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Review article

Lake Eutrophication Mechanism and Control: Current Status and Future Tendency

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ABSTRACT

This study reviewed eutrophication in terms of causes, areas of prevalence, and highly accepted control measures with some provable recommendations. Wastes thrown from different sources make the water highly rich in nutrients especially nitrogen and phosphorus which in turn make the water source eutrophicated. Nutrients from industrial sources such as the food industry, phosphorus mines, chemical manufacturers, and daily activities like household wastes, fertilizer applications, and agriculture runoff are vital ways of loading nutrients and eutrophicating the water bodies. Such phenomena deteriorate water quality; clog the usual flow of water, cause mass death of aquatic habitats, and cause imbalance in the ecosystem. Controlling of eutrophication includes physical, chemical, and biological treatments. Physically eutrophication can be managed through filtration, floating, and adsorption by lake water; chemically through electrochemical techniques, chemical oxidation, and treatment with ozone; biologically through activated sludge, biological aerated filters, microbial capacitive desalination cell, and reed bed technique. Some other further steps can be taken to alleviate the present status of eutrophication. Among them, recommend undertaking nutrient sources management, aquatic ecosystem engineering as a regional solution, socio-economic guidance for reclamation, formation of an early eutrophication alert system, and moving towards systemic research. Besides, a far more detailed and scientific investigation is required to find the exact relation between eutrophication and the environment so that some more effective measures can be taken to control eutrophication.

Introduction

Earth can be termed as a 'water planet'; Water covers roughly 70 percent of the total of the earth's surface. On the Earth, over 1.386 billion m^3 of water is preserved. But most of them are stored as seawater; the amount of freshwater is very low, only 2.53% of the whole amount of water (Shiklomanov & Rodda 2003). Eutrophication is one of the major causes of fresh and marine water quality deterioration (de Jonge et al. 2002; Smith 2003). It is a nutrient and sediment-receiving process of lakes especially nitrogen and phosphorous from the surrounding sources. More than 54 % of Asian lakes, 53 % of European lakes, 48 % of North American lakes, 41 % of South American lakes, and twenty-eight percent of African lakes are eutrophic (Fernández et al. 2009). To describe the usual nutritional condition of soils in German bogs, Weber first uses the te-

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rms "eutrophic" and "oligotrophic" (Hutchinson 1969). The eutrophy is used to indicate the phytoplankton algal growth status of a lake. Naumann also noticed that highly algae-contaminated lakes are connected to productive and populated lowland areas. Based on N and P concentrations in different trophic states of water bodies shown in (Table 1). The algal-deficient water bodies are located in the primary rocks-dominated area. The significant predictors of algal production are nitrogen, phosphorus, and calcium. Additional nutrient causes algal blooms, additional plant growth, and reduce the water quality. Lake water eutrophication is a composition of biological, chemical, and physical processes resulting in light, heat, and hydrodynamics. It promotes the rapid growth of phytoplankton and other microorganisms, as well as decreases water quality. All of these things are bad for aquatic ecology and water bodies' normal behavior (OECO 1982). Eutrophication mechanisms are not fully understood. Fang and his research team stated that the major factor should be the excessive nutrient drains into the groundwater system. Because of increasing household trash and non-point contaminants from farming sectors and urban expansion over the last half-century, the nutrient status of freshwater bodies has deteriorated dramatically (Mainstone and Parr 2002). Agricultural production significantly increases with the improvement of fertilizer use like nitrogen and phosphorous which ensure the food security for the growing population. Unused excess nutrients run into water pathways and carry through waterways to sea and ocean causing eutrophication to the water bodies (Ngatia1et al. 2019). A highly algal bloom is the general symptom of eutrophication causes opacity and an anoxic situation in the deep of the watercourses because of the degradation of detritus which also destroy aquatic organisms (Schindler et al. 2008; Wang and Wang 2009). Eutrophication may provide serious health risks to humans and animals in different ways. It would be highly dangerous if a eutrophic water body is used as a drinking water source. Eutrophication also hampers the ecological balance of an area (Bhagowati and Ahmed 2019). It can reduce the transparency of water which restricts the sunlight penetration into a water body. A little amount of sunlight decreases or even stops the photosynthesis of plants under the water. Water eutrophication creates a supersaturation situation that means a lack of oxygen dissolved in water, hazardous to aquatic organisms and destroys them. Excess organic carbon accumulated by the eutrophication system causes a biological makeup shift in organic matter (Dell′Anno et al. 2002). Due to eutrophication algae, cyanophytes and green algae create a dense "green scum" on the surface of the water. Toxins released from algae which poison the fish and seashell (Yang et al. 2008). Natural and cultural are the two types of eutrophication that generally take place. The natural eutrophication process is very slow but cultural or man-made eutrophication is accelerated by anthropogenic activities (Khan and Ansari 2005; Serrano et al. 2017).

The bioplasm of autotrophic algae flowering in water is made of solar energy and inorganic matter through photosynthesis—the eutrophication pattern is given below:

$$106CO_2 + 16NO_3^- + HPO_4^{2-} + 122H_2O + 18H^+ \xrightarrow{Energy+microelement} C_{106}H_{263}O_{110}N_{16}P\ (algal\ bioplasm) + 138o_2$$

Chemical nitrogen and phosphorus fertilizer, particularly phosphorus is the main regulating matter for algal development, as per the equation above. Despite the use of over 17000 ha of stormwater purification regions, the Florida Everglades waterway has experienced an effective change in its indigenous species because of extreme total phosphorus (TP) input and a high average TP density from farmland and Outflow from Lake Okeechobee (Richardson et al. 2007). The eutrophication problem become more exquisite worldwide, but the way of occurrence has not been properly recognized. More studies need to be done to know the eutrophication processes in various watershed situations. Comprehensive direction for determining eutrophication should be found considering various factors; especially sustainable ecological development and human health (Yang et al. 2008). This study aims to expand the worldwide status, mechanism, and evolution of water eutrophication. Also investigates the origins and causes of pollution and sets the prevention measures to monitor water pollution (Le et al. 2010). The exact mechanism is still unknown. Further study is required to identify the pathway of proper water eutrophication of both inland and marine water. To conserve the ecosystem, it is high time to reduce the eutrophication of water bodies.

Table 1. N and P concentrations in different trophic states of water bodies (Yang et al. (2008); RMBEL (2021))

Trophic status	Total phosphorus (mg/L)	Total nitrogen (mg/L)	Feature
Oligotrophic	5–10	250–600	• Poor nutrition • Low primary productivity extremes • Aquatic plants that are mostly of low quality • Contaminants-free Water
Mesotrophic	10–30	500–1100	• Excessive primary productivity • Moderate nutrition • Most of the aquatic plants of high-grade • Good quality of water
Eutrophic	30–100	1000–2000	• Adequate nutrition; • Extreme high primary productivity • Mainly algae species • Extreme poor water quality
Hypertrophic	>100	>2000	• Excess of nitrogen and phosphorus in mineral forms • Very high primary production • Oversaturated with oxygen surface water layer

Types of Lake Eutrophication

Incipient eutrophication

Incipient eutrophication could result in a biological rise in biomass, numerical as well as qualitative alterations to benthic, planktonic, and fish communities on the coast. The concept may relate to declining water clarity and color from a physic-chemical standpoint; a development of chemically measurable average N and P values in hypolimic layers of a lake due to a reduction in dissolved oxygen content in summer thermal stratification.

Advanced eutrophication

The above-mentioned signs may have increased. A dense development of phytoplankton, particularly blue-green algae, with a complete lack of oxygen; in the dry season, there is a collection of anaerobic metabolic byproducts in the lower layers, as well as the departure of fauna.

