/tempo (24.5 %), followed by local bus (23.2 %), contract car (19.3 %) and Air (17.0 %); (vii) maximum respondents spent money in the range of Rs 1000–2000, followed by Rs 500–750 and the total money spent on boarding and lodging was 1,10,500 rupees; and (viii) likewise, maximum money spent on snacks was in the range of 1000–1500 followed by 500–750 and the net amount totaled to rupees 92,812.50. During the study period, it was found that (23.8 %) people spent 250–500 on boating and the amount spent on this was rupees 20,600. Scenic beauty and recreational activity were found to be the main driving force of the tourists however the difficult terrain, security concerns and the pandemic conditions prevalent during the study period hampered their visit to the lake.

To sum up, it was observed that more money was spent on boarding and lodging which amounted to Rs1,10,500/ = during the study period and the more commonly used travel was private cars and tempos rather than the air travel. Significant amount of money was spent on food and snacks, however money actually spent on the trip was lesser than what was intended/expected to be spent, which possibly could be due to non-availability of big shopping malls in the area (TCM Supplementary figure 2a to 2s).

3.5. Contingent valuation method (CVM)

The analysis of the 'Contingent valuation' results indicated that the qualification, nature of income and the environmental education of the person can actually help in the conservation of a particular ecosystem. The results of the contingent valuation are as follows: (i) people were willing to pay for the restoration of Dal Lake voluntarily and the payment option Rs 250–500 was opted by majority of the people, and were ready to curtail their personal expenses, (ii) moreover, people were ready for the voluntary payment of compulsory tax which amounted to about Rs 59660/ = during the study period; (iii) people living near the lake appeared to be unaware of the precautionary measures required to make the water safe for drinking, as only 16.5 percent people used aqua guards and 15.5 percent used chlorine tablets and alum for purification. However, 53.4 percent people said they were using boiled water to prevent the spread of diseases, which in both the cases add up to the economy of the state; (iv) 50 % of the people said that Dal Lake needs special conservation measures and 70.9 % of the people were of the opinion that there should be gate fee at the entrance of the water body for its proper management. Although the installation of a gate fee at Dal Lake would create money for the lake, certain stipulations regarding the distribution aspect of entrance fees, such as granting free admission to school and university students or a 50 % discount to senior residents, must be addressed. These safeguards would ensure that people from all socioeconomic backgrounds may visit the lake (CVM Supplementary Figs. 3a–3m). Due to increased pollution, the waters of Dal Lake are no longer portable and have been found to cause different types of water borne diseases like typhoid and dysentery to the people living in the immediate vicinity or within the Dal Lake and on that huge amount of money to the tune of rupees 76,04250/ = were spent to get rid from the water-borne diseases (Supplementary Table 7). Though this money is being spent on the cost of medicine however, it indirectly contributes to the economy of the state (cost of illness approach). The floating gardens/vegetable market present in the water body is a source of income for the thousands of people, the vegetables cultivated in the floating gardens are sold each day wherein three to four hundred 'Shikaras' come around and sell the vegetables early in the morning from 4 a.m. to 6 a.m. During the study it was observed that there is a turnover of corers of rupees per year from the floating gardens/vegetable market of the Dal Lake. If the Indian Government takes up some market intervention activities, the unemployment rate in the valley can be tackled significantly. During this study period of one year, around 16,18,39,000 rupees were estimated to be earned by the stake holders. Table 1 provides a summary of revenues as determined though different direct and indirect valuation techniques (contingent valuation, travel cost and cost of illness approach).

4. Conclusions

Dal Lake, a world-famous water body has been for centuries a major tourist attraction and contributing to the economic wellbeing of the people in the union territory of Jammu and Kashmir. The hotel and the houseboat industry in the valley of Kashmir is surviving because of the Dal Lake as the huge amount of revenue is generated every year by these two sectors. Besides direct benefits some indirect benefits are derived from the Dal Lake in view of the cost of illness approach and the increase in the cost of real estate (Hedonic pricing). As aforementioned, due to the anthropogenic activities and related pollution load, the water body is losing its charm and the physical and chemical parameters of water are changing very fast which is an indication of transition of the water body to a highly eutrophic state. So, the present study is an attempt to evaluate the economic benefits of the water body and the anthropogenic factors which contribute to the deteriorating water quality of the Dal Lake.

