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Review Article

Understanding the complex interplay: how social and economic development impact lake ecosystems

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Lakes play an important role in the ecosystem and offer a variety of benefits for humans, such as providing water and food for humans to consume as well as purifying water to benefit ecosystems. There has been an increase in the quantity of contaminants due to the growth in and around the lake, which has resulted in a decrease in the water level of the lake. Runoff from agricultural fields, untreated sewage discharge, and silt from nearby water catchments are all factors that have contributed to the degradation of the lake's water quality. Due to the vulnerability of lakes to water pollution as a result of socioeconomic development, the quality of the water in lakes is under enormous pressure, which highlights the importance of fully comprehending how developments such as these negatively impact the quality of the water in lakes. In spite of this, studies that investigate the relationship between socioeconomic development and the quality of water often overlook those factors that have a theoretical basis and those that influence the selection process of those factors. There are certain lakes that become eutrophic due to the presence of excessive algae and macrophytes as a result of high nutrient levels. The management of a lake can be enhanced through a variety of mitigation measures, such as planting trees in the catchment area, educating the public, managing solid waste, and conducting continuous monitoring in order to reduce the impact on the lake.

Keywords: *lake ecosystem, socio-economic, anthropogenic, water quality, pollution, conservation*

Introduction

The importance of water in our day-to-day lives cannot be overstated. Water plays a very crucial role in our everyday lives in numerous ways (Sharma et al., 2022). It is not only consumed directly by humans but also used for various household activities such as cooking, cleaning, and sanitation. In addition to this, it is used for recreational purposes, aesthetic purposes, as well as providing habitats for wildlife and biodiversity in our communities (Sharma et al., 2023). The use of water is also an integral part of the production of food and most consumer products, and almost all manufacturing processes include water in some capacity in their operation (Sharma et al., 2020). A significant portion of the Earth's surface has been covered by water, approximately 71%. However, only a small percentage of it, just 3%, is freshwater, and the majority of this freshwater is trapped in the ice and glaciers, leaving a relatively small amount that can theoretically satisfy the world's needs for freshwater. The problem of access to safe, clean, and affordable water sources is a significant one, as progress in socioeconomic development has resulted in poor systems for water distribution, and the source water is increasingly polluted as a result. As a result, preserving and maintaining natural streams and lakes can be a significant asset which generates value for the future (Kumari et al., 2023). It is common for people to have access to water sources without restriction, so they can withdraw from them, use them for recreational

purposes, or even dispose of pollutants into them, if they are not regulated. It is clear from the fact that water pollution is a classic example of an externality, which is a side effect that is unintended, and that can negatively affect a person or the environment (Thakur et al., 2021). It is often necessary for the government to intervene in order to address water pollution in an efficient and effective manner. As a result of socioeconomic development, lakes are particularly susceptible to pollution caused by environmental changes, which are putting pressure on the quality of the water. Therefore, it is critical to understand the extent to which socioeconomic development impacts water quality, and what can be done about it.

It has been determined that lakes are one of the best habitats for the study of ecosystem dynamics due to the unique interactions between physical, chemical, and biological processes that operate within them and their unique effects on ecosystems. As a result of the distinct boundaries between water and land and between water and air, there is a close coupling between many of the components of the water-based ecosystem, making lakes a highly complex and fascinating place to study. According to the location of the lake, it may maintain a variety of water inputs and outputs, depending on whether it is located within a river basin or not. In headwater lakes, there is no single river input source and inflow is a result of inflows from small streams that flow into the lakes and from direct surface rainfall that enters the lakes, as well as groundwater inflows. A lake of this type usually has a single outlet river which flows into the lake. As the water flow moves downstream, the inputs and outputs of lakes become more evident, and the water balance varies as a result of additional water sources. There is an estimated 49.8% of freshwater in lakes on the surface of the Earth, even though the lakes made up only 50.01% of all the water on the Earth's surface. In addition to the survival of many organisms, freshwater lakes provide a variety of goods and services to humans, including drinking water, waste removal, fisheries, irrigation for agricultural purposes, industrial activity, and recreational opportunities. Nevertheless, human activities such as land use changes and longer growing seasons can cause a greater use of fertilizers, and one of the consequences is that fertilizers can leach into watercourses, rivers, and lakes, increasing the risk of water pollution and eutrophication (Kumar et al., 2023).

