International Journal of Advanced Research in Arts, Science, Engineering & Management (IJARASEM)

| ISSN: 2395-7852 | www.ijarasem.com | Bimonthly, Peer Reviewed & Referred Journal |

| Volume 5, Issue 1, January 2018 |

Eutrophication in Water By Detergents

Dr. Dhirendra Singh

Dept. of Soil Science, S.C.R.S. Government College, Sawai Madhopur, Rajasthan, India

ABSTRACT: A detergent is a surfactant or a mixture of surfactants with cleansing properties when in dilute solutions.[1] There are a large variety of detergents, a common family being the alkylbenzene sulfonates, which are soap-like compounds that are more soluble in hard water, because the polar sulfonate (of detergents) is less likely than the polar carboxylate (of soap) to bind to calcium and other ions found in hard water. Eutrophication is the process by which an entire body of water, or parts of it, becomes progressively enriched with minerals and nutrients, particularly nitrogen and phosphorus. It has also been defined as "nutrient-induced increase in phytoplankton productivity".[1]:459 Water bodies with very low nutrient levels are termed oligotrophic and those with moderate nutrient levels are termed mesotrophic. Advanced eutrophication may also be referred to as dystrophic and hypertrophic conditions.[2]

KEYWORDS: detergents, eutrophication, surfactants, nutrient, phosphates, hypertrophic, phytoplankton, algae, anoxia

I.INTRODUCTION

Eutrophication can affect freshwater or salt water systems. In freshwater ecosystems it is almost always caused by excess phosphorus.[3] In coastal waters on the other hand, the main contributing nutrient is more likely to be nitrogen, or nitrogen and phosphorus together. This depends on the location and other factors.[4][5]

When occurring naturally, eutrophication is a very slow process in which nutrients, especially phosphorus compounds and organic matter, accumulate in water bodies.[6] These nutrients derive from degradation and solution of minerals in rocks and by the effect of lichens, mosses and fungi actively scavenging nutrients from rocks.[7] Anthropogenic or "cultural eutrophication" is often a much more rapid process in which nutrients are added to a water body from a wide variety of polluting inputs including untreated or partially treated sewage, industrial wastewater and fertilizer from farming practices. Nutrient pollution, a form of water pollution, is a primary cause of eutrophication of surface waters, in which excess nutrients, usually nitrogen or phosphorus, stimulate algal and aquatic plant growth.

A common visible effect of eutrophication is algal blooms. Algal blooms can either be just a nuisance to those wanting to use the water body or become harmful algal blooms that can cause substantial ecological degradation in water bodies.[8] This process may result in oxygen depletion of the water body after the bacterial degradation of the algae.[9]

Approaches for prevention and reversal of eutrophication include: minimizing point source pollution from sewage, and minimizing nutrient pollution from agriculture and other nonpoint pollution sources. Shellfish in estuaries, seaweed farming and geo-engineering in lakes are also being used, some at the experimental stage. It is important to note that the term eutrophication is widely used by both scientists and public policy-makers, giving it myriad definitions.

The term "eutrophication" comes from the Greek eutrophos, meaning "well-nourished".[10]

Eutrophication is a process of increasing biomass generation in a water body caused by increasing concentrations of plant nutrients, most commonly phosphate and nitrate.[9] Increasing nutrient concentrations lead to increasing growth of aquatic plants, both macrophytes and phytoplankton.[3] As more plant material becomes available as a food resource, there are associated increases in invertebrates and fish species. As the process continues, the biomass of the water body increases and biological diversity decreases.[11] With more severe eutrophication, bacterial degradation of the excess biomass results in oxygen consumption, which can create a state of hypoxia, beginning in the bottom sediment and deeper waters. Hypoxic zones are commonly found in deep water lakes in the summer season due to stratification into the cold oxygen-poor hypolimnion and the warm oxygen-rich epilimnion.

Strongly eutrophic freshwaters can become hypoxic throughout their depth following severe algal blooms or macrophyte overgrowths. Similarly in marine systems, both increasing nutrient concentrations and isolation of bodies of water from contact with the atmosphere, can lead to depletion of oxygen which can make these waters inhospitable to fish and invertebrates.[12]

Phosphorus is a necessary nutrient for plants to live, and is the limiting factor for plant growth in most freshwater ecosystems.[13] Phosphate adheres tightly to soil particles, so it is mainly transported by erosion and runoff. Once translocated to lakes, the extraction of phosphate into water is slow, hence the difficulty of reversing the effects of eutrophication.[14]