Seasonal and/or periodic eutrophication

Constant drop in lake water level because of volatilization and irrigation drain-off, accompanied by an increase in organic matter content, allowing the values for organic matter content to be computed simply from water body level. Eutrophication can alternatively be characterized as "a disruption caused by a rise in the level of primary production of organic substances as a result of anthropogenous nutrient development."

Pseudo – eutrophication

Another sort of organic matter enriching occurs when the water in a lake reaches the top layer of sand at the lake's bottom. When the sulphate-reducing *spirillum desulfuricans* becomes active and reduces the sulphate in raw water to H_2S, anaerobic conditions are created inside the three-foot depth of the fine sand layer of a slow sand filter and the concomitant production of sulphur bacteria or sewage fungus in the filtered water appears as gray color scum on the lake's surface.

Current Status of worldwide eutrophication

According to UNEP (United Nations Environmental Protection) around 30-40 % of lakes and reservoirs of the world were impacted by water eutrophication in some way. Erie Lake in the USA has excessive nutrients resulting from urbanization and agricultural operations (Epa gov 2018). Eutrophication creates severe flowering of drifting blue-green algae and adherent green algae, *Cladophora spp.* City Park Lake (Ruley and Rusch 2002), Okeechobee Lake and Washington Lake, etc. are also highly affected by eutrophication in the USA (Khan 2014). Okeechobee Lake is contaminated by the waste of dairy and cattle farms around it. TN & TP of this lake is 1.5 and 0.1 mg/L. Lake Apopka, which is another important lake

Table 2. Current status of worldwide eutrophication

Name of water sources	Surface Area (km²)	Total Phosphorus mg/L	Total Nitrogen mg/L	Chlorophyll-a mg/L	Causes of Eutrophication	References
City Park Lake, USA	0.23	0.33	0.682	0.0351	Contamination of the water from nearby residences	Ruley and Rusch (2002)
Erie Lake, USA	25,744	0.115		0.058	Blue-green algae	Maggie (2004)
Lake Apopka, USA	124.6	0.2	5.14		Anthropogenic activities around the catchment area	Schelske et. al. (2005)
Okeechobee Lake, USA	1,891	0.05~0.1	1.5		Nearby area has a lot of P inputs	Schelske (1989)
Lugano Lake, Switzerland and Italy	48.7	0.14	0.98		P emission was high and oxygen concentration in the hypolimnion was zero	Barbieri and Simona (2001)
Bassenthwaite Lake, England	53	0.025	0.8	0.015	Agricultural and urban waste	Winfield et al. (2004)
Danish lakes		0.370	0.029	0.073	High-input nutrients from domestic sources and farms	Jeppesen et al. (1999)
Pamvotis Lake, Northwest Greece	19.4	0.011	NH_4^+: 0.25 NO_3^-: 0.56		Release over the last 40 years from the agricultural, industrial and urban sectors	Romero et al. (2002)
Chivero Lake, Zimbabwe	26.32	1.01~5.01	0.3~8.4	0.01802~0.02248	Sewage effluent hypereutrophic	Nhapi (2004)

in Florida, USA. In lake water high nutrient loading from lake shore farms which increases phytoplankton and suspended matter. TN & TP is 5.14 mg/L and 0.2 mg/L (Schelske et. al. 2005). In the case of City Park Lake of Louisiana, USA contaminated by Sewage in the local area and pollutants from the heavily traveled railroad. The current worldwide eutrophication status is stated in (Table 2).

During the 1960s lake eutrophication starts in Europe due to the increase of population and industrial growth. A massive algal bloom deteriorates the quality of water and decreases oxygen levels which are primers for developing policies and implementing them (EEA 2012). Lugano Lake between Italy and Switzerland reported a rapid eutrophication rate because of the excessive discharge of migrants surrounding the lake (Barbieri and Simona 2001). From the nineteen sixty's, agricultural wastages, industrial effluents, and internal loading made the lake highly eutrophic with P concentration reaching at 140 mg/m^3. Most of the lakes (almost 41 lakes) among the Danish are excessively eutrophic because of excess nutrient washout from household wastes and agricultural operations (Jeppesen et al. 2007). Maximum inland water bodies of the Netherlands are eutrophic by outside and inside loading of N & P fertilizer (Søndergaard et al. 2007). Northwest Greece's Pamvotis Lake has continuously been affected last forty years by cultural eutrophication and become eutrophic (Romero et al. 2002). Kastoria Lake in Northern-western Greece is affected by agricultural wastes and underground runoff from the surrounding area (Matzafleri and Psilovikos 2018). Lake Balaton is situated in Western Hungary. External loading of nutrients especially P contaminated the lake and caused eutrophication. Lake Peipsi is situated between Estonia and Russia. Excess fertilizer and manure applied in surrounding agricultural areas are the major sources of nutrients. P concentration reaches at 30-60 mg/m^3. Hamilton Harbour which is located at the western end of Lake, Ontario, Canada. It is atrophied by agricultural manure and fertilizer, industrial waste, and urban sewage (Munawar et al. 2010). Vancouver Lake of Washington, USA is also affected by eutrophication due to urbanization. Chivero Lake of Zimbabwe is contaminated by untreated sewage from illegal domestic and industrial sources, and agricultural and mining activities (Nhapi 2004).

Eutrophication in Asia

Almost half of the total volume of phosphorus is dumped into lakes from industrial wastes and household sewages from communities of human beings (Smith et al. 1999). Nearly 15 % of Indian people supply phosphorus-containing waste water to water bodies which causes eutrophication. Faulty septic systems are also the principal source of phosphorus overload which is liable for polluting waterways water (Carpentar 2008). Lake Mansarovar, Upper Lake, and Lower Lake are the three lakes of Bhopal, of India; The Mansarovar Lake is the highest eutrophic lake among them. The nutrient loading initially increases the growth of phytoplankton which enhances the lake's eutrophication (Garg et al. 2002). Urban sewage, chemical fertilizers, and pesticides from agriculture field leading eutrophication of Deepor Beel of Guwahati, Assam, India. Bellandur Lake of Bangalore, India untreated sewage and effluents from urban area made this lake hypereutrophic at present (Ramesh and Krishnaiah 2014). Dantaramakki Lake of Karnataka is an important water body in India. Continuous flowing discharge from municipal and agricultural areas to lakes increases the Nitrogen and Phosphorus concentration of lake water which turns the water source eutrophic (Mahesh et al. 2014). In Pakistan, Rawal Lake is the main source of fresh water for Rawalpindi municipality and adjacent areas. It is built on the Kurrang River and capable of supplying $10x10^7$ cubic meters of water in an average rainfall year. But the lake was polluted by human settlements, recreational and agricultural activities, erosion, and especially poultry wastes last few years. About 360 poultry sheds remain in the nearby area of Rawal Lake (GOP 2004). Poultry litter consists of high nutrients including NO_3 (3.3%), P_2O_5 (3.4%), and K_2O (1.7%) (North and Bell 1990). The runoff from the poultry sheds contains excessive amounts of nutrients which cause eutrophication. Lake Uluabat in Turkey is highly polluted day by day which is an important water source (Karaer et al. 2013). Nutrients from Organic and inorganic sources affect the lake water and cause eutrophication (Akbulut et al. 2010; Katip et al. 2015). A large number of natural lakes and artificial reservoirs are remain in Iran and which are used for water supply. Anthropogenic activities lead the lakes to various environmental problems, especially eutrophication. Lake Zribar of Kurdistan province of Iran is also polluted due to watershed sources and adjacent agricultural land's nutrient washout (Nezhad et al. 2014). In (Table 3), we show some eutrophic lakes status of the Asia.

