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Review Article

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Environmental Effects on the Release of Nutrients at the Sediment-Water Interface

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Abstract

To investigate the biogeochemical properties of nitrogen and phosphorus, to calculate the loads of these nutrients, and to evaluate their effects on water quality, surface sediment and water samples were taken from Daihai Lake. Total Phosphorus (TP), Total Nitrogen (TN), and various nitrogen forms in sediments were examined, as well as their regional distributions. TN and TP concentrations in surface sediments were found to range from 0.27 to 1.78 g/kg and from 558.31 to 891.29 mg/kg, respectively, according to the results. The C: N ratios ranged from 8.2 to 12.1, which showed that the majority of the nitrogen collected, came from terrestrial sources. All sampling sites had N: P ratios that were less than 10, indicating that N was the limiting nutrient for algae development in this lake. An impact of it was also determined what effects the environment has on the release of nitrogen and phosphorus in lake sediments; high pH levels may facilitate the release of nitrogen and phosphorus. To determine the trophic classification of the studied lake, modified Carlson's Trophic State Index (TSIM) and Comprehensive Trophic State Index (TSIC) were used. The values of TSIM and TSIC ranged from 53.72 to 70.61 and from 47.73 to 53.67, respectively, indicating that the Daihai Lake was in the stage of hypereutropher.

Keywords: Biogeochemical; Lake; Environment of Change; Nitrogen

Introduction

Eutrophication, which is brought on by excessive phosphorus and nitrogen inputs, has become one of the most prevalent impairments of surface waters in China and is one of the main threats to the health of freshwater ecosystems. It frequently takes the form of harmful algal blooms, which make it difficult for sunlight to reach underwater plants and lower oxygen levels. In general, sewage discharges, agricultural wastewater, and diffuse runoff from agricultural land are external sources that contribute nutrients into lakes and reservoirs. These nutrients may accumulate over time in the sediment and could provide an internal load that, depending on the environmental circumstances, could be recycled back into the water column. In addition, there is internal source of nutrients that may be crucial because, in the summer, when dissolved oxygen levels are at their lowest, nutrients from sediment can be released into the water column to support the growth of algae. However, it is unclear what the internal sources are. Understanding the effects of the chemical composition and trophic level of aquatic systems, especially in shallow lakes and coastal marine habitats, depends greatly on the complicated exchange mechanisms of nutrients across the sediment-water interface. P, one of the essential nutrients for aquatic ecology, is the nutrient that photosynthetic organisms need in the greatest amounts and is therefore the main factor limiting their growth. In estuary and lake conditions that support algal development, P can also inhibit or colimit that growth. Large N inputs Sediment is recognised as one of the main constituents of the internal source because it contributes significantly to the phosphorus concentration in the water that lies above estuarine and coastal areas. The water quality could be significantly impacted by such a release from bottom sediment, which could lead to continuous eutrophication. For freshwater ecosystems, sediments are an essential source of nutrients. Phosphorus is released to the water column from underlying sediments by a variety of processes, such as the microbial mineralization of organic matter, the desorption and dissolution of P bound in precipitates and inorganic materials, and the diffusion of dissolved P from sediment pore fluids. Temperature, dissolved oxygen concentration, pH level, and redox potential are the environmental factors that seem to control the rate at which dissolved P is released from sediments. Most experimental research conducted during the past few decades have focused on the static releases of phosphorus from lake sediments. Contaminated sediment discharged under hydrodynamic conditions is becoming more and more of a research priority because studies on dynamic release are still insufficient. Experiments in the lab using an oscillating grid, an annular tank, and open water channel have been used to evaluate how frequently contaminated material is released when there is running water. A variety of papers have classified lakes using different methods and indexes [1].

Mathematical models are vital tools to depict the level of eutrophication of natural water bodies because of the significance, complexity, and variability of eutrophicated systems. However, the assessment techniques for the various forms of lakes eutrophication varies due to varied geographic locations, environments, and human activities. The scoring method, nutritional index method, integrated nutrition state index method, modified Carlson trophic status index, and other methodologies are currently presented. The biomass related trophic status index created by Carlson is one of them, and it is the traditional and most widely applied measure that is based on the productivity of the water body. TSI, or Carlson's Trophic State Index, is a widely used a technique for describing the trophic status or general health of a lake. To determine the degree of eutrophication of the lake environment, the estimation of TSI requires knowledge of six physical, chemical, and biological parameters, including Total Phosphorus (TP), Total Nitrogen (TN), Chemical Oxygen Demand (COD),

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Secchi Disc Depth (SD), Chlorophyll-a (Chl-a), and Phytoplankton Biomass (CA). Carlson's trophic status index will be calculated using the average TSI values of these six factors. The TSI provides a 0-100 scale with continuous numerical classifications of lake trophic states and a solid theoretical framework for quantitative investigations of the eutrophication mechanism [2].