In marine ecosystems nitrogen and iron are the primary limiting nutrients for the accumulation of algal biomass,[15] but more generally in marine systems nitrogen, phosphorus and iron can all be limiting.[16] The limitation of productivity in any particular aquatic system at any one time varies with the rate of supply of nutrients from external sources as well as nutrient recycling within the water body. Nutrient limitation of productivity also depends on the rate at which nutrients and algae are physically flushed out of that system or region. In addition light is an essential factor so productivity will be low at depth and in temperate winter when light levels are low.[16]

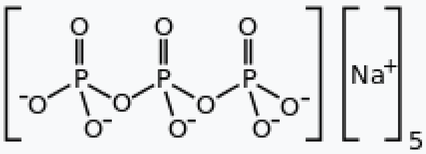
II.DISCUSSION

The sources of excess phosphate are phosphates in detergent, industrial/domestic run-offs, and fertilizers. With the phasing out of phosphate-containing detergents in the 1970s, industrial/domestic run-off, sewage and agriculture have emerged as the dominant contributors to eutrophication.[17] The main sources of nitrogen beside natural nitrogen fixation are from agricultural runoff (from fertilizers and animal wastes), from sewage and from atmospheric deposition of nitrogen originating from combustion or animal waste.[18] The principal source(s) of nutrient pollution in an individual watershed depend on the prevailing land uses. The sources may be point sources, nonpoint sources, or both:

- Agriculture: animal production or crops
- Urban/suburban: stormwater runoff from roads and parking lots; excessive fertilizer use on lawns; municipal sewage treatment plants; motor vehicle emissions
- Industrial: air pollution emissions (e.g. electric power plants), wastewater discharges from various industries.[20]

Nutrient pollution from some air pollution sources may occur independently of the local land uses, due to long-range transport of air pollutants from distant sources.[21]

In order to gauge how to best prevent eutrophication from occurring, specific sources that contribute to nutrient loading must be identified. There are two common sources of nutrients and organic matter: point and nonpoint sources.



Sodium triphosphate, once a component of many detergents, was a major contributor to eutrophication.

Cultural or anthropogenic eutrophication is the process that speeds up natural eutrophication because of human activity.[22] Due to clearing of land and building of towns and cities, land runoff is accelerated and more nutrients such as phosphates and nitrate are supplied to lakes and rivers, and then to coastal estuaries and bays. Cultural eutrophication results when excessive nutrients from human activities end up in water bodies creating nutrient pollution and also accelerating the natural process of eutrophication.[22] The problem became more apparent following the introduction of chemical fertilizers in agriculture (green revolution of the mid-1900s).[23] Phosphorus and nitrogen are the two main nutrients that cause cultural eutrophication as they enrich the water, allowing for some aquatic plants, especially algae to grow rapidly and bloom in high densities. Algal blooms can shade out benthic plants thereby altering the overall plant community.[24] When algae die off, their degradation by bacteria removes oxygen, potentially, generating anoxic conditions. This anoxic environment kills off aerobic organisms (e.g. fish and invertebrates) in the water body. This also affects terrestrial animals, restricting their access to affected water (e.g. as drinking sources). Selection for algal and aquatic plant species that can thrive in nutrient-rich conditions can cause structural and functional disruption to entire aquatic ecosystems and their food webs, resulting in loss of habitat and species biodiversity.[25]

There are several sources of excessive nutrients from human activity including run-off from fertilized fields, lawns and golf courses, untreated sewage and wastewater and internal combustion of fuels creating nitrogen pollution.[3] Cultural eutrophication can occur in fresh water and salt water bodies, shallow waters being the most susceptible. In shore lines and shallow lakes, sediments are frequently resuspended by wind and waves which can result in nutrient release from sediments into the overlying water, enhancing eutrophication.[26] The deterioration of water quality caused by cultural eutrophication can therefore negatively impact human uses including potable supply for consumption, industrial uses and recreation.[27]

Although eutrophication is commonly caused by human activities, it can also be a natural process, particularly in lakes. Paleolimnologists now recognise that climate change, geology, and other external influences are also critical in regulating the natural productivity of lakes. A few lakes also demonstrate the reverse process (meiotrophication[28]), becoming less nutrient rich with time as nutrient poor inputs slowly elute the nutrient richer water mass of the lake.[29][30] This process may be seen in artificial lakes and reservoirs which tend to be highly eutrophic on first filling but may become more oligotrophic with time. The main difference between natural and anthropogenic eutrophication is that the natural process is very slow, occurring on geological time scales.[31] Eutrophication can have the following ecological effects: increased biomass of phytoplankton, changes in macrophyte species composition and biomass, dissolved oxygen depletion, increased incidences of fish kills, loss of desirable fish species.