The Second World War has disastrous effects on the Japanese economy. But, the Korean War in 1950 sped up the growth of the Japanese economy. High economic growth causes heavy water pollution. Lake Biwa is the largest lake in Japan situated in Shiga Prefecture in the center of Honshu Island. It supplies a major amount of drinking water for more than 14 million people. Both national and local governments tried to maintain of the water quality of this lake. The Shiga Prefectural government acted an ordinance to the Biwa Lake eutrophication in 1979. The ordinance at first tried to forbid the usage of phosphorous-containing detergents. An anaerobic-anoxic-oxic-based improved sewage treatment system was established with the addition of coagulant and sand filtration. This system improves the lake water environment against the extreme eutrophication record from the sixties to the seventies (Tsugeki et al. 2010; Hsieh et al. 2010). Kasumigaura Lake is the second largest lake in Japan which supplies water to the Tokyo metropolitan area. An average 4m depth shallow lake of is highly eutrophic. In summer sometimes heavy algae cover the whole upper surface of the lake. To control the quality of lake water in 1982 government established an ordinance that helps to maintain the filling up of nutrients into a lake (Ken 1984).

Table 3. Eutrophic lakes in Asia

Name of water sources	Area	Total Phosphorus	Total Nitrogen	Phytoplankton or Chlorophyll-a status	Causes of Eutrophication	References
Taihu Lake, China	2,250	0.25~0.35 g/L	2.56~4.5 mg/L	Algae biomass: 2.7~6.4 mg/L	Discharge nutrients from local and agricultural industries	Ye et al. (2007) Jin et al. (2006)
Songhua Lake, China		0.038~0.102 mg/L	1.14~1.98 mg/L	Algae density: 210.84×104~ 432.68 ×104 cell/L	High phosphorus and nitrogen from surrounding area	Wang et al. (2004)
Dianchi Lake, China	298	0.33~0.59 mg/L	2.13~8.27 mg/L		Industrial wastes are the main cause.	Guo and Sun (2002)
Honghu Lake, China	344.4	0.053 mg/L	1.33 mg/L	37.58	Anthropogenic activity, agricultural operation	Minghao et al. (2009)
Biwa Lake, Japan	674				Urbanization and industrialization in the lake area	Yamashiki et al. (2003)
Lake Bellandur, India	3.61				The injection of sewage from urban areas has resulted in a hypertrophic stage.	Chandrashekar et al. (2003)
Deepor Beel, India	40.14				Discharge of sewage and municipal wastes has seriously harmed the water quality.	Churing Still Water (2012)

The Boyanghu and Dongtinghu Lake of China are in mesotrophic condition now. Probably the world's most hypertrophic lake is Dianchi Lake of Yunnan. In the early 1970s, the water quality of Dianchi Lake was graded as Class III but at present the quality of water is reduced and graded as Class V (Lu et al. 2005). Taihu Lake of the Yangtze River Delta is the third largest freshwater lake in China. Liu and Qiu stated that the water quality in the lake decreased from Class I/II at the beginning of the sixties to Class II/III in the early nineties and then to Class IV in the mid-nineties caused of severe pollution. Now 83.5% of the lake water is eutrophic and the water quality ranking is Class V (Liu and Qiu 2007). During the 2007 summer excessive water scarcity was created in Wuxi City because of excess blue algal bloom. Chaohu Lake is the fifth largest lake in China situated in central Anhui Province. Its catchment has a population of 2.3 million people and over 3000 industries. The lake became the most eutrophic freshwater lake in China since the 1990s in excess and fast nutrient discharge (Yang et al. 2008). Nowadays lake eutrophication is a great problem in China. The recent research shows that 80% of lakes have been polluted out of sixty-seven main lakes of the countries have been upgraded to a category IV status which indicates lake water is unhealthy for human use (Li et al. 2009). 49 lakes which are about 62.4% of the total area are dangerously eutrophide (Le et. al. 2010). Lake Donghu of Wuhan, China was contaminated by sewage water discharge which supplies the most proportion of phosphorus about 60% into the lake water which causes extreme eutrophication.

In South Korea natural lakes are small and limited in number. Reservoirs and controlled rivers are the main sources of fresh water. The governments of South Korea created about 18000 for water supply to the society. Nowadays eutrophication reduces the water quality and creates problems (Choi et al. 2017). South Korea is a densely populated country, anthropogenic wastage is the main source of water quality degradation. Nutrients from agricultural land, animal manure, and municipal sewage are the major reason for the enrichment of nutrients in lake water which causes eutrophication. South Koreans apply fertilizer at a high rate for agricultural operations, during summer heavy rain and fall wash out the excess fertilizer to the water bodies and increase the nutrients in lake water. Livestock manures and supplied foods for aquaculture in reservoirs are also responsible for nutrient enrichment in water. Phosphorus is the main element responsible for eutrophication than other nutrient compounds. When it is released to the upper layer of the lake water it is taken by phytoplankton (Kim et al. 2001).

How eutrophication occurs

The uncontrolled discharge of contaminants from phosphate mines, chemical manufacturers, distilleries, and household wastes is the most common cause of lake eutrophication (Das 1999). The majority of water bodies absorb nutrients from natural sources such as rock weathering, soil leaching, and rain, although agricultural runoff and residential sewerage play an important role in nutrient loading. Extensive agricultural activity together with higher precipitation was found to intensify the nutrient concentrations. Research concluded that agricultural runoff or base flow is responsible for over 90% of the contaminants released by the entire stream. Though floor and utensil cleaning causes pollution through phosphorus accumulation in the aquatic ecosystem. Food waste from the food industry also contributes greatly to this incidence (Tusseau-Vuillemin 2001). A crucial factor in river and lake eutrophication is the fertilizers used in agroecosystems (Egli et al. 1990). Manure application to agricultural land influences in phosphorus loading in soil (Sharpley 1999). A study was conducted on detergents containing 0.6–11.3% phosphorus in Uruguay's Rio de La Plata and Monte Vida resulting detergent contributed everyday P burden is 58 % (Sommaruga et al. 1995). Nitrogen and phosphorus play a pivotal role in developing water blooms as well as their intensity of development. The process of the development of three factors contribute to eutrophication: (1) physical factors-natural circumstances (namely, ideal temperature and light) and hydrodynamic conditions are represented, (2) Chemical factors- nutrient levels in water (particularly N and P) and (3) Biological factors- composition and structure of aquatic ecosystems are specifically represented. In Fig. 1, demonstrate a flow chart of the occurrence of eutrophication. Also, the sources of nutrients and organic matter contributing to nutrient loading are of two types: (1) Point sources and (2) Nonpoint sources (Table 4).

Table 4. Sources of pollutants

Types	Sources
Point sources	• Sewage from wastewater (municipal and industrial) • Waste disposal system runoff and leaching • Animal feedlots, hog, and chicken farms produce runoff and infiltration. • Mine, oilfield, and industrial waste runoff • Combined storm and sanitary sewer overflows • Sewage that has not been treated
Non-point sources	• Agriculture/irrigation runoff • Grassland and rangeland runoff • Runoff from un-sewer regions in the city • Leaching from septic tanks • Runoff from mines that have been abandoned • Over a sea surface, atmospheric deposition • Other land-based activities that produce pollutants

Eutrophication-bounding factors

Freshwater plants' average wet-weight composition: the plants require all of the above components in the approximate percentages given (Table 5). When plants form after photosynthesis, N (0.7 %) and/or P (0.09 %) are frequently the initial constituents that are depleted. In comparison to their composition in plants, these two nutrients are not as abundant in water as other essential nutrients. Nitrogen is required eight times as much as phosphorus. If nitrogen is more than eight times as abundant as phosphorus, eutrophication is limited, whereas nitrogen limits eutrophication if nitrogen is less than eight times as abundant.

