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Biological Impacts on Aquatic Systems of Surface Water Pollutants Derived from Agriculture – A Review

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Abstract:

One of the main causes of stress on natural ecosystems is human activity, including environmental alteration. Agricultural practices have been found to be one of the main causes of environmental stress, which impacts every element of the ecosystem, out of the numerous sources of surface water pollution. Although more subtle, sublethal chronic impacts may be just as harmful over extended periods of time, agricultural toxins in water are most visible when they have quick, dramatic toxic effects on aquatic life. If aquatic systems are not severely overwhelmed with irreversible contaminants, they can recover from contamination harm. Therefore, the degree of contaminant loading is just as crucial as the kind of pollutant. Pesticides, fertilizers, and organic enrichment are all significant stresses for aquatic life, even though suspended sediment makes up the majority of aquatic contaminants. Contaminants are captured and processed by stream corridor habitat. When evaluating harm to aquatic life, the loss of buffering habitat, such as riparian zones, should be taken into account since it speeds up the impacts of pollution. The most efficient way to preserve biological variety is through habitat protection. Numerous issues pertaining to contaminants in aquatic systems are being resolved by promising new technologies and current management approaches.

Keywords: Ecosystem recovery, Sublethal chronic toxicity, Aquatic biodiversity conservation

Introduction:

In nature, there is tremendous diversity of both habitats and organisms. The distribution of organisms in unpolluted natural systems is a reflection of environmental constraints such as light, substrate, nutrients, temperature, dissolved oxygen concentrations, and other elements. One of the main components of aquatic habitat is substrate. Opportunities for adaptable species to flourish are represented by the variety of habitats found in nature. Animal and plant communities have evolved into self-balancing systems in a variety of natural systems with varying habitats and specializations. Since pollution seldom impacts a single type of creature in an aquatic environment, these ideas are crucial when talking about how pollution affects aquatic life. Pollution has an indirect effect on other organisms when it directly impacts one by altering the natural equilibrium, such as the predator-prey relationship.

Furthermore, pollution can change environmental factors or habitat, which might impact species or populations and upset the delicate balance. Primary receivers and secondary receivers are two categories into which aquatic systems can be arbitrarily divided. Wetlands, tiny streams, and impoundments that absorb runoff and contaminants straight from the land are the main recipients. These systems may experience both acute and long-term impacts from pollution due to high concentrations of toxins from direct intake. Larger lakes and downstream rivers that get inflow from several tributaries in addition to a small amount of direct runoff are considered secondary receivers. Pollution in these water bodies has observable acute consequences, but persistent issues that are harder to quantify are more likely to arise.

The Indian government has taken a number of actions to solve the problem after realizing how much agricultural pesticides contribute to water contamination. Because of the possible threats to human health and the environment, the Ministry of Agriculture and Farmers Welfare recommended in May 2020 to outlaw 27 pesticides that are already illegal in other nations. The goal of this idea is to reduce the amount of these dangerous chemicals that end up in water sources due to agricultural runoff. In India, the Central pollution Control Board (CPCB) has drawn attention to the serious water contamination brought on by fertilizer and pesticide-containing agricultural runoff. Human health and aquatic ecosystems are impacted by this pollution, which also impacts rivers, lakes, and groundwater. Strict pesticide regulations and sustainable farming methods are advocated by the CPCB. Despite the lack of a thorough state-specific assessment, the Maharashtra government has recognized the problem and taken steps to rectify it. (Francis, D. J., & Das, A. K., 2020)