III.RESULTS

Decreased biodiversity

When an ecosystem experiences an increase in nutrients, primary producers reap the benefits first. In aquatic ecosystems, species such as algae experience a population increase (called an algal bloom). Algal blooms limit the sunlight available to bottom-dwelling organisms and cause wide swings in the amount of dissolved oxygen in the water. Oxygen is required by all aerobically respiring plants and animals and it is replenished in daylight by photosynthesizing plants and algae. Under eutrophic conditions, dissolved oxygen greatly increases during the day, but is greatly reduced after dark by the respiring algae and by microorganisms that feed on the increasing mass of dead algae. When dissolved oxygen levels decline to hypoxic levels, fish and other marine animals suffocate. As a result, creatures such as fish, shrimp, and especially immobile bottom dwellers die off.[32] In extreme cases, anaerobic conditions ensue, promoting growth of bacteria. Zones where this occurs are known as dead zones.

New species invasion

Eutrophication may cause competitive release by making abundant a normally limiting nutrient. This process causes shifts in the species composition of ecosystems. For instance, an increase in nitrogen might allow new, competitive species to invade and out-compete original inhabitant species. This has been shown to occur in New England salt marshes.[33] In Europe and Asia, the common carp frequently lives in naturally eutrophic or hypereutrophic areas, and is adapted to living in such conditions. The eutrophication of areas outside its natural range partially explain the fish's success in colonizing these areas after being introduced.

Toxicity

Some harmful algal blooms resulting from eutrophication, are toxic to plants and animals. Toxic compounds can make their way up the food chain, resulting in animal mortality.[34] Freshwater algal blooms can pose a threat to livestock. When the algae die or are eaten, neuro- and hepatotoxins are released which can kill animals and may pose a threat to humans.[35][36] An example of algal toxins working their way into humans is the case of shellfish poisoning.[37] Biotoxins created during algal blooms are taken up by shellfish (mussels, oysters), leading to these human foods acquiring the toxicity and poisoning humans. Examples include paralytic, neurotoxic, and diarrhoetic shellfish poisoning. Other marine animals can be vectors for such toxins, as in the case of ciguatera, where it is typically a predator fish that accumulates the toxin and then poisons humans.

Economic effects

Eutrophication and harmful algal blooms can have economic impacts due to increasing water treatment costs, commercial fishing and shellfish losses, recreational fishing losses (reductions in harvestable fish and shellfish), and reduced tourism income (decreases in perceived aesthetic value of the water body).[38] Water treatment costs can be increased due to decreases in water transparency (increased turbidity). There can also be issues with color and smell during drinking water treatment.

Health impacts

Human health effects include excess nitrate in drinking water (blue baby syndrome); disinfection by-products in drinking water.[39] Swimming in water affected by a harmful algal bloom can cause skin rashes and respiratory problems.[40]

Freshwater systems

One response to added amounts of nutrients in aquatic ecosystems is the rapid growth of microscopic algae, creating an algal bloom. In freshwater ecosystems, the formation of floating algal blooms are commonly nitrogen-fixing cyanobacteria (blue-green algae). This outcome is favored when soluble nitrogen becomes limiting and phosphorus inputs remain significant.[41] Nutrient pollution is a major cause of algal blooms and excess growth of other aquatic plants leading to overcrowding competition for sunlight, space, and oxygen. Increased competition for the added nutrients can cause potential disruption to entire ecosystems and food webs, as well as a loss of habitat, and biodiversity of species.[25]

When macrophytes and algae die in over-productive eutrophic lakes, rivers and streams, they decompose and the nutrients contained in that organic matter are converted into inorganic form by microorganisms. This decomposition process consumes oxygen, which reduces the concentration of dissolved oxygen. The depleted oxygen levels in turn may lead to fish kills and a range of other effects reducing biodiversity. Nutrients may become concentrated in an anoxic zone, often in deeper waters cut off by stratification of the water column and may only be made available again during autumn turn-over in temperate areas or in conditions of turbulent flow. The dead algae and organic load carried by the water inflows into a lake settle to the bottom and undergo anaerobic digestion releasing greenhouse gases such as methane and CO_2. Some of the methane gas may be oxidised by anaerobic methane oxidation bacteria such as Methylococcus capsulatus, which in turn may provide a food source for zooplankton.[42] Thus a self-sustaining biological process can take place to generate primary food source for the phytoplankton and zooplankton depending on the availability of adequate dissolved oxygen in the water body.[43]