Therefore, it is crucial to understand the complex dynamics of lake ecosystems and their vulnerability to human impacts to ensure their sustainable management and conservation. The ever-increasing population, urbanization, and modernization have brought about various problems in sewage disposal and contamination of surface waters such as lakes. The natural water sources can get contaminated due to weathering of rocks, leaching of soils, mining processing, and other activities. These activities can lead to nutrient enrichment in the lake, causing harmful algal blooms and loss of biodiversity. Pollution by plastic debris is also a growing environmental concern in water bodies, affecting open-water, shoreline, and benthic environments. Various methods, such as Hyperion, water quality index, and hazard quotient, have been used to analyse the water quality of lakes. Yes, the degradation of ecosystems is indeed one of the most significant threats to water resources. Changes to landscapes, such as deforestation, conversion of natural landscapes to farmland, urbanization, and surface mining, can lead to the loss of natural habitats, biodiversity, and ecosystem services. These changes can have direct and indirect impacts on water resources. For example, deforestation can lead to soil erosion, increased sedimentation, and decreased water quality in nearby rivers and lakes. The conversion of natural landscapes to farmland can result in the extensive use of fertilizers and pesticides, which can contaminate nearby water sources. Urbanization can lead to the increase in impervious surfaces, which can cause flooding, reduce groundwater recharge, and alter the hydrological cycle. Surface mining can cause the loss of wetlands, destruction of habitats, and contamination of water sources with heavy metals and other pollutants. Indeed, understanding the impact of socioeconomic development on water quality is crucial for lake protection and sustainable management.

Rapid urbanization, industrialization, and agricultural intensification have led to increased nutrient loadings and pollution of surface waters, including lakes (Bahukhandi et al., 2023). Population growth and urbanization have increased demand for freshwater resources, leading to overuse and depletion of water resources. Changes in land use, such as deforestation and conversion of natural landscapes to agricultural or urban land, can also lead to erosion and sedimentation of lakes, which affects water quality and aquatic ecosystems. Industrial activities and discharge of untreated sewage into lakes also contribute to water pollution. Therefore, it is important to identify the main sources of pollution and adopt appropriate measures to reduce the pollution load on lakes. Such measures may include improved wastewater treatment, sustainable agricultural practices, and control of industrial pollution. Education and awareness campaigns can also play a significant role in promoting public participation in lake conservation and reducing pollution. Also, socioeconomic development and associated activities have a significant impact on lake water quality and ecosystem health. A comprehensive understanding of the sources and causes of pollution can aid in the development and implementation of effective management strategies for lake protection and restoration (Maurya et al., 2019). Therefore, it is essential to adopt sustainable land-use practices and protect natural ecosystems to ensure the availability of safe and clean water for all. This can be achieved through measures such as conservation of natural habitats, reforestation, and promotion of sustainable agriculture practices. Really, the management of degraded lake ecosystems is a complex issue that requires a comprehensive understanding of the social-ecological system. A deeper understanding of how social and

ecological systems co-evolve through time is crucial for effective management. It is important to recognize that lake ecosystems are not isolated entities but rather are interconnected with the surrounding landscapes and the socio-economic activities of the human population in the catchment area.