- **Detection of Pesticides in Drinking Water**: Studies have found chlorpyrifos and malathion in drinking water sources in Maharashtra, posing acute and chronic health risks to residents.
- **Surface Water Contamination**: According to research, pesticides like Chlorpyrifos are present in surface water bodies, including rivers like the Wainganga, Wardha, Purna, and Kanhan—tributaries of the Godavari River at quantities as high as 0.46 µg/L in certain areas.
- **Impact on Farmers in Vidarbha**: The Vidarbha region has experienced excessive pesticide use in cotton farming, leading to severe health issues among farmers, including cases of pesticide poisoning.
- **Health Implications**: Residents are more likely to have both acute and long-term health problems if they find organophosphate pesticides, such as malathion and chlorpyrifos, in their drinking water. Notably, around 45 farmers have died in Vidarbha since August 2017 as a result of pesticide poisoning, mostly from exposure during Bt cotton plantation spraying operations.
- **Groundwater Contamination**: The Central Ground Water Board's Annual Ground Water Quality Report indicates that nearly a fifth of groundwater samples in India exceed permissible pollutant limits, including nitrates and pesticides. While this report covers the entire country, Maharashtra's extensive agricultural activities suggest it faces similar challenges.
- **Groundwater Pollution**: Groundwater sources, including dug wells, hand pumps, and tube wells, have been found to contain pesticide residues, though at generally lower concentrations than surface waters. The presence of pesticides such as HCH isomers, Endosulfan, and DDT has been confirmed, raising concerns about the safety of drinking water supplies.

Large-scale agricultural operations, especially cotton cropping, are causing serious chemical pollution in Maharashtra's Vidarbha area. Health and environmental issues have arisen as a result of the toxic residues that have been found in surface and groundwater sources. The Maharashtra government is encouraging environmentally friendly farming methods like integrated pest control and organic farming in order to lessen dependency on chemical pesticides. In an effort to reduce water pollution, efforts are also being made to monitor the quality of the water and instruct farmers on how to use agrochemicals safely. These programs seek to maintain the integrity of the environment and safeguard public health.

Stresses and Effects:

Natural habitats may cause stress to the species that live there, despite the fact that all organisms are suited to their surroundings. Estuarine and rocky coastline ecosystems experience stress twice a day due to tidal movements. Natural rainfall-induced runoff can raise stream flow to the point that bed movement occurs. Every year, ephemeral streams experience a cycle of desiccation stress. Aquatic life has evolved to these typical stressors, but it is frequently unprepared for the additional environmental stresses brought on by pollution. While many imposed pressures are unfamiliar to the aquatic environment, some are comparable to natural ones. Take low dissolved oxygen, for instance. Low levels of dissolved oxygen are found naturally in aquatic environments, such as those that drain large wetlands with a lot of organic debris. Fish respond to low oxygen levels by pumping more water over their gill surfaces. An extra stress is produced at a crucial moment when harmful contaminants like Cu are injected. During times of dissolved oxygen stress, fish that pump more water over their gills absorb more copper (Cu), which increases the risk of metal poisoning. various causation and the synergy of various stressors operating in the environment concurrently are the effects of ecological complexity.

Stressors increase an organism's vulnerability to parasites and illness (Wedemeyer et al., 1976). Stress is the cause of more than a dozen prevalent fish nursery illnesses (Wedemeyer and Wood, 1974). Numerous definitions of pollution have been put out; all of them rely on anything that alters the environment and creates stress that is not natural (Hynes, 1960; Holdgate, 1971). Thermal pollution is heated water that is out of place, even if it may look like water coming from a hot spring. A useful definition of pollution was provided by Edwards, (1977)., who defined it as the "release of substances or energy into the environment by man in quantities that damage either his health or his resources."

Agricultural Inputs and Impacts:

Sediments:

In the Vidarbha, the biggest pollutants by volume are bedload and instream suspended sediments. Every year, the Wainganga, Wardha, Purna, and Kanhan Rivers transport millions of tons of topsoil In main receiving streams, bedload and suspended particles scour epiphytic communities (organisms that live on the sediment surface) and can drastically lower community production. Not all aquatic communities can adapt to sedimentation. Certain macrophytes may persist in disturbed environments, according to Budhlani and Musaddiq’s early research on the Wardha River (2014). Because it was unable to change its root level, Budhlani and Musaddiq’s observed that Isoetes was readily suffocated by silt buildup. When silting increased, Potamogeton perfoliatus frequently took its place. Dredging in the River of Vidarbha caused changes in flow patterns that coincided with increases in sedimentation rates. The marsh's plant and animal species were decimated by this combination, leaving only a windswept, bare body of shallow, unproductive water. The periphyton population and benthic invertebrates are destroyed in unstable streams with increased discharge from big storm events, which also starts bedload movement, including sand and gravel.