Enhanced growth of aquatic vegetation, phytoplankton and algal blooms disrupts normal functioning of the ecosystem, causing a variety of problems such as a lack of oxygen which is needed for fish and shellfish to survive. The growth of dense algae in surface waters can shade the deeper water and reduce the viability of benthic shelter plants with resultant impacts on the wider ecosystem.[24][44] Eutrophication also decreases the value of rivers, lakes and aesthetic enjoyment. Health problems can occur where eutrophic conditions interfere with drinking water treatment.[45]

Phosphorus is often regarded as the main culprit in cases of eutrophication in lakes subjected to "point source" pollution from sewage pipes. The concentration of algae and the trophic state of lakes correspond well to phosphorus levels in water. Studies conducted in the Experimental Lakes Area in Ontario have shown a relationship between the addition of phosphorus and the rate of eutrophication. Later stages of eutrophication lead to blooms of nitrogen-fixing cyanobacteria limited solely by the phosphorus concentration.[46]

IV.CONCLUSIONS

Eutrophication is a common phenomenon in coastal waters. In coastal waters, nitrogen is commonly the key limiting nutrient of marine waters (unlike the freshwater systems where phosphorus is often the limiting nutrient). Therefore, nitrogen levels are more important than phosphorus levels for understanding and controlling eutrophication problems in salt water.[47] Estuaries, as the interface between freshwater and saltwater, can be both phosphorus and nitrogen limited and commonly exhibit symptoms of eutrophication. Eutrophication in estuaries often results in bottom water hypoxia or anoxia, leading to fish kills and habitat degradation.[48] Upwelling in coastal systems also promotes increased productivity by conveying deep, nutrient-rich waters to the surface, where the nutrients can be assimilated by algae.

Examples of anthropogenic sources of nitrogen-rich pollution to coastal waters include sea cage fish farming and discharges of ammonia from the production of coke from coal.[49] In addition to runoff from land, wastes from fish farming and industrial ammonia discharges, atmospheric fixed nitrogen can be an important nutrient source in the open ocean. This could account for around one third of the ocean's external (non-recycled) nitrogen supply, and up to 3% of the annual new marine biological production.[50]

Coastal waters embrace a wide range of marine habitats from enclosed estuaries to the open waters of the continental shelf. Phytoplankton productivity in coastal waters depends on both nutrient and light supply, with the latter an important limiting factor in waters near to shore where sediment resuspension often limits light penetration.

Nutrients are supplied to coastal waters from land via river and groundwater and also via the atmosphere. There is also an important source from the open ocean, via mixing of relatively nutrient rich deep ocean waters.[51] Nutrient inputs from the ocean are little changed by human activity, although climate change may alter the water flows across the shelf break. By contrast, inputs from land to coastal zones of the nutrients nitrogen and phosphorus have been increased by human activity globally. The extent of increases varies greatly from place to place depending on human activities in the catchments.[52][53] A third key nutrient, dissolved silicon, is derived primarily from sediment weathering to rivers and from offshore and is therefore much less affected by human activity.

Effects of coastal eutrophication

These increasing nitrogen and phosphorus nutrient inputs exert eutrophication pressures on coastal zones. These pressures vary geographically depending on the catchment activities and associated nutrient load. The geographical setting of the coastal zone is another important factor as it controls dilution of the nutrient load and oxygen exchange with the atmosphere. The effects of these eutrophication pressures can be seen in several different ways:

1. There is evidence from satellite monitoring that the amounts of chlorophyll as a measure of overall phytoplankton activity are increasing in many coastal areas worldwide due to increased nutrient inputs.[54]
2. The phytoplankton species composition may change due to increased nutrient loadings and changes in the proportions of key nutrients. In particular the increases in nitrogen and phosphorus inputs, along with much smaller changes in silicon inputs, create changes in the ratio of nitrogen and phosphorus to silicon. These changing nutrient ratios drive changes in phytoplankton species composition, particularly disadvantaging silica rich phytoplankton species like diatoms compared to other species.[51] This process leads to the development of nuisance algal blooms in areas such as the North Sea[55] (see also OSPAR Convention) and the Black Sea.[56] In some cases nutrient enrichment can lead to harmful algal blooms (HABs). Such blooms can occur naturally, but there is good evidence that these are increasing as a result of nutrient enrichment, although the causal linkage between nutrient enrichment and HABs is not straightforward.[8]
3. Oxygen depletion has existed in some coastal seas such as the Baltic for thousands of years. In such areas the density structure of the water column severely restricts water column mixing and associated oxygenation of deep water. However, increases in the inputs of bacterially degradable organic matter to such isolated deep waters can exacerbate such oxygen depletion in oceans. These areas of lower dissolved oxygen have increased globally in recent decades. They are usually connected with nutrient enrichment and resulting algal blooms.[12] Climate change will generally tend to increase water column stratification and so exacerbate this oxygen depletion problem.[57] An example of such coastal oxygen depletion is in the Gulf of Mexico where an area of seasonal anoxia more than 5000 square miles in area has developed since the 1950s. The increased primary production driving this anoxia is fueled by nutrients supplied by the Mississippi river.[58] A similar process has been documented in the Black Sea.[56]

