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Rapid sedimentation and organic matter accumulation in the Kashmir Himalayan lakes: a challenge for lake managers

Freshwater constitutes a little less than 3% of the total volume of water present on the earth's surface. However, freshwater ecosystems have a strong bearing on the economy of a country by providing potable water, fish and fodder for the local people. They are also the most vulnerable habitats as they act as major sinks for weathered sediments, sewage and waste disposal from catchment areas. Human interferences within the lacustrine systems have significantly altered them. The primary anthropogenic activities responsible for the degradation of lacustrine ecosystems include massive population growth, deforestation, land reclamation and other land-use/land-cover changes. Two primary concerns regarding the vulnerability of these freshwater ecosystems include extensive sedimentation and accumulation of organic matter. The organic content of the sediments reflects the quantity of living organisms in and around the lake ecosystems, including the level of lake productivity and leaching from humus-rich catchment soils. While the changing climate plays an important role in changing these ecosystems, anthropogenic-induced variations in the nutrient load inputs have had a distinct effect on the freshwater lakes during the past few centuries.

The Kashmir Himalayan lakes (Wular, Dal, Manasbal and Anchar Lake), located within the inter-mountain settings receive exceptionally high amounts of sediments from the tectonically active hinterlands. Furthermore, the unique climate of the Kashmir Himalayan region with intense cold winters and steep slopes augments the physical weathering of the exposed surfaces resulting in increased erosion and subsequent deposition of sediments in these freshwater lakes. The lakes in Kashmir Valley are the potable sources of freshwater for the region, but due to their exploitation for various purposes like drinking, domestic use, agriculture and hydropower, these freshwater ecosystems are getting eutrophicated and are shrinking in area at a rapid pace. The sedimentation rate reported from a few of the Himalayan lakes reveals contribution of sediments due to both natural and human interference. High sedimentation rates are reported from the Kashmir Himalayan lakes[1]. For example, Manasbal Lake shows a sedimentation rate of 0.44 cm/yr, and the average sedimentation rates of the Dal and Mansar lakes are 0.93 and 0.23 cm/yr respectively[1]. Since these lakes also act as hotspot centres for tourism, high anthropogenic gross pollutants settles within these lakes. Traditionally, our lake management strategies are primarily focused on flood management, wherein these lakes act as flood buffer systems by absorbing excess water during the floods[2]. For instance, during the September 2014 Jhelum basin flood, Wular Lake acted as one of the major regulators by absorbing excess water carried by the Jhelum River. However, if the sediment accumulation in the lakes increases and remains unchecked, it will lead to rising bed levels and increased flood risks.

The Wular, Dal, Manasbal and Anchar lakes are classical examples of lacustrine ecosystems where sediment and organic matter management is urgently needed. All these lakes are severely polluted by the human population living in the hinterland. The main culprits are the sewage inputs by local population, floatables, including polythene covers and used plastic bottles, medicinal trash, agriculture fertilizers, etc. (Figure 1).

Therefore, any extensive sediment and organic matter management strategy would involve a proper balance between the local population and lake ecosystems. The situation has further worsened during the past few centuries as the trophic status of these lakes has altered from oligo to eutrophic conditions due to intense human activities. Recently, the Supreme Court of India has directed the Jammu and Kashmir government to concentrate on efforts to restore and ensure proper conservation of the pristine beauty of these lakes. The suggested measures are catchment area treatment, including afforestation and construction of check dams, construction of settle basins at the lake–river interface, marginal dredging, diversion of inflow of sewage and agricultural waste products, selective deweeding, restricted population growth along the lake margins, etc. It is imperative to mention here that in Sydney, Australia, 'Pratten traps' (capture netting system) have been used at drainage inlets to capture the trash and other gross pollutants, allowing only water to flow into the lakes. This can be one of the effective systems to trap solid gross pollutants from settling in the lake systems in Kashmir Valley.

Studies regarding the environmental conditions of these lake ecosystems have mostly focused on the impact of increased human population along the hinterlands

Figure 1. Spatial view of the Kashmir Himalayan lakes (Manasbal, Wular, Anchar and Dal) showing significant eutrophic environments.

and subsequent vast land-use/land-cover changes. Overall, these studies point out that complex and mixed organic matter accumulation pattern occur in Manasbal, Anchar and Wular lakes along with higher sediment influx as a result of intense human activities in the hinterlands. A study carried out on the environmental risk assessment of the Anchar Lake suggested that in the absence of industries and metal mines in the lake catchment areas, agricultural inputs, domestic effluents and untreated sewage discharges are the primary sources of organic materials resulting in increased lake eutrophication[3]. Further, a study on sediment distribution, organic matter accumulation and diatom diversity carried out in the Wular Lake revealed that organic carbon varies from 0.83% to 4.52%, and nitrogen from 0.06% to 0.5% in the lake surface sediments[4]. In addition, analysis of diatom species has suggested wide distribution of *Cymbella*, *Cyclotella* and *Tabularia*, indicating high organic pollution and alkaline environment of the Wular Lake[4]. The integration of all these studies carried out on several lakes in the Kashmir Himalayan region points out that anthropogenic activities (agriculture activities, quarrying, tourism pressure, deforestation and other land-cover changes) along the lake catchment areas have detrimental effects on the trophic status of these lakes. Continued expansion of population is of great concern for the ecological stability of these freshwater lakes due to the further reduction of lake margins.

In order to preserve the pristine ecology and environment of these lakes, continued long-term monitoring of sediment and organic matter influx studies and strategies need to be undertaken. A region like Kashmir attracting a huge number of tourists annually, where the local population is entirely dependent on these lakes for drinking water, fishes, chestnuts, boating rides, etc. needs immediate monitoring assessment of sediment and organic matter loading. In particular, several issues need to be resolved prior to any mitigation measures for improving the present condition of these lakes from the frequent problems of sediment and organic matter accumulation. Hence, an accurate assessment of the total sediment and organic matter influx draining into these lakes through different modes is necessary. This will help in the distinction of natural and anthropogenic factors adding to sediment and organic matter loading in the lakes. In order to facilitate the lake management strategies and monitoring assessment components for restoration of these freshwater lakes, the following points need to be taken into account.

(1) Qualitative and quantitative understanding of the sediment dynamic processes and their provenances such as natural and anthropogenic sources.

(2) Continuous monitoring of lake health and habitat suitability using various geological and geochemical approaches.

(3) Adopting approaches to reduce catchment soil erosion, mass wasting and terrestrial organic matter influx into these lakes.

(4) Local population has to be educated and well trained about the sustainable use of these lakes and consequences of their overuse.

(5) Finally, strong and full-fledged capacity-building programmes on sediment and organic matter management involving state ministry, environmentalists, concerned lake and wetland officials, and particularly, the local population are recommended for timely restoration of these freshwater and highly valuable natural ecosystems. If timely robust strategies and action plans are not devised and implemented, there will be gradual extinction of these freshwater bodies as a result of excessive sediment influx, hydrophyte blooms and subsequent eutrophication, and this will affect millions of people who are directly or indirectly dependent on these freshwater ecosystems.

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