Aquatic biodiversity response to eutrophication

According to the Baltic Marine Environment Protection Commission, eutrophication plays as the biggest intimidation of the aquatic environment which in turn changes in fish communities, underwater animals, plankton, and microalgal bands. In Vouga River (Portugal), it was reported that, when effluents from a bleached kraft mill are discharged into the river

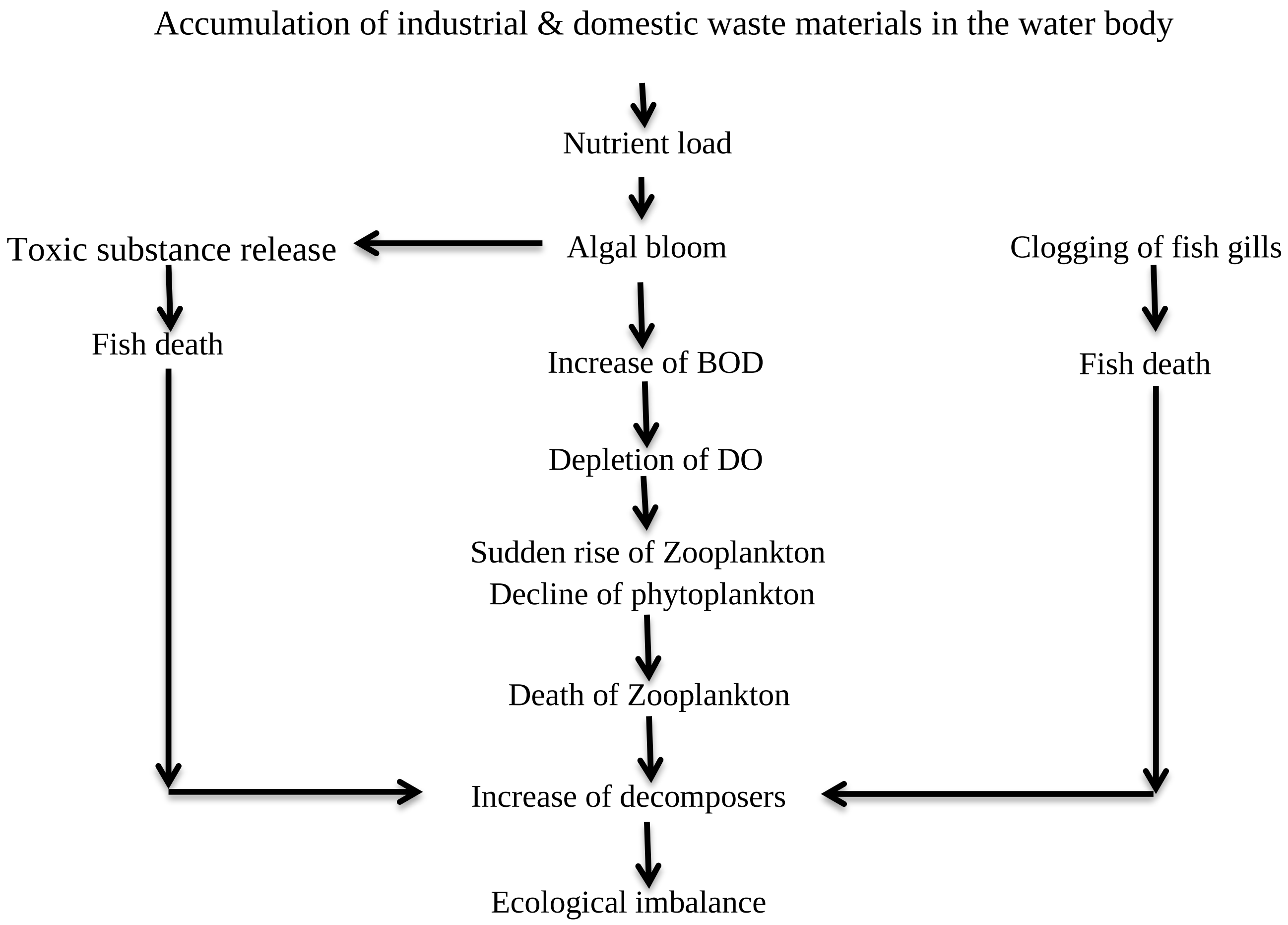

Fig. 1. Typical flow chart of eutrophication

it changes the color, COD, conductivity, suspended solids, pH, and also the temperature of the water. In the summer season, these effluents abate the variety of diatoms (Ferreira et al. 2002). Zhejiang River network, China was found with modified algal growth due to eutrophication (Shen 2002). In the arid soils of Rohtak (India), the pH of nine cyanobacteria species, eight Chlorophyta species, and three Bacillariophyta species was 7.8 in the dry season and 8.4 in the wet season (Manchanda and Kaushik 2000). In naturally eutrophicated lakes with reduced in total water capacity due to drought are found with affected dissolved oxygen concentration and hereby influencing climate change. Droughts associated with El Nino impacts, for example, can have an impact on the phytoplankton population as proven in marine ecosystems (Tunner et al. 2003). Species diversities are being changed due to the deducted nutrient loading to the lakes because of drought (Tracy et al. 2003). Nutrient enrichment owing to eutrophication in estuarine and coastal water shafts hasten natural calamities e.g., Droughts, hurricanes, and floods.

Phytoplankton diversity, productivity, and biogeochemical cycling are all influenced by such environmental conditions (Paerl et al. 2003). Twelve cutoff channels of the Rhone River (France) were studied showing that species diversity is decreased with lower or higher nutrient levels. The presence of species with differing nutritional requirements was favored by the intermediary nutrient concentration. Rare species are getting rarer and hyper-eutrophic species are increasing their population due to eutrophication. The eutrophicated lakes rich in organic matter and sewage water are being covered with aquatic weeds hindering larvivorous fishes from consuming the mosquito larvae which in turn influences in increased larval colony (Lee and Lee 2002). As a result of eutrophication, reduced the variety of races in the reed beds of Lake Balaton, several aquatic plants were found to be gone, as well as the absence of others (Hungary) (Kovacs et al. 1996). Submerged macrophytes are equally vulnerable to eutrophication as they are to man-made acidification of water. Chambers et al. (2008) stated that