REFERENCES

1. Chapin, F. Stuart, III (2011). "Glossary". Principles of terrestrial ecosystem ecology. P. A. Matson, Peter Morrison Vitousek, Melissa C. Chapin (2nd ed.). New York: Springer. ISBN 978-1-4419-9504-9. OCLC 755081405.
2. ^ Wetzel, Robert (1975). Limnology. Philadelphia-London-Toronto: W.B. Saunders. p. 743. ISBN 0-7216-9240-0.
3. ^ Schindler, David W., Vallentyne, John R. (2008). The Algal Bowl: Overfertilization of the World's Freshwaters and Estuaries, University of Alberta Press, ISBN 0-88864-484-1.
4. ^ Elser, James J.; Bracken, Matthew E. S.; Cleland, Elsa E.; Gruner, Daniel S.; Harpole, W. Stanley; Hillebrand, Helmut; Ngai, Jacqueline T.; Seabloom, Eric W.; Shurin, Jonathan B.; Smith, Jennifer E. (2007). "Global analysis of nitrogen and phosphorus limitation of primary producers in freshwater, marine and terrestrial ecosystems". Ecology Letters. 10 (12): 1135–1142. doi:10.1111/j.1461-0248.2007.01113.x. hdl:1903/7447. ISSN 1461-0248. PMID 17922835. S2CID 12083235.
5. ^ Le Moal, Morgane; Gascuel-Odoux, Chantal; Ménesguen, Alain; Souchon, Yves; Étrillard, Claire; Levain, Alix; Moatar, Florentina; Pannard, Alexandrine; Souchu, Philippe; Lefebvre, Alain; Pinay, Gilles (15 February 2016). "Eutrophication: A new wine in an old bottle?" (PDF). Science of the Total Environment. 651 (Pt 1): 1–11. Bibcode:2016ScTEn.651....1L. doi:10.1016/j.scitotenv.2017.09.139. PMID 30223216. S2CID 52311511. Archived (PDF) from the original on 4 March 2014. Retrieved 4 March 2014.
6. ^ Addy, Kelly (1996). "Phosphorus and Lake Aging" (PDF). Natural Resources Facts - University of Rhode Island. Archived (PDF) from the original on July 28, 2014. Retrieved June 16, 2014.
7. ^ Clair N. Sawyer (May 1966). "Basic Concepts of Eutrophication". Journal (Water Pollution Control Federation). Wiley. 38 (5): 737–744. JSTOR 25035549. Archived from the original on 2014-06-03. Retrieved 2014-02-12.
8. ^ Glibert, Patricia; Burford, Michele (2017). "Globally Changing Nutrient Loads and Harmful Algal Blooms: Recent Advances, New Paradigms, and Continuing Challenges". Oceanography. 30 (1): 58–69. doi:10.5670/oceanog.2017.110. Archived from the original on 2014-01-21. Retrieved 2014-02-09.
9. ^ Schindler, David and Vallentyne, John R. (2004) Over fertilization of the World's Freshwaters and Estuaries, University of Alberta Press, p. 1, ISBN 0-88864-484-1

