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A Comprehensive Review on the Impact of Aquatic Pollution on Fish

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Abstract

Freshwater is one of the most important natural resources that are used for various activities in our daily lives. Here, 70% of our Nation's liquid freshwater is unfit for consumption. Effect of heavy metals on hydrophobicity provides general information about the distribution of heavy metals in the atmosphere from different sources around the world, such as atmospheric precipitation, river and lake sediments. Human activities such as chemicals are increasing day by day, resulting in an increase in pollution. This review investigates the present state of scientific advancements in addressing the extensive range of pollutants, highlights the influence of enduring organic pollutants on water bodies global, caused by mining activities and hazardous waste sites. Water pollution has a negative impact on all the living creatures on earth. Water pollution not only hinders fish growth, reduces fish quality, but also affects its edible value and also causes reduction in the proportion of fish due to water pollution. The consequences on the aquatic life due to water pollution in different fish species showed alterations in histopathology, physiological damages, migration, embryonic and developmental modifications. The impact of pollution on fish is a complex and multifaceted issue with far-reaching ecological, economic and social consequences. Effective pollution control measures, sustainable resource management and global cooperation are essential to mitigate these effects and ensure the health and resilience of aquatic ecosystems. To raise public understanding of the significance of clean water and its direct relationship to fish health, it is necessary to educate communities on proper trash disposal, the effects of pollution on local ecosystems and the role that citizens may play in maintaining water quality. Global food security is largely dependent on the rapidly expanding industries of aquaculture and fishing. Furthermore, histopathological investigations also play a great role to confirm the damage in fish gill, liver, intestine, kidney and brain which can also be utilized as histological indicators, thereby damage to the lamellae as a result of fusion or excessive mucus production, which slows down the intake of oxygen has been evident. This is because additional factors, like high ammonia content in the water may also have an impact on the gill's histopathology and likewise in other organs such as liver and kidney also alterations are seen. Therefore, to conserve and protect aquatic life from the pollution, furthermore some additional effective measures should be implemented.

Keywords: Aquatic pollution, heavy metals, histopathology, fish quality, edible value

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INTRODUCTION

Water is considered as the essence of life, as its resources have been extensively exploited by humankind since their existence on earth. It is undeniable truth water is vital necessity for all living organisms and fortunately, it is abundantly present on our planet [1]. The demand for water was increased by 6 times between 1900 and 1995, surpassing the rate of population growth which doubled during the same period [2], a report highlighted the importance of addressing global environmental concerns, starting with the UN conference held in Stockholm in June 1972 which was projected towards human environment. The concept like environment, carrying end capacity of earth has become the central theme of policy making round the globe [3]. Despite the fact that the exact rule governing the effects of pollution on fish health is still up for debate [4]. There is solid evidence that certain fish species, particularly those found in the North Sea and Great Lakes, have suffered long-term health effects from exposure to pollutants [5]. It plays a role in recycling the nutrients and great natural resources used for drinking water and other development purpose [6]. Nowadays, water pollution also known to affect the lifestyle of human creatures and animals. Most probably a freshwater environment includes the chemical composition of the water as well as the physical characteristics of rivers, fish, farms and lakes [7]. Though, heavy metals are a natural component of the aquatic environment, domestic industrial mining and agriculture operations that have led to a rise in their levels [8]. So that, fishes are primarily affected by human reasons and it will take time to pay proper attention to this issue and implement the necessary corrective measures formulated in 1992 [9]. Fish also die due to water pollution and cultivated land pollution caused by pesticides. The impact of environmental pollution on fish parasites varies according on the specific parasite and the pollutants that interact with it. Pollution can directly influence fish immune systems or can alter the quality of the water which can lower fish immunity to parasites [10]. Additionally, water pollution might hasten the external parasite's life cycle and encourage its spread [11]. Alterations in vital organs such as gills, kidney and liver might distress the physiology, rate of survival, osmoregulation, buoyancy and reproduction process etc. in fish (Khoshnood, 2017) leading to resources concentration and population failure change point [12].

SOURCES OF WATER POLLUTION

Water pollution mostly comes from a variety of sources such as direct source and indirect source. Both the sources are recognized as pollution when all pollutants enter a body of water from a single source, easily identifiable sources that serve as the final influent discharge point for various industrial facilities [13] (Figure 1).