Table 5. Percentage of plant nutrient composition

Component	Percentage in plant	Component	Percentage in plant
Oxygen	80.5	Chlorine	0.06
Hydrogen	9.7	Sodium	0.04
Carbon	6.5	Iron	0.02
Silicon	1.3	Boron	0.001
Nitrogen	0.7	Manganese	0.0007
Calcium	0.4	Zinc	0.0003
Potassium	0.3	Copper	0.0001
Phosphorus	0.09	Molybdenum	0.00005
Magnesium	0.07	Cobalt	0.000002
Sulphur	0.06		

eutrophication threatens the faunal diversity of aquatic ecosystems by deducting macrophyte diversity and enhancing the development of at the risk of native and foreign species are being introduced. The majority of freshwater lakes in Europe's heavily populated lowlands feature diverse submerged plants and when compared to the last 100 years' record are now high in phytoplankton. The presence of biomass and summer transparency below 2 m is a sign of eutrophication. Most of the submersed species of the majority of 17 lakes have been lost during the past 100 years. According to Broderson and his team (2001), the eutrophication process resulted in with the progression of macrophyte dominance via *Chara*, *Ceratophyllum*, and *Potamogeton* dominance to the current state, with complete loss of submerged vegetation and phytoplankton dominance; chironomid populations have undergone different changes. In a temperate estuary in the north, the enrichment of nutrients alters the ecosystem by altering its habits, food webs, and physical and chemical structures. It also increases microalgal biomass with a decrease in eelgrass shoot density also fish population, abundance, biomass, and variety have all increased significantly. Eutrophication enhances the development of opportunistic plant species by replacing the initial species by altering the environmental conditions as well as the structure and function of phytoplankton, zooplankton, benthic fauna, fish, etc. Oxygen depletion and toxic emissions of CO_2, H_2S, and CH_4 in the aquatic environment are observed as a result of the degradation of such aquatic communities by bacteria. Initially, individuals show their responses at physiological/biochemical levels, then at behavioral or morphological levels, and finally at the levels of the populations and communities. Most notably, vegetative growth is greatly influenced by eutrophication, which sometimes gets toxic, loss of biodiversity, and anoxia, which in turn leads to the vast mortality of aquatic organisms. (Table 6) shows the various effects of Lake Eutrophication.

Control of eutrophication

Physical efforts are being made to mitigate the water column's (Visser et al. 2016) de-stratification due to residence time (Romo et al. 2013); chemical actions to overcome the hypoxia by Imposed environmental re-oxygenation (Zamparas and Zacharias 2014) or by adding aluminum salts, lime or calcite to help in phosphorus precipitation. In ecological actions, algaecides are used to eradicate symptoms or to introduce new species known as bio-manipulation to dominate the formation of the food chain (Paerl 2018). All these actions are helpful in fixing the symptoms though these require cost and risk (Carpenter et al. 2006). Table 7 describes the physical, chemical, and biological treatment for control of lake eutrophication.

In bio-manipulation, some of the higher plants are used to manipulate a contaminated environment which is considered as an environmentally sound remediation technology with low impact and cost-effective (Cunningham and Ow 1996). This process is also termed phytoremediation which includes rhizofiltration, phytostabilization, phytoextraction, phytovolatilization, and phytotransformation (Ghosh and Singh 2005). Plant roots are employed in Rhizofiltration to absorb and precipitate pollutants from a contaminated aquatic environment. Rather than removing polluted materials, phytostabilization involves stabilizing contaminated soils by absorption, precipitation, complex formation, or metal valence decrease. Plants absorb, concentrate, and precipitate

Table 6. Effects of eutrophication

Effect types	Occurrences
General effects	• Increased nutrient levels correspondingly • The ratio between dissolved nitrogen to phosphorus in the water changes. • Enhanced primary production of plankton in comparison with benthic production. • Microbial food webs dominate over linear planktonic food chains. • Dominance over diatomic species of non-siliceous phytoplankton • Dominance of gelatine zooplankton against zooplankton crustacean
Primary & secondary effects	• Phytoplankton respond rapidly to nutrient concentration changes in the term of chlorophyll-a concentration or carbon biomass, bloom frequency. • Phytoplankton shadowing and reduced light penetration can diminish depth distribution, biomass, composition, and species diversity. • Increased growth of filamentous and short-lived nuisance macroalgae at the expense of long-lived species, perhaps resulting in a shift in the structure of algal communities and a loss of diversity. • The common effect of eutrophication in the low waters is oxygen depletion or hypoxia. This generally occurs during in summer/autumn season. Hypoxic and anoxic conditions can cause the creation and release of hydrogen sulphide (H_2S) which is a poisonous gas that can kill organisms. The expected effect of global warming is that as the temperature rises, hypoxia will increase as well. • Oxygen depletion affects invertebrate benthic fauna in different ways. All creatures are killed instantly if O_2 falls below zero and H_2S is emitted. When O_2 levels drop, mobile benthic invertebrates in sediment move to the surface, resulting in greater captures of fish and crustaceans. When animals return following eutrophication episodes, it's difficult to say when they'll do so. The affected area plays a role: small areas have been decolonized and rebuilt faster than larger areas. • Lake Eutrophication increases emissions of greenhouse gases significantly. Algal blooms release toxins that can contaminate drinking water. When dense algal blooms die, microbes that breakdown algae diminish oxygen levels in the water (University of Minnesota 2019).

pollutants in biomass during the phytoextraction procedure. Phytovolatilization is the process by which plants extract specific pollutants from their surroundings and then exhale them into the atmosphere. Plants use their metabolism to eliminate pollutants from the environment during the phytotransformation process.

Duckweed has been found to be an effective phytoremediation tool in wastewater treatment for more than two-decade period in light of its ability to thrive in a wide range of temperatures, pH levels, and nutrient concentrations in eutrophicated places (Krishna and Polprasert 2008). It can inhibit the growth of algae by covering the surface of the lake and reducing nitrogen availability ammonia absorption and denitrification as they prefer absorbing NH_4^+ than NO_3^- by roots as well as fronds. Duckweeds have the ability to remove surplus nutrients from the growing area and uptake nutrients from their adjacent environment (Landesman 2000). After a certain period of growth and development, these plants are collected to erase excess nitrogen and phosphorus (Cheng et al. 2002). Thus, duckweed can accumulate Nitrogen and phosphorus fifty to sixty percent from household garbage as it acts as a nutrient-releasing plant. Water covered with duckweed can take aside chemical oxygen demand (COD) quicker than that of uncovered water. Duckweeds are best suited in eutrophic lake water treatment due to their rapid growth nature in nutrient-enriched environments (Li et al. 2009) and accumulating nutrients in their bodies which in turn helps in improving degraded water by Duckweed biomass collecting. Duckweed species can also absorb hazardous organic molecules such as phenols, chlorinated phenols, medicines, and surfactants, especially fluorinated farming agents (Reinhold 2006). Chlorinated phenols can be neutralized. The species duckweed *Lemna minor* is the

Table 7. Treatment of Lake Eutrophication (Lin et al. (2021))

Treatment	Methods	Advantages	Disadvantages
Physical treatment	Filtration	• Improved bacterial clearance effectiveness • No chemicals necessary • A higher percentage of COD and nitrogen is removed • Membrane filtration offers a higher permeability, a smaller footprint, and is simpler to use	• Untreated water particles will block the system, resulting in low efficiency. • Efficacy in removing undesirable color and turbidity • Fouling
	Flotation	• Separating process that is cost-effective; • simple to use; durable and sturdy • a faster loading rate and a shorter retention time • There are no technical challenges	• Multiphase system, a substance's complex flow properties • High removal efficiency restricted to a small number of particles • Low mobility and recovery of froth • Separation will take a long time
	Adsorption by lake water	• Activated carbon (AC) is a cost-effective, simple, and efficient substance • AC is more efficient in removing pollutants	• Adsorption systems are expensive to install and maintain • The created waste must be disposed of using a reclamation process for the media • Suspended particles can block the adsorbent medium, which lowers the removal effectiveness
Chemical treatment	Electrochemical Techniques (lake inflows)	• Environmentally friendly; low-cost operation without the use of additional chemicals or the production of secondary waste • Compared to photocatalysis or electrochemical oxidation, this method is more effective at eliminating COD • Effectiveness in eliminating organic molecules is high • Produces and saves energy, as well as the ability to recover valuable elements from wastewater without harming the environment	• Per mass of pollutant removed, it consumes a significant amount of electrical energy • Metallic sludge is difficult to dewater because metallic compounds can contain tiny particles
	Chemical oxidation (lake inflows)	• Decomposes organic contaminants in water • Requires minimal equipment • Water recovery rates can approach nearly 100% with minimal waste output	• Chemical costs are higher • Chemical pumps must be maintained and calibrated regularly • By-products from the technique are difficult to eliminate
	Treatment with Ozone (lake inflows)	• Can breakdown hazardous organic substances and microorganisms that are resistant to decomposition	• The effectiveness of chemical oxidation removal is low • The energy needs and chemical usage result in high operating expenses • In water, ozone has an unfavorable solubility and stability