Excessive sediment loads prevent the formation of nearly all aquatic plant communities. Fish reproductive habitat is destroyed or buried as a result of such movement, which results in a scour-aggradation cycle and reproductive failure (Cooper and Knight, 1987). The two most commonly utilized biotic markers for aquatic stress are fish and benthos. Tebo (1955) demonstrated that high sedimentation rates decreased benthos through drift and death. Gammon (1970) examined the sediment load from a crushed limestone quarry in a small stream and recorded changes in fish and invertebrate populations. Benthic populations dropped by 60% as the sediment load rose to the point where sediments accumulated. The densities below the quarry ranged from 86 organisms/m^2 to 10,750 organisms/m^2 above it. By eradicating species that were sensitive to sediment during times of sediment deposition, particularly the more vulnerable larval stages, Cooper also demonstrated how sediments were harmful to stream benthos. Due to the buildup of fine particles, the primary factor limiting benthic production was a lack of appropriate substrate. After testing the mortality of three kinds of sessile invertebrates, he discovered that while the invertebrates could tolerate large concentrations of suspended sediments (> 1000 mg/L) for short periods of time, their mortality rates rose quickly over time. The primary production of algae in lakes and reservoirs may be restricted by suspended sediments. Although certain "low light" phytoplankton need "shaded" circumstances (Tilzer et al., 1976), light reduction from suspended sediments inhibits the development of the majority of limnetic algae. The photic zone shrinks as a result of suspended sediments reducing the depth of light penetration into the water column.

Nutrients:

The second type of contaminants that have an impact on aquatic life are nutrients derived from agriculture. Crop lands play a significant role because nutrient availability, which is often obtained via the use of commercial fertilizer, is necessary for adequate crop output. Another source of runoff in rural areas is limited feeding operations. Excessive lawn fertilization and sewage discharge can be major sources of nutrients in urban areas. A physical or chemical element limits the development of plants in water. Aquatic plants are powered by sunlight. Similar to crop productivity, the availability of P and N typically restricts development in freshwater environments (Vollenweider, 1968). On the other hand, plants flourish in water when there is an overabundance of P and N. Excessive nutrients can cause eutrophication, which is not always a good or negative thing. It is a natural occurrence when viewed in the right light. However, human activity is directly responsible for increased cultural eutrophication, which reduces lake life and prevents functional water usage.

Eutrophication causes excessive plant growth, which leads to a number of issues. Physical changes in habitat caused by the blanketing impacts of macrophytes and algae can modify the makeup of faunal species. Toxins are produced by some eutrophication-related algae species. Plant respiration lowers dissolved oxygen at night and even during the day if there is less light penetration. The depletion of plant biomass can further reduce oxygen levels in a manner similar to that of massive inputs of organic matter. Accordingly, excessive plant development can cause fish fatalities by lowering oxygen concentrations below the 4 mg/L threshold for warmwater fishes (Wedemeyer et al., 1976). The main cause of stress related to eutrophication is most likely oxygen deficiency. As with fish deaths, short-term deficiencies could be easily noticeable, but long-term decreases might have far more severe effects. These later deficits change the primary consumer level of aquatic life and cause changes in benthic ecosystems. Aquatic life is directly poisoned by some nutrients. Fish may be poisoned by ammonia (NH) from animal waste at concentrations as low as 0.02 mg/L, particularly when the pH is high. Although land use has a direct impact on stream nutrient concentrations, streams are often impacted by dominant physical causes. Regardless of nutrient availability, stream features including slope, depth, current velocity, canopy, and stream order may affect phytoplankton population.