Analysis Methods

According to the book Lake Ecosystem Observation Method, the locations of the sampling sites in Lake Daihai were chosen. In September 2007, the samplings in this area were conducted. In plastic bottles prepared overnight with a 1 M HCl solution and then twice rinsed with redistilled water, water samples were taken at a depth of 0.5 m below the water surface for nutrient analysis. Two parallel water samples were taken at each location, one of which. Filters that had been purified via a 0.45 m nitrocellulose membrane were kept at 20˚C until they were ready for analysis. Grab samplers were used to swiftly pack samples of surface sediments that were collected at a depth of 0 to 10 cm in airtight containers. The laboratory for storage at 20˚C prior to the analytical determinations in polythene bags. The sites were located using a Global Positioning System (GPS) during the sample collection. Additionally, the investigated lake's water quality was monitored in situ for pH, salinity, temperature, dissolved oxygen, and Secchi depth. A 2 mm screen was used to filter out the gravel and coarse debris after drying sediment samples in an oven at 60˚C to constant mass for roughly 48 hours. Prior to laboratory testing, the sieved samples were homogenised, then ground to a fine powder using a mortar and pestle. The Kjeldahl nitrogen method was used to calculate the Total Nitrogen (TN) of the sediment. After being digested with HNO_3-HCl at 200˚C, Total Phosphorus (TP) was measured using a spectrophotometer technique. Every sample was examined in triplicate, and the TN and TP concentrations reported here were the mean of two examinations. For TN and TP, the overall analytical precision was found to be 5% and 3%, respectively [3].

The main component of Inorganic Nitrogen (IN) in lake silt. The amounts of NH_4^+-N, NO_3-N, and NO_2-N in TN are negligible and can be omitted. 0.5 g dried sediment samples were added to 100 mL acid-washed screw-cap polyethylene centrifuge tubes with a 2 mol/L KCl solution to evaluate the concentrations of $NH4^+$-N and NO_3-N in lake sediments. The tubes were sealed and incubated for 2 hours at 25 1˚C with a 200 rpm orbital shaker. The sample solution was immediately centrifuged at 5000 g for 15 min after homogenization before being filtered through a 0.45 m GF/C filter membrane. For NH_4^+-N and NO_3-N tests, the filtrate was removed. The following methods were used to analyse Lake Daihai water samples. The levels of TP and TN were measured in the unfiltered waters. By oxidising all forms of nitrogen to nitrate using alkaline persulfate, and then analysing the nitrate using the 2, 6-dimethylphenol technique, total nitrogen was determined. Ascorbic acid was used as a reducing agent in the spectrophotometric analysis of the phosphorus contents of all samples using the Murphy and Riley's ammonium molybdate method. Nitrite-N, nitrate-N, ammonia-N, and ortho-P concentrations in the filtered fluids were measured. The indophenol-blue method was used to measure ammonia-N, whereas cadmium reduction was used to measure nitrite-N and nitrate-N. Spectrophotometry was used to evaluate the chlorophyll-a in a sample of water [4].

Chemical Properties

The physical and chemical traits of the water and sediments in Daihai Lake as determined by sample operations. The average pH of the water sample was found to range between 8.18 and 8.84 but did not significantly change between sampling sites, indicating that the water was slightly to moderately alkaline. Salinity levels at the sampling sites were uniform and ranged from 0.23 g/kg to 0.44 g/kg. The average surface water temperature in the lake under study was 23.1 0.84˚C, and there were no appreciable variations across the sampling locations. In all sampling sites, the relationship between temperature and Dissolved Oxygen (DO) was inverse, and the amounts of dissolved oxygen ranged from 2.81 to 4.83 mg/L. High temperature locales had lower measured DO concentrations, suggesting that the oxygen levels there may be depleted. Be a result of biological processes and a decrease in oxygen gas solubility caused by the increased temperature. Furthermore, water's ability to contain DO diminished due to quick saturation at high water temperatures. The Daihai Lake's electric conductivity was discovered to constantly range between 8.19 ms/cm and 9.78 ms/cm, with DH-10 recording the lowest number and DH-4 recording the highest. The Chemical Oxygen Demand (COD) in the lake under investigation ranged from 17.12 to 20.73 mg/L. The water column's concentrations of TN, TP, and Chl-a ranged from 2.52-2.87 mg/L, 0.06-0.80 mg/L, 2.60-3.48 mg/L, and 17.12-20.73 mg/L, respectively [5].