Treatment	Methods	Advantages	Disadvantages
Biological treatment	Activated sludge (Lake water itself)	• Treatment technique that is low-cost, clean, and straightforward • Metals and suspended solids can be eliminated	• Oxygen and large filter dimensions are required • After the treatment procedure, sludge is formed, which has a low biodegradability • Separation of precipitated solids, biomass, and dissolved gases requires post-treatment
	Biological aerated filters	• No post-treatment is necessary • A variety of adaptability to the water quality and quantity • Small or not demanded maintenance and chemicals; long cycle life • High nitrogen removal efficiency • Provide an alternative small footprint process at various stages of treatment of wastewater	• Solid sediment disposal is necessary • The solid disposal sludge accounts for almost 40 percent of the total cost
	Microbial capacitive desalination cell (MCDC) treatment process	• Complete pH changes and imbalances by using two cation exchange membranes • Protons can transfer to prevent significant pH changes without any restrictions • Reduce membrane fouling and scaling by partial organic pretreatment and water desalination	• Toxic properties and high costs • Low salinity water desalination is more efficient
	Reed bed technique	• Method involving reduced energy use and emissions • No need to use chemicals to improve dewatering ability • Have a high effectiveness in removing basic contaminants; friend to the environment • Hydrocarbons and heavy metals can be removed	• Several elements influence efficiency: sludge quality, climate, and the number of beds • A rapidly developing layer of residual sludge forms, resulting in a limited operating time; inadequate dewatering, and poor vegetative development

best suited for phytoremediation at 20-30◦C and acidic conditions (Ansari and Khan 2008) whereas the duckweed *Scleroderma polyrhizum* thrives well at 10–12◦C and thereby getting less preferable for eutrophic water treatments (Song et al. 2006). Besides, duckweed *Spirodela oligorrhiza* L. was found to absorb and transform organophosphorus pesticides and DDT (Gao et al. 2000). It also contributes to the cost-effective phytoremediation of heavy metal contamination in an environment (Ghosh and Singh 2005).

Eutrophication influenced by Phosphorus loading causes problems with water quality in aquatic ecosystems where periphytons could play a role in P removal from the water column, including P absorption and deposition, as well as particle P filtering. Periphytons can increase a maximum of 1 unit of pH through photosynthesis which causes persistent mitigation of P. Usually; periphytons increase discharge and retention of P (Dodds-Walter 2003). In Lake Washington, Daphnia was positively reported in recovering the lake from eutrophication by increasing the biomass and transparency of algae. It played a vital role in clearing the water column of Lake Washington. Billore et al. (1998) reported the water hyacinth's (*Eicchornia crassipes*) contribution roots in particulate matter and nitrogen are eliminated. *Typha*, *Phragmites*, and *Glyceria* spp. are some other aquatic weeds potentially useful in nutrient removal from eutrophic water sources. These aquatic macrophytes including water peanut and *Alternanthera philoxeroides* are capable of purifying and improving eutrophic lake water's clarity.

Nutrients must not be added to the lake water by inlets, sewage inflow, industrial contamination or run-off from agricultural land. Eutrophication is caused by the continuous intake of nutrients such as N, P, and Si into the water body turning the water unfit for fish culture without reclamation.

Ecosystem response to lake eutrophication

Ecosystems typically differ from one another depending on local geological, geomorphological, hydrological, ecological, and meteorological characteristics, as well as previous historical cycles, current anthropogenic pressures, and the sociological and economic situations (Scheffer et al. 2001; Duarte et al. 2009). Lake Eutrophication results in a sequence of unusual ecosystem reactions through the enrichment of nutrients, including nitrogen and phosphorus. Most notably, the development of phytoplankton biomass together with algal bloom (Tang et al. 2010) sometimes with algae toxin (Shi et al. 2008). N and P are crucial for plant development. Hence, an increased amount of these nutrients results in high phytoplankton biomass with a decrease in water transparency.

Water eutrophication causes the degeneration of the water ecosystem by disintegrating the usual aquatic ecosystem's stability. It affects water quality and reduces water clearness. Such turbid water hinders sunlight penetration into it and hereby weakens or even stops the photosynthesis of underwater plants. Lake Eutrophication causes the supersaturation or due to a scarcity of dissolved oxygen in the water, aquatic species are in danger and are dying in large numbers. It helps in developing a swarm of green algae including Cyanophyta creating a dense stratum of “green scum” on the surface of the water. Thus, they can decompose the organic matter into harmful gases by releasing toxins resulting in inflammation of fish and another aquatic animal in water.

The ecology, economy, and human health are all threatened by eutrophication (Von Blottnitz et al. 2006; Sutton et al. 2011). In 2014, toxicity from eutrophicated algal blooms disrupted water supplies for 400,000 people in the western Lake Erie basin (Smith et al. 2015). It causes huge water pollution by losing the dissolved oxygen resulting threat to aquatic fauna and a relatively faster mortality rate of fish. Also, they emit health hazardous toxins upon their deaths causing a deficit of drinking water sources by degrading water quality, reducing oxygen levels (Hypoxia) at the site of occurrence, and enormous growth of diseases causing bacteria. Thus, the water bodies become hazardous by transforming infectious or toxic material of toxic algal blooms (HABs) into the food chain (Van et al. 2009). As the human population is the lienholder of the food chain it becomes easily susceptible to potential impacts of accumulated toxic material and increases the risk of food poisoning and other gastric infections in humans.

Rapid upwelling of a water body occurs when eutrophication gets uncontrolled and the water-holding capacity of the lakes gets contracted by silting. It makes the lakes permanently terrestrial in nature by steadily losing their aquatic entity. Eutrophication makes the water body less likely for industrial, and recreational uses and tourism. Rapid algal bloom makes it unfit for swimming as well as for boating. Eutrophic water becomes scummy, cloudy, or even soupy green. High winds or storms cause the vigorous growing aquatic plants to be washed onto the shore and die which in turn spreads malodor similar aquatic areas everywhere. Organic matter's biochemical structure is getting altered by depositing a huge percentage of organic carbon in Eutrophic systems (Dell′Anno et al. 2002). Nitrite concentration produced in the nitrite nitrification process in the eutrophic water is extremely endangering public health as it is considered as a strong carcinogen. Living beings are poisoned by cyanotoxins in acute fatal, acute chronic, and sub-chronic forms. The neurotoxins anatoxin-a, anatoxin-a(s), and saxitoxins, as well as the hepatotoxins microcystins, nodularins, and cylindrospermopsins are among the biotoxins (Carmichael 2001).

Heavy metals contamination in association with the eutrophication process creates a complicated circumstance. Clements and Newman (2002) stated that community-level impacts play a crucial effect in understanding the contamination effects on the environment. Eutrophication results in reduced biomass of micro and mesozooplankton. It also influences the structure and size of plankton (Moore and Folt 1993). Small oligotrichs along with rotifers suppress the zooplankton biomass in highly eutrophic waters.