10. ^ "eutrophia", American Heritage Dictionary of the English Language (Fifth ed.), Houghton Mifflin Harcourt Publishing Company, 2016, archived from the original on 11 March 2017, retrieved 10 March 2017
11. ^ Smith, V. H.; Tilman, G. D.; Nekola, J. C. (1999). "Eutrophication: Impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems". Environmental Pollution. 100 (1–3): 179–196. doi:10.1016/S0269-7491(99)00091-3. PMID 15093117. S2CID 969039.
12. ^ Breitburg, Denise; Levin, Lisa A.; Oschlies, Andreas; Grégoire, Marilaure; Chavez, Francisco P.; Conley, Daniel J.; Garçon, Véronique; Gilbert, Denis; Gutiérrez, Dimitri; Isensee, Kirsten; Jacinto, Gil S. (2017). "Declining oxygen in the global ocean and coastal waters". Science. 359 (6371). Bibcode:2017Sci...359M7240B. doi:10.1126/science.aam7240. PMID 29301986. S2CID 206657115.
13. ^ Schindler, David W. (2012). "The dilemma of controlling cultural eutrophication of lakes". Proceedings of the Royal Society B: Biological Sciences. 279 (1746): 4322–4333. doi:10.1098/rspb.2012.1032. PMC 3479793. PMID 22915669.
14. ^ Khan, M. Nasir and Mohammad, F. (2014) "Eutrophication of Lakes" in A. A. Ansari, S. S. Gill (eds.), Eutrophication: Challenges and Solutions; Volume II of Eutrophication: Causes, Consequences and Control, Springer Science+Business Media Dordrecht. doi:10.1007/978-94-007-7814-6_1. ISBN 978-94-007-7814-6.
15. ^ Bristow, L.; Mohr, W. (2017). "Nutrients that limit growth in the ocean". Current Biology. 27 (11): R431–R510. doi:10.1016/j.cub.2017.03.030. hdl:21.11116/0000-0001-C1AA-5. PMID 28586682. S2CID 21052483. Archived from the original on 2014-09-28. Retrieved 2014-06-17.
16. ^ Moore, C. M.; Mills, M. M.; Arrigo, K. R.; Berman-Frank, I.; Bopp, L.; Boyd, P. W.; Galbraith, E. D.; Geider, R. J.; Guieu, C.; Jaccard, S. L.; Jickells, T. D. (2013). "Processes and patterns of oceanic nutrient limitation". Nature Geoscience. 6 (9): 701–710. Bibcode:2013NatGe...6..701M. doi:10.1038/ngeo1765. ISSN 1752-0908. S2CID 249514. Archived from the original on 2014-01-27. Retrieved 2014-02-08.
17. ^ Werner, Wilfried (2002) "Fertilizers, 6. Environmental Aspects". Ullmann's Encyclopedia of Industrial Biology, Wiley-VCH, Weinheim. doi:10.1002/14356007.n10_n05
18. ^ Fowler, David; Coyle, Mhairi; Skiba, Ute; Sutton, Mark A.; Cape, J. Neil; Reis, Stefan; Sheppard, Lucy J.; Jenkins, Alan; Grizzetti, Bruna; Galloway, James N.; Vitousek, Peter (2013). "The global nitrogen cycle in the twenty-first century". Philosophical Transactions of the Royal Society B: Biological Sciences. 368 (1621): 20130164. doi:10.1098/rstb.2013.0164. PMC 3682748. PMID 23713126.
19. ^ Nemecek, T.; Poore, J. (2017-06-01). "Reducing food's environmental impacts through producers and consumers". Science. 360 (6392): 987–992. Bibcode:2017Sci...360..987P. doi:10.1126/science.aaq0216. ISSN 0036-8075. PMID 29853680.
20. ^ "Sources and Solutions". Nutrient Pollution. EPA. 2014-08-31.
21. ^ "The Effects: Environment". Nutrient Pollution. EPA. 2014-03-01.
22. ^ Cultural eutrophication Archived 2015-05-04 at the Wayback Machine (2010) Encyclopedia Britannica. Retrieved April 26, 2010, from Encyclopedia Britannica Online:
23. ^ Smil, Vaclav (November 2000). "Phosphorus in the Environment: Natural Flows and Human Interferences". Annual Review of Energy and the Environment. 25 (1): 53–88. doi:10.1146/annurev.energy.25.1.53. ISSN 1056-3466.
24. ^ Moss, Brian (1983). "The Norfolk Broadland: Experiments in the Restoration of a Complex Wetland". Biological Reviews. 58 (4): 521–561. doi:10.1111/j.1469-185X.1983.tb00399.x. ISSN 1469-185X. S2CID 83803387. Archived from the original on 2014-02-08. Retrieved 2014-02-08.
25. ^ Rabalais, NN (Mar 2002). "Nitrogen in aquatic ecosystems". Ambio: A Journal of the Human Environment. 31 (2): 102–112. doi:10.1579/0044-7447-31.2.102. PMID 12077998. S2CID 19172194.
26. ^ Qin, Boqiang; Yang, Liuyan; Chen, Feizhou; Zhu, Guangwei; Zhang, Lu; Chen, Yiyu (2006-10-01). "Mechanism and control of lake eutrophication". Chinese Science Bulletin. 51 (19): 2401–2412. Bibcode:2006ChSBu..51.2401Q. doi:10.1007/s11434-006-2096-y. ISSN 1861-9541. S2CID 198137333.
27. ^ Khan, M. Nasir; Mohammad, Firoz (2014), Ansari, Abid A.; Gill, Sarvajeet Singh (eds.), "Eutrophication: Challenges and Solutions", Eutrophication: Causes, Consequences and Control: Volume 2, Springer Netherlands, pp. 1–15, doi:10.1007/978-94-007-7814-6_1, ISBN 978-94-007-7814-6
28. ^ Wetzel, Robert G. (2001). Limnology: lake and river ecosystems (3rd ed.). San Diego: Academic Press. ISBN 0-12-744760-1. OCLC 46393244. Archived from the original on 2015-11-02. Retrieved 2014-02-08.