Organic Contamination:

One of the oldest and most pervasive types of water pollution is excessive organic waste. The high solids content of organic waste can quickly cover benthic habitat. A common sign of organic pollution is the emergence of large populations of "sewage fungus," a community of heterotrophic bacteria (Hellawell, 1986). The impact of organic pollution on the levels of dissolved oxygen in water and sediments is its most obvious effect. An "oxygen-sag" occurs when an aquatic system cannot meet the biochemical oxygen demand (BOD) due to the high levels of organic matter from animal feces. Organic enrichment is often linked to nutrient loading, creating a more complex issue. While chicken excrement can have a BOD of 24,000 to 67,000 mgK, natural waters typically have a BOD of 0.5 to 7 mg/L (Klein, 1959). A deterioration cycle starts when the amount of organic matter in a system is greater than its ability to absorb it. First, the higher amount of organic matter encourages aerobic decomposers to work harder. The dissolved oxygen content starts to decrease and certain species are eliminated when the pace at which aerobic decomposers use oxygen surpasses the rate at which reaeration occurs. Aerobic decomposers stop working and anaerobic organisms take over the sediment and water if the dissolved oxygen drop persists.

Low dissolved oxygen has implications that go beyond shifts in species composition since chemical processes are impacted by oxygen concentration. One example is ammonia. Nitrifying bacteria predominate in aerobic environments, where Nitrobacter sp. converts ammonia to nitrates after bacteria (*Nitrosomonas* sp.) convert it to nitrite. This cycle oxidizes harmful ammonia to produce easily accessible nutrients. Other bacteria, including *Thiobacillus denitrificans*, often carry out denitrification under anaerobic conditions.

Pesticides and Metals:

The fight against food shortages and vector-borne illnesses has been mostly fought by pesticides. Without them, our economy and society would be quite different. However, pollution from pesticides is a persistent issue. Since toxicity testing is required before a pesticide can be approved for widespread use, the deadly consequences of pesticides have been extensively recorded. The impact of recurrent usage has frequently not been included in the documentation of persistence or biotic absorption of currently used pesticides, which has frequently been restricted to initial preregistration testing. Long-term usage increases the likelihood that pesticides will be present at low but steady levels and may cause unidentified, non-lethal issues (Cooper, 1991). Millions of kilos of pesticides were sprayed on India's main agricultural crops. According to Pimental and Levitan (1986), fewer than 0.1% of pesticides used on crops truly reach the intended organisms. This means that over 99 percent of the substance that has been applied will either deteriorate or possibly pollute the air, soil, or water.

The aqueous-sediment phases of surface waters during the winter-spring wet season had substantially greater residual pesticide concentrations than during the dry season. Significantly elevated runoff concentrations highlight the significance of watershed management for long-term ecosystem quality and indicate the extent of the DDT source that is still present in watershed soil.

In freshwater invertebrates behavioral alterations or mortality at surface water concentrations as low as 0.022/zg/L for fenvalerate and 0.03/zg/L for permethtin. He discovered that snails' accumulated fenvalerate ranged from 177 to 1286 times higher than their water content. In addition to accumulating, certain currently used pesticides can be just as harmful as or even more toxic than prohibited organochlorines. The acute toxicity (LCso) of parathion and matathion is comparable. DDT [1,1,1-trichloro-2,2-bis(p-chlorophenyl)-ethane] is a cladoceran belonging to the genera Daphnia and Simocephalas (Sanders and Cope, 1966). Herbicides have received less environmental research attention than insecticides because of their lower acute toxicity to animals. Although off-site problems from herbicides have rarely been documented in aquatic systems, residues of several frequently used herbicides are common in agricultural drainages. Baker and Richards (1989) found atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine], alachlor [2-chloro-2',6'-diethyl-N-(methoxymethyl)acetanilide], and metolachlor [2-chloroN-(2-ethyl-6-methylphenyl)-N-(2-methoxy- 1-methylethyl) acetamide] routinely during a 4-yr study of a corn (Zea mays L.) and soybean [Glycine max (L.) Merr.] producing area, but they found no incidences of adverse effects from herbicides on aquatic animal communities or human health.