An integrated approach that considers the interplay between social, economic and ecological factors is necessary for sustainable lake management. This approach should involve a broad range of stakeholders including scientists, policymakers, and local communities. For instance, lake managers need to consider the effects of land use practices, agricultural activities, industrial discharges, and urbanization on lake ecosystems. There is also a need for innovative and adaptive management strategies that can effectively respond to changing socio-economic and environmental conditions. Adaptive management approaches that involve ongoing monitoring and evaluation of lake conditions, coupled with stakeholder engagement and participation, can help to ensure the sustainability of freshwater lake ecosystems. While preventing and reducing pollution at the source is crucial, protecting and restoring degraded ecosystems is also necessary to ensure the health of lakes and their associated ecosystem services. This can involve measures such as wetland restoration, sediment removal, and nutrient reduction programs. A combination of these strategies can help to address both the root causes of pollution and degradation, resulting in more resilient and sustainable freshwater ecosystems. It is important to take into account the seasonal variation in agricultural activities, as they can have a significant impact on water quality. For example, the use of fertilizers and pesticides during certain times of the year can lead to increased nutrient and chemical runoff into lakes and other water bodies. Thus, it is important to not only consider annual records, but also to analyse data at a more fine-grained temporal scale to accurately capture the influence of agricultural activities on water quality. Absolutely, understanding the impact of socioeconomic development on water quality is crucial for ensuring sustainable development and protecting the environment. By identifying the key influencing factors, policymakers and stakeholders can develop effective measures to mitigate the negative effects of development on water quality and promote sustainable water management practices. This can help to protect the health of ecosystems, ensure the availability of clean water resources, and support the well-being of communities that rely on these resources for their livelihoods and quality of life. Social and economic development can have a significant influence on a lake ecosystem, both positive and negative.

Land Use: There are many land use practices that can impact the quality of water in lakes, including agriculture and urbanization. These practices can introduce pollutants like fertilizers and sewage runoff into lakes that can negatively impact water quality. Whenever the size of an urban area increases, more impervious surfaces like concrete, asphalt, and other materials are created, which can lead to increased runoff and erosion in urban areas? Consequently, sediments can accumulate in the lake, causing its water quality to deteriorate, as well as the health of aquatic ecosystems due to the accumulation of sediments (Sharma et al., 2022).

Industrial Activities: Lake ecosystems can also be negatively affected by industrial activities such as mining, manufacturing, and power generation, all of which can negatively impact lake ecosystems. Water quality can be decreased as a result of these activities, which can lead to the introduction of chemicals and other pollutants to the water, causing harm to aquatic organisms, and decreasing biodiversity as well (Thakur et al., 2021).

Tourism: Lake ecosystems can both benefit and suffer from the impact of tourism on them. It has the potential to contribute to the economic growth of local communities and to the conservation efforts at the same time. It is also possible that it can cause overcrowding, habitat destruction, and pollution as well (Sharma et al., 2020).

Climate Change: Climate change has the potential to have unprecedented impacts on lake ecosystems, including the occurrence of droughts, floods, and changes in precipitation patterns as well as changes in water temperatures. There are a number of factors that can affect the distribution of aquatic species and can affect the functioning of the food web, which can lead to impacts on the overall health and functioning of the ecosystem (Sharma et al., 2023).

Conclusion

As a whole, social and economic development can have a significant impact on lake ecosystems, and it is essential that these activities be carefully managed so that negative impacts are minimized, and sustainable development practices are promoted so that these natural resources remain healthy and intact. The sustainable management of freshwater lake ecosystems depends on the integration of ecological, social and economic factors into a holistic management approach. There is also a need for a long-term perspective that considers both the historical legacy of human activities and the dynamic nature of the social-ecological systems as a whole. This approach may prove helpful in mitigating the adverse effects caused by the degradation of lake ecosystems for future generations, and in promoting sustainability for lake ecosystems for future generations as well. A comprehensive approach to addressing these problems involves not only

preventing pollution, but also reusing water and repurposing nutrients in controlled urban agriculture in order to address them. Due to the change in land use patterns and the longer growing seasons, more fertilizers may be used, which can lead to the leaching of fertilizers into watercourses, rivers, and lakes, which can lead to eutrophication, subdue biodiversity, and increase the risk of extinction. To reduce the environmental impact of these activities and to ensure the availability of safe and clean water for all, it is essential to adopt sustainable practices in order to reduce their impact on the environment.

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Author contributions

MS[1] and SS[2], AKS[3] collected the data and involved in original draft preparation, MS[5] has invesigated and designed the study. The final editing was done by MS[4] and AKS[6*] supervised and approved the final version.

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