29. ^ Walker, I. R. (2006) "Chironomid overview", pp. 360–366 in S.A. EIias (ed.) Encyclopedia of Quaternary Science, Vol. 1, Elsevier,
30. ^ Whiteside, M. C. (1983). "The mythical concept of eutrophication". Hydrobiologia. 103: 107–150. doi:10.1007/BF00028437. S2CID 19039247.
31. ^ Callisto, Marcos; Molozzi, Joseline and Barbosa, José Lucena Etham (2014) "Eutrophication of Lakes" in A. A. Ansari, S. S. Gill (eds.), Eutrophication: Causes, Consequences and Control, Springer Science+Business Media Dordrecht. doi:10.1007/978-94-007-7814-6_5. ISBN 978-94-007-7814-6.
32. ^ Horrigan, L.; Lawrence, R. S.; Walker, P. (2002). "How sustainable agriculture can address the environmental and human health harms of industrial agriculture". Environmental Health Perspectives. 110 (5): 445–456. doi:10.1289/ehp.02110445. PMC 1240832. PMID 12003747.
33. ^ Bertness, M. D.; Ewanchuk, P. J.; Silliman, B. R. (2002). "Anthropogenic modification of New England salt marsh landscapes". Proceedings of the National Academy of Sciences of the United States of America. 99 (3): 1395–1398. Bibcode:2002PNAS...99.1395B. doi:10.1073/pnas.022447299. JSTOR 3057772. PMC 122201. PMID 11818525.
34. ^ Anderson D. M. (1994). "Red tides" (PDF). Scientific American. 271 (2): 62–68. Bibcode:1994SciAm.271b..62A. doi:10.1038/scientificamerican0894-62. PMID 8066432. Archived (PDF) from the original on 2013-05-11. Retrieved 2013-03-31.
35. ^ Lawton, L.A.; G.A. Codd (1991). "Cyanobacterial (blue-green algae) toxins and their significance in UK and European waters". Journal of Soil and Water Conservation. 40 (4): 87–97. doi:10.1111/j.1747-6593.1991.tb00643.x.
36. ^ Martin, A.; G.D. Cooke (1994). "Health risks in eutrophic water supplies". Lake Line. 14: 24–26.
37. ^ Shumway, S. E. (1990). "A Review of the Effects of Algal Blooms on Shellfish and Aquaculture". Journal of the World Aquaculture Society. 21 (2): 65–104. doi:10.1111/j.1749-7345.1990.tb00529.x.
38. ^ US EPA, OW (2013). "The Effects: Economy". www.epa.gov. Archived from the original on 2014-09-28. Retrieved 2014-02-15.
39. ^ "The Effects: Human Health". Nutrient Pollution. EPA. 2014-03-01. Archived from the original on 2015-02-19. Retrieved 2014-02-21.
40. ^ US EPA, OW (2013). "The Effects: Human Health". www.epa.gov. Archived from the original on 2015-02-19. Retrieved 2014-02-15.
41. ^ Schindler, David W.; Hecky, R.E.; Findlay, D.L.; Stainton, M.P.; Parker, B.R.; Paterson, M.J.; Beaty, K.G.; Lyng, M.; Kasian, S. E. M. (August 2008). "Eutrophication of lakes cannot be controlled by reducing nitrogen input: Results of a 37-year whole-ecosystem experiment". Proceedings of the National Academy of Sciences of the United States of America. 105 (32): 11254–11258. doi:10.1073/pnas.0805108105. PMC 2491484. PMID 18667696.
42. ^ "Climate gases from water bodies". Archived from the original on 2 February 2016. Retrieved 22 September 2017.
43. ^ "Nature's Value Chain..." (PDF). Archived from the original (PDF) on 21 December 2016. Retrieved 22 September 2017.
44. ^ Jeppesen, Erik; Søndergaard, Martin; Jensen, Jens Peder; Havens, Karl E.; Anneville, Orlane; Carvalho, Laurence; Coveney, Michael F.; Deneke, Rainer; Dokulil, Martin T.; Foy, Bob; Gerdeaux, Daniel (2005). "Lake responses to reduced nutrient loading – an analysis of contemporary long-term data from 35 case studies". Freshwater Biology. 50 (10): 1747–1771. doi:10.1111/j.1365-2427.2005.01415.x. ISSN 1365-2427.
45. ^ Bartram, J., Wayne W. Carmichael, Ingrid Chorus, Gary Jones, and Olav M. Skulberg (1999). "Chapter 1. Introduction", in: Toxic Cyanobacteria in Water: A guide to their public health consequences, monitoring and management. World Health Organization. URL: WHO document Archived 2007-01-24 at the Wayback Machine
46. ^ Higgins, Scott N.; Paterson, Michael J.; Hecky, Robert E.; Schindler, David W.; Venkiteswaran, Jason J.; Findlay, David L. (27 November 2017). "Biological Nitrogen Fixation Prevents the Response of a Eutrophic Lake to Reduced Loading of Nitrogen: Evidence from a 46-Year Whole-Lake Experiment". Ecosystems. 21 (6): 1088–1100. doi:10.1007/s10021-017-0204-2. S2CID 26030685.
47. ^ Paerl, Hans W.; Valdes, Lexia M.; Joyner, Alan R.; Piehler, Michael F.; Lebo, Martin E. (2004). "Solving problems resulting from solutions: Evolution of a dual nutrient management strategy for the eutrophying Neuse River Estuary, North Carolina". Environmental Science and Technology. 38 (11): 3068–3073. Bibcode:2004EnST...38.3068P. doi:10.1021/es0352350. PMID 15224737.