Long-term toxicity It is challenging to identify the impact of low pesticide doses on aquatic ecosystems. Certain herbicides are harmful to phytoplankton, which lowers primary production. When large amounts of organic matter from dead plants consume the available oxygen, others have indirect consequences. When aquatic macrophyte communities are destroyed by aquatic herbicides, the habitat shift causes significant changes in the structure of the communities. Metals, notably As and Hg, were the first contemporary insecticides. Paris green, a vivid pigment containing 40% As, was the first widely used arsenical pesticide (McEwen and Stephenson, 1979). In 1865, it was initially applied against the Colorado potato beetle (*Lepinotarsa decemlineata*). Before 1900, lead arsenate took its place since it was extremely harmful to both plants and animals. Mercury has long been utilized as a fungicide and seed treatment. Metals do not break down like synthetic pesticides do; they may oxidize or form bonds in chemical processes, but they never vanish. As is still used in trace amounts, and mercury was utilized until 1985. Although both normally occur in small amounts, elevated quantities in stream and lake sediments in agricultural areas are concerning for the ecosystem.

Solutions:

Priorities for agricultural water quality must include downstream issues as well as surface water pollution input issues. Agriculturally driven surface water issues may be resolved mostly by good land use policies and best management techniques. According to land use policy, land should only be utilized to sustain agricultural output in an unabused manner.

The best way to avoid sediment-related pollution is to use a number of strategies that either stop erosion or capture sediment. These include of contour farming, grassed streams, terraces, filter strips, riparian zones, cover crops, different levels of conservation tillage, and basins for water and sediment control. Winter cover crops were assessed for cotton (*Gossypium hirsutum* L.) land by Mutchler and McDowell (1990). They discovered that when winter cover crops were grown, runoff decreased from 48 to 26 percent of total runoff and yearly soil loss decreased from 74 t/ha-yr to 20 t/ha-yr.

Stream channel stabilization projects can also be utilized to restore habitat that has been destroyed or deteriorated. Cooper and Knight (1987) discovered that grade control structures benefited stream ecosystems in unstable streams by creating high-quality habitat. The structures provided a sustaining ecosystem of food organisms and essential reproductive habitat. Several rock placement arrangements utilized for stream training and stability were assessed by Knight and Cooper (1990). According to their findings, transverse stone dikes or groins improved habitat in unstable streams, resulting in treated stream reaches that were similar to natural reaches in terms of fish weight and population size. Scour holes associated with transverse dikes did not effect fish productivity directly, but supplied more regions capable of supporting more fish and larger fish as well as related food communities. Many of the management measures that minimize sediment loads help reduce nutrients. Dairy farming methods were assessed by Schofield et al. (1990) to determine which had the most effects on water quality. They found that the biggest decline in downstream water quality was caused by washing in the dairy yard and parlor. Waste from enclosed livestock activities, such as milking parlor washoff, can be filtered and processed by constructed wetlands, a fast expanding technology. In their first season of operation, three built wetland cells at a dairy farm eliminated 91% of ammonia, 62% of total organic P, and 76% of BOD when paired to an anaerobic lagoon.

Economic realities restrict the adoption of instream and reservoir approaches to reduce nutrient effects. Fortunately, fertilizer consequences are mitigated when supplies are limited, and natural processes including plankton absorption and sediment adsorption lower surface water nutrient levels. As pollutants, pesticides and organic wastes are similar to nutrients in that there is nothing that can be done to mitigate their effects after they have entered aquatic systems. On-site decomposition of organic wastes requires management techniques including soil insertion for enrichment and built wetlands. Metals used in pesticide formulations will be in the environment for some time to come, even if certain pesticides break down quickly. As stewards of our natural resources, this compels us to utilize agricultural chemicals carefully, according to all safety precautions, and to keep looking for novel ways to apply and degrade them.

The two biggest issues when assessing typical agricultural pollutants and their effects on aquatic systems are habitat change or destruction and hazardous contamination outcomes. In the same way, we can advance the restoration of aquatic systems or the avoidance of further pollution in these two regions. Our goals must include watershed management in addition to stream and lake supervision if we are to effectively safeguard downstream water resources and their biota.

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