Lake Eutrophication research worldwide

Lakes can usually be classified as low, shallow, polymic, eutrophic, or hypereutrophic lakes. Based on the growth characteristic of aquatic lives are three different types of large lakes: 1) lakes with low biomass of phytoplankton and plenty of macrophytes; 2) limited phytoplankton biomass lakes with high inorganic turbidity and restricted populations of macrophytes; and 3) Light availability reduces the productivity of the lakes and results from direct human behavior on their watershed (Quiros et al. 2002). As eutrophication causes the degeneration of water quality, hence Limnological Research has been highlighted on lakes, rivers, and streams. Erie Lake is a good eutrophication example of defective human activity. It is the lowest and warmest lake highly bio-productive and nutrient-rich. The human activities on the lake affected the stacking of nutrients accelerating the eutrophication. Accumulation of phosphorus in this caused a large mass of floating blue-green algae and attached the green algae *Cladophora spp*. These flowering prevented the light availability in the lake and decreased the photosynthesis and the generation of oxygen. When the algae were dying, dissolved oxygen was consumed by the decomposer. A study conducted in 1965 showed that over than 80 tons of phosphates were introduced daily to the water body, with each 400g of phosphate causing nearly 350 tons of algal slime to be injected (Sharma 1998). The water body became a marsh, then a bog, and lastly a dry land as a result of the eutrophication cycle. Lake Apopka of Florida was loaded with extreme levels of phytoplankton, suspended matter, and nutrients especially phosphorus causing it to become a hypereutrophic lake (Coveney et al. 2002). Studying Lake Jaroslawieckie of Poland in the summer of 1996, it was found that the lake possesses several plant communities of variable environments causing it as a eutrophic one (Peleehaty et al. 1997). In the Netherlands, lakes by the northern and western portions are mostly shallow and eutrophic with phosphorus and nitrogen input from the contaminated river and canal waters (Gulati and van Donk 2002). Based on data from land degradation levels, population settlements, and fertilizer use, watercourses in the central south, western zone, and eastern paddy fields were shown to be phosphorus sensitive.

Study on Danish lakes showed the main reasons for eutrophication as the farming activity and excessive nutrient input from domestic consumption. Eutrophication is also caused by reduced nutrient retention, faster nutrient removal in catchments, and stream channelization (Jeppesen et al. 1999). Lake Kastoria, Greece was found in intense eutrophication through the surface runoff containing agricultural wastes, as well as seepage from both cities and towns (Koussouris et al. 1991). In the Lake Lammijarv and the Lake Phikva of Rassia, the mean N and P contents in groundwater were 42 and 767 mg/m^3, respectively. Phytoplankton biomass ranges from 1 to 125 mg/m^3, while zooplankton biomass ranges from 0.088 to 6.344 g/m^3 with a summer average of 3.092 g/m^3.

Nutrients from the manufacturing sector and farmlands are contaminating the Taihu Lake of China which is in a state of meso-eutrophication. Meiliang Bay is the dominant eutrophic area of this lake. Eutrophication promotes growth in green algae and shallow water in China's Donghu Lake (He et al. 2002). In the shallow eutrophic Donghu Lake, abnormal proliferation of *Eicchornia crassipes* and *Alternanthera pheloxirodes* has been observed. *Alternanthera pheloxirodes* started of blooming in September; *E. crassipes*, in October (Liu et al. 2004). Singhal and Mahto (2004) found low species density, debris food web domination, and water unfit for human consumption at Robertson Lake in the Jabalpur metropolitan area. To gain a better appreciation of the scale of the harm caused by eutrophication to our dwindling water supplies, a quick review of the ecological features of distribution and water cycle is offered herewith.

To compare the Lake Eutrophication study, Vinçon-Leite and Casenave (2018) considered some lakes as a case study. An algorithmic search strategy was used to look for lake names in the title, abstract, and keywords of the bibliographic database references. The result was a list of 118 lake names and 230 citations. Table 8 shows the distribution of references by nation and the names of the lakes. Fig. 2 and Table 8 shows the number of articles published based on the continent where the lake was investigated. The North American lakes have been studied the most (primarily in Canada and the United States) and Asia especially in Russia,

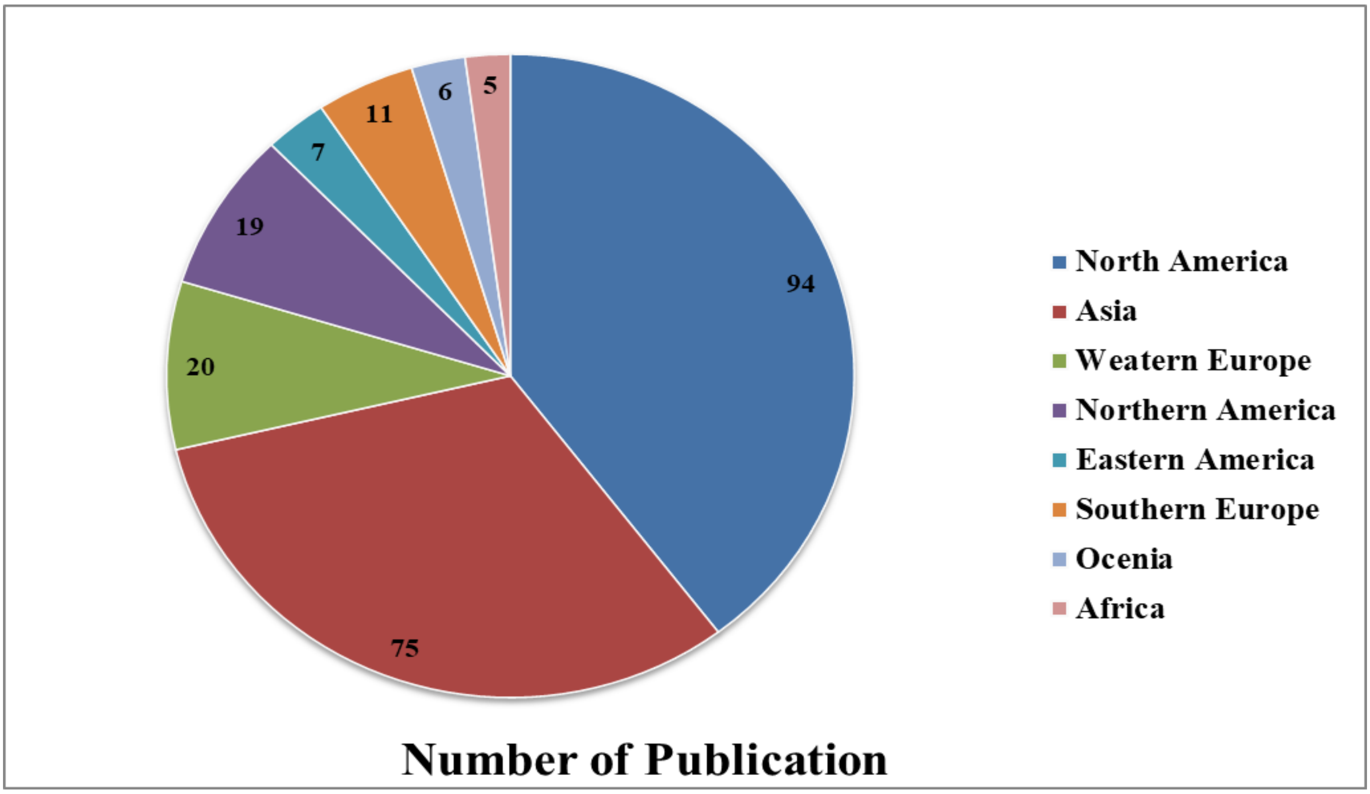

Fig. 2. Number of publications according to the region (Vinçon-Leite and Casenave 2018)