Horizontal Distribution of Nutrients

Numerous variables, including the rate of sedimentation, sediment type, the amount and type of organic matter, the intensity of organic matter mineralization in the sediment and water column, and redox conditions in sediment and near bottom water, all influenced the nutrient contents of sediments. It displays the findings of the Lake Daihai sediment for TP, TN, $NH4^{+-}$, and NO_3-N concentrations in the surface sediment. And TP concentrations in the surface sediment of Daihai Lake ranging from 558.31 mg/kg to 891.29 mg/kg with a mean of 708.82 mg/kg, the lake sediments had a significant ability to feed phosphorus to the water above them. The silt at location DH-14 contained the highest levels of TP. which is situated in a neighbourhood with a lot of industries and people. Site DH-14 was situated near a beautiful tourist destination, suggesting that human activities there may have had an impact on the site's phosphorus levels. The source of organic matter can be either autogenetic or allochthonous, depending on the nutritional ratio. The ratio of C: N: P would be near to the redfield value (106: 16: 1) and the ratio of C: N would be about 6.6 if all the organic materials in the sediment came from phytoplanktons. If they came from a terrestrial source, the ratio of C:N would typically be > 20. The C: N ratio in the surface sediment of Lake Daihai is distributed spatially in a reasonably regular manner, with values ranging between 8.2 and 12.1. Because more terrestrial materials is ingested by the sediments from rivers in the north of the lake than in the south, it is significantly greater there [6].

Additionally, these locations' sediments acquire more autogenic organic materials, which results in a low C:N ratio. Since nitrogen can be broken down more quickly than carbon, it is crucial for organic matter to accumulate because it shows intensive biological activity and releases nitrogen into the water before carbon does. The high C/N values seen in the majority of the lake may be the result of this process. The experiment on the effects of light on phosphorus concentration changes. Both in the dark and in the light, there were no phosphorus concentrations that differed significantly from one another. This showed that the amount of illumination and its intensity had no impact on the release of phosphorus from sediment. However, it is essential for algal growth in the sediment-water system. Bacteria were primarily responsible for the phosphorus release process at the sediment-water interface under the dark conditions, which led to an increase in dissolved inorganic phosphorus in the surrounding water. In the presence of light, benthic algae and phytoplankton as well as bacteria had an impact on this process [7].

Discussion

Increased water abstraction from AW for soda ash production, as well as from its primary feeder river, the Bulbula, for irrigation and domestic use, has resulted in a rapid reduction in the wetland's water level. Irrigation around Ziway Lake and its two tributaries, the Katar and Meki Rivers, has been extensive. As a result, the amount of water flowing into Lake Ziway, which is the river Bulbula's principal source, has decreased significantly. Apart from small-scale irrigation, the expansion of large-scale farming projects for horticulture, floriculture, and vegetation production along the banks of Lake Ziway and the Bulbula river consumes a lot of water and discharges chemical pollutants into the water. Various farming operations also drain water from the Bulbulaa river during the dry season, preventing water from flowing into the wetland. Similarly, Giweta & Worku (2018) stated that agriculture's modernisation and expansion of capital-intensive agriculture, such as greenhouse flower and fruit production, is driving up irrigation water needs in the CRV region, putting a strain on the wetlands' water resources [8].

Conclusion

As a result, total phosphorus levels in the overlying water were higher in the dark than they were in the day illustrates how temperature affects the sediments release of phosphorus. With rising temperatures, there was a clear increase in total phosphorus concentration. At 20˚C, 30˚C, and 40˚C, the maximal release of phosphorus was 4.34 mg/kg, 7.39 mg/kg, and 10.11 mg/kg, respectively, while the concentration of phosphorus at 5˚C (3.27 mg/kg) was just a third of that at 4^{0}˚C. The maximal phosphorus release and temperature had a good correlation, R^2 = 0.9194). Increased phosphorus rates were also caused by rising temperatures and a decline in the water column's dissolved oxygen concentration. The biomass and development of bacteria and autotrophic algae were undoubtedly impacted by temperature. The activity of bacteria, benthic algae, and phytoplankton increased as the temperature rose, and the increased bioturbation was advantageous [9, 10].

Conflicts of Interest

The authors declare no conflict of interest.

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