Dal Lake provides economic benefits by acting as a major tourist attraction thereby improving the livelihood of people, however due to excessive footfall of tourists and reckless use of fertilizers and pesticides in the floating gardens, the water quality index (WQI) is gradually deteriorating. In order to maintain the charm of the water body, immediate steps need to be taken for the sake of posterity. Hyperaccumulator plants (phytoremediation properties) must be grown on the banks of the lake. *Salix alba* and some macrophytes which have proven capacity of removing toxic metals are *Eichhornia* and *Lemna minor*. *Azolla pinnata* can sequester large amounts of Zn, Cu, Pb, Cr and Cd from polluted waters [29]. *Ceratophyllum demersum* too can remove Co, Cd and Mn from the water [32]. Emergent plants such as *Typha angustifolia*, *Phragmites communis* must be grown at the entry points so as to filter out the pollutants and excess silt at the first place. Moreover, the municipal wastes before their entry into the water body must be properly treated in the sewage treatment plants to decrease the concentration of pollutants. Last but not the least, there should be effective legislation to educate the people about pollution of key water bodies and imposition of fine to the serial offenders. The outcome of the research carried out on the lake is intended to be submitted to the Govt. agencies for implementation so that the long-lasting solutions can be found for the sustainability of the lake. The coordination and synergism between the academia and the administration will facilitate in analyzing the repercussions of the problem and shall seek solutions that can be implemented in letter and spirit through public participation, by the administrative machinery of the State.

Data-availability

The data that support the findings of this study are available from [Bhupendra Koul]. Still, restrictions apply to the availability of these data, which were used under license for the current study and are not publicly available. However, data are available from the authors upon reasonable request and with permission of [Bhupendra Koul].

Table 1
Summary of the values as determined through various valuation techniques.

Category	Uses	Stakeholders	Valuation Technique	Value (Rs)
A	Drinking Water	PHE Department	Supply Cost	68941200/-
B	Boating (Shikaras)	Boatmen	Income Estimation	3,1100000/-
C	Secondary activities			
	1. Cold drinks and Ice cream	Individual owner	Income Estimation	240000000/-
	2. Tea Stall	Individual owner	Income Estimation	7000000/-
	3. Golegappa Selling	Golegappa seller	Income Estimation	2000000/-
D	Water Borne Diseases	Population using lake water	Cost of Illness Approach	7604250/-
E	Handicrafts	Handicraft seller	Income Estimation	35000000/-
F	Shopping Complexes	Salesmen	Income Estimation	42000000/-
G	Public Parks	Floriculture Dept.	Income Estimation	720000/-
H	Public Toilets	SMC	Income Estimation	18900000/-
Income Estimation of Floating Market in the Dal Lake				
I	Nadroo Harvesting (*Nelumbo nucifera*)	Hanji (green grocer)	Income Estimation	138600000/-
J	Haakh (KnolKhol) (*Brassica oleracea kashmariana*)	Hanji	Income Estimation	17280000/-
K	Raddish and Turnip (*Raphanus sativus & Brassica rapa*)	Hanji	Income Estimation	273000/-
L	Bottle gourd and cucumber (*L. siceraria &C. sativus*)	Hanji	Income Estimation	1800000/-
M	Tomato (*Lycopersicon esculentum*)	Hanji	Income Estimation	270000/-
N	Carrot (*Daucus carota*)	Hanji	Income Estimation	280000/-
O	Brinjal (*Solanum melongena*)	Hanji	Income Estimation	360000/-
P	Spinach (*Spinacia oleracea*)	Hanji	Income Estimation	1800000/-
Q	Capsicum (*Capsicum annuum*)	Hanji	Income Estimation	300000/-
R	Bhindi (*Abelmoschus esculentus*)	Hanji	Income Estimation	162000/-
S	Dhania (*Coriandrum sativum*)	Hanji	Income Estimation	90000/-
T	Spring Onion (*Allium fistulosum*)	Hanji	Income Estimation	120000/-
U	Trapa (*Trapa natans*)	Hanji	Income Estimation	504000/-
V	Increase in property prices	Lake front property owners	Hedonic Pricing	6.4 % per square ft
Total Revenue Generated				16,18,39,000+ 45,44,76,650 = 61,5104450

Animal research

Not applicable.

Additional information

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CRediT authorship contribution statement

Siraj Yousuf Parray: Writing – review & editing, Writing – original draft. **Simranjeet Singh:** Writing – review & editing, Writing – original draft. **Bhupendra Koul:** Writing – review & editing, Writing – original draft, Visualization. **Nadeem A. Khan:** Writing – review & editing, Writing – original draft. **Praveen C. Ramamurthy:** Writing – review & editing, Writing – original draft. **Joginder Singh:** Writing – review & editing, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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