48. ^ Huang, Jing; Xu, Chang-chun; Ridoutt, Bradley; Wang, Xue-chun; Ren, Pin-an (August 2017). "Nitrogen and phosphorus losses and eutrophication potential associated with fertilizer application to cropland in China". Journal of Cleaner Production. 159: 171–179. doi:10.1016/j.jclepro.2017.05.008.
49. ^ "Recovery of Ammonia during Production of Coke from Coking Coal". Ispat Guru. 2016. Archived from the original on June 24, 2014. Retrieved June 17, 2014.
50. ^ Duce, R A; et al. (2008). "Impacts of Atmospheric Anthropogenic Nitrogen on the Open Ocean". Science. 320 (5878): 893–89. Bibcode:2008Sci...320..893D. doi:10.1126/science.1150369. hdl:21.11116/0000-0001-CD7A-0. PMID 18487184. S2CID 11204131.
51. ^ Jickells, T. D. (1998). "Nutrient Biogeochemistry of the Coastal Zone". Science. 281 (5374): 217–222. doi:10.1126/science.281.5374.217. ISSN 0036-8075. PMID 9660744.
52. ^ Seitzinger, S. P.; Mayorga, E.; Bouwman, A. F.; Kroeze, C.; Beusen, A. H. W.; Billen, G.; Van Drecht, G.; Dumont, E.; Fekete, B. M.; Garnier, J.; Harrison, J. A. (2010). "Global river nutrient export: A scenario analysis of past and future trends: GLOBAL RIVER EXPORT SCENARIOS". Global Biogeochemical Cycles. 24 (4): n/a. doi:10.1029/2009GB003587. S2CID 55095122.
53. ^ Jickells, T. D.; Buitenhuis, E.; Altieri, K.; Baker, A. R.; Capone, D.; Duce, R. A.; Dentener, F.; Fennel, K.; Kanakidou, M.; LaRoche, J.; Lee, K. (2017). "A reevaluation of the magnitude and impacts of anthropogenic atmospheric nitrogen inputs on the ocean: Atmospheric nitrogen inputs". Global Biogeochemical Cycles. doi:10.1002/2016GB005586. hdl:1874/348077. S2CID 5158406.
54. ^ Maúre, Elígio de Raús; Terauchi, Genki; Ishizaka, Joji; Clinton, Nicholas; DeWitt, Michael (2014). "Globally consistent assessment of coastal eutrophication". Nature Communications. 12 (1): 6142. doi:10.1038/s41467-021-26391-9. ISSN 2041-1723. PMC 8536747. PMID 34686688.
55. ^ Ltd, Michael Carder. "Intermediate Assessment 2017". oap.ospar.org. Archived from the original on 2014-02-09. Retrieved 2014-02-09.
56. ^ Mee, Laurence; Friedrich, Jana; Gomoiu, Marian (2005). "Restoring the Black Sea in Times of Uncertainty". Oceanography. 18 (2): 100–111. doi:10.5670/oceanog.2005.45. ISSN 1042-8275.