Table 8. Number of publications according to Country and Lake

Country	Publication number	Name of lake	Area (Km^2)	Publication number
USA-Canada	62	Great Lakes	244000	47
China	51	Lake Erie	25700	27
USA	39	Lake Taihu	2250	26
Netherlands	10	Lake Onatrio	19000	13
Japan	8	Lake Michigan	58000	11
Finland	7	Lake Superior	82000	9
Canada	7	Lake Dianchi	298	9
Israel	6	LakeWashington	88	8
UK	5	Lake Huron	60000	6
Hungary	5	Lake kinneret	166	6
New-Zealand	4	Lake Balaton	592	5
Estonia-Russia	3	Lake Veluwe	30	5
Greece	3	Lake Chaohu	760	5
Switzerland	3	Lake Okeechobee	1891	4
Germany	3	Lake Peipsi	3555	3
Turkey	3	Lake Bassenthwaite	5	3
Russia	3	Lake Columbia	3	3
		Lake Spokane	19	3
		Lake Kasumigaura	220	3

China, Turkey, and Japan. Western Europe (Netherlands, Estonia, Switzerland, and Germany) and Finland, and the United Kingdom, the countries of Northern Europe lakes were highlighted. Many publications have been published about the Laurentian lakes (Lakes Erie, Ontario, Michigan, Superior, and Huron) which are between the United States and Canada. The case of Lake Taihu of China, which has been extensively examined (26 publications), is similar to but at an excessive rate than Lake Erie. Lake Erie publications began in 1984, while Lake Taihu publications began in 2004. There are a lot of lakes remaining with more than a surface size of 100 km^2 like Lake Dianchi in China, Kinneret in Israel, Balaton in Hungary, Chaohu in China, Okeechobee in the United States, Peipsi in Finland, and Kasumigaura in Japan (Vinçon-Leite and Casenave 2018).

Recommendation

Aquatic ecosystem engineering as a regional solution

The action to fight against aquatic system eutrophication may be formed by three types of levers, physical levers designed to reduce aquatic organisms or de-stratify the water spine, chemical levers designed for combating hypoxia through the artificial re-sprinkling of the environment, or phosphorus precipitation. These methods are expensive and occasionally dangerous, but they can help to control a symptom in tiny geographical areas on a one-by-one basis (Morgane et al. 2019).

Nutrient sources management

Actions are essential to control the input of nutrients from watersheds. They must be set in the longer run in relation to the mechanisms of nutrient transfer, retention, and removal along the continuum of land and sea. Long transport times partly explain that, because of the efforts to reduce inputs over a couple of years, the restricted reduction reported in the amount of N and P loads in the watershed channels. Nowadays a wide range of objectives support a scientific agreement to restrict the inputs of nitrogen and phosphorous in water bodies to municipal, commercial, or agricultural activities, whether inputs from a point source or non-point source. The nutrient cycles are interconnected. Actions undertaken to control one element affect other elements and ultimately the natural ecosystems.

Significant progress has been made in residential and sources from the industry such as non-collective sanitation, modes of collection, and management of trash, but there is still scope for development. Agricultural sources are important in industrialized countries and should be emphasized. It is the time to focus on animal feeding, reprocessing of wastewater where number of animal population is higher, maintenance of fertilization by crops, and conservation or restoration of landscapes particularly at interconnects between land and water (Schoumans et al. 2014).

Socioeconomic guidance for reclamation

Economic studies assist in identifying incentives or regulatory tools capable of helping decision-making individually or in appropriate combinations. Existing economic studies reveal that too-ambitious goals are often unattainable and have resulted in unproductive programs, particularly in terms of cost (Ahlvik et al. 2014). Targeting instruments spatially distributed is usually more effective than applying generic measures on a broad scale; this raises the question of zoning and of the scale of its definition. Adaptive management by updating objectives and tools and attempting experiments based on achievable objectives and a suitable scale appears the best approach to adopt (Pahl-Wostl 2007). Sociological and political factors are beginning to be considered, necessitating distinct approaches based on socio-ecosystems and their various spatial scales, as well as incorporating the concerns of many stakeholders with eutrophication.

Formation of an early eutrophication alert system

Eutrophication is an important environmental problem, as explained previously. Cyanobacterial blooms float on the water's surface or amass on the edge of lakes, especially during the summer. Under high temperatures, portions of these blooms degrade, emitting an unpleasant odor. To avoid water quality degradation, technologies have been utilized to manage severe cyanobacterial blooms. However, if remediation is not done effectively, toxins and algal metabolic products will be discharged into the water, making it more difficult to remove these substances. In these conditions, establishing an early warning system to avoid catastrophic cyanobacterial blooms and limit the frequency of eutrophication is preferred. To create a proper warning system 3S (Remote sensing, Global Information System, Global Positioning System) should be applied. Remote sensing (RS) technology is a quick and accurate way to study and monitor lake water quality. Geographic information systems (GIS) can be used to organize, manage, analyze, and visualize spatial data, and global positioning system (GPS) devices can give accurate positioning information for the obtained water quality data (Xu et al. 2001).

Moving toward systemic research

The current difficulty is that, despite the fact that nutrient pollution has similar impacts on freshwater, coastal, and marine aquatic systems, unable to apply remediation approaches developed in the 1970s and 1980s because of dealing with diffuse nutrient inputs. However, the new headwater management issues catching, coastal and floodplain routes regions are still lacking from highly inclusive territorial research. As a result, eutrophication restoration should aim for systemic techniques that include hydrosystems, agricultural and urban regions, as well as activities for manufacturing, food, and recycling. In general, the issues of agricultural development and eutrophication are interlinked. Models that include biophysical and economic factors must be improved. The relationship between eutrophication and socio-ecosystem alteration should also be better understood, moving beyond sector-specific focuses such as those in recent years, significant progress has been made in farming. Knowledge exchange can be reproduced connections that are currently distinct from one another between social and business groups. Existing investigation sites should be preserved, and there should be a greater number and variety of interdisciplinary inquiry sites (lakes, rivers, and coastal areas) where biophysical and sociocultural dynamics can be examined over time. The public and governance problems must also be studied in sociological terms. Research must be carried out in terms of efficiency, enforceability, and overlap on the limits of sector-specific regulatory approaches, with a common approach that provides better inclusion of the land-sea continuum and specific vulnerability of every type of environment (Morgane et al. 2019).

Conclusion

Eutrophication is characterized by a significant rise in the amounts of algae because one or more growth factors, such as sunlight, carbon dioxide, and mainly nitrogen and phosphorus are more widely available for photosynthesis. When algae grow uncontrollably vast biomass is created, which is destined to decay. The eutrophic process is controlled through preventative strategies, such as the removal of nutrients injected into water bodies from the water. Reduce the concentrations of one of the two main nutrients nitrogen and phosphorus, particularly phosphorus, which is thought to be the limiting factor for algae growth, acting on both localized and widespread loads. The internal nutrient outflow could be stopped by physical, chemical, biological, and even bionic methods. However, controlling nutrient reduction, especially in farming areas where algal nutrients are supplied from nonpoint sources, should be difficult and expensive. The link between macrophytes and the lake ecology is poorly understood. To discover the exact relationship, a far more detailed and scientific investigation is required. The goal of ecological restoration in a eutrophic lake is to change the ecosystem's dominance from phytoplankton to macrophytes. Environmental condition improvement is the foundational activity required to achieve a change in ecosystem status.

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