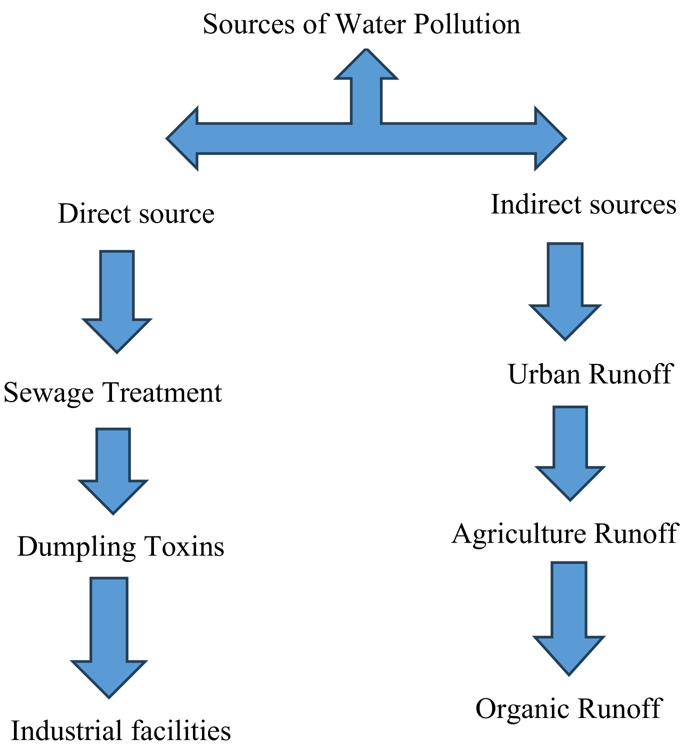

Figure 1. Sources of water pollution.

Table 1. Inorganic and organic pollutants from different industries. Adopted from D.S. Malik *et al*. (2020) [14].

Industry	Inorganic pollutants	Organic pollutants
Mining Industry	Chlorides, ferrous sulphate, hydrogen sulphate, ferric hydroxide, suspended solids and heavy metals.	-
Steel/iron Industry	Suspended solids, iron cyanide, sulphides, oxides, of copper, chromium, cadmium, and mercury.	Oil, phenol, naptha
Chemical Industry	Sulphates, nitrates, phosphorus, fluorine, silica and suspended particles.	Aromatic compound solvents organic acids, nitro compound dyes etc.
Pharma Industry	-	Proteins, Carbohydrates, organic solvents, intermediate products, drugs and antibiotics.
Detergent Industry	Tertiary ammonia compounds, alkalies.	Fats and Fatty acids, glycerols, polyphosphates sulphonated hydrocarbons.
Paper Industry	Sulphide, bleaching liquors.	Cellulose, fibers, bark, wood, sugars and organic acids.

PHYSICAL FACTORS ALTERING FISH TOXICITY

Temperature

It rises during thermal pollution, which occurs when water is used to cool power plants and absorbs waste heat from industries, this phenomenon also affects the rate at which certain substances become toxic at low temperature and can ionize certain substances such as ammonia and dissolve oxygen, which can lead to pathological changes in gills [15].

pH

Acid water from acid rain and from the burning of coal changes the pH of water bodies, the last acid and organic amounts of mines and many industrial processes such as waste generated from DDT factory, from battery etc. [16].

Dissolved Oxygen

Discharge oxygen content in dissolved form in a liter of water is called as dissolved oxygen. It is crucial for sewage treatment. Additionally, the presence of solar radiation stimulates photosynthesis in aquatic plants which increases the production of oxygen as these plants have chloroplasts [17].

Heavy Metals

Heavy metals are present in a variety of industrial effluents. They are absorbed by hydrophytes [18]. Some common heavy metals are As (arsenic), Cr (chromium), Cd (cadmium), Hg (mercury), Tl (Thallium) and Pb (lead). There are some trace elements which include Zn (Zinc), Se (Selenium), Cu (copper). These elements are necessary for the healthy metabolism, but their concentration rises, so they may also become toxic [19]. In microbial fish diseases, debilitating effects of copper in concentration and duration of exposure have been extensively studied with regard to the increasing susceptibility to vibriosis (vibrio anguillarum; Rodsaether et al., 1977) and infection by *Edwardsiella tarda* [20,21]. Due to copper exposure, coagulation in mucus layer of gills which transport oxygen and cause respiratory stress [21] or reduced number of lymphocytes and granulocytes in the blood was observed and that led to reduce phagocytosis [22].

Color and Turbidity

The variations in the type of pigment and turbidity of the water and the color of the water are also altered [23]. In terms of relevance, SPM suspended particulate materials present in water influences water turbidity. Mitchell and Furnas [23] created a river logger apparatus to measure aquatic SPM [24].

ADVERSE EFFECT OF POLLUTION ON AQUATIC LIFE

With the exposure to lower quantities of pollutants may result in chronic damage whose effects may not become apparent for a relatively long time, but exposure to high concentrations of pollutants may quickly cause a clear correlation between pollution and mortality in aquatic animals [25]. Due to pollution sometimes, animals may become weaker or immunosuppressed [26,27]. A pair of global conferences with the goal of assessing their worldwide presence and lowering their environmental emissions, the Aarhas Protocol and the Stock Lo Ham Convocation have named and discussed a number of well-known classical pop artists, sometimes known as legacy pop artists, or the "dirty dozen." Extremely chloromethane compounds, such as DDT, dichlorodiphenyltrichloroethane, polychlorinated dioxins, dibenzofurans and polycyclic aromatic hydrocarbons (PAHs), possesses different negative effects, such as endocrine, immunological system, reproductive system, their potential to lead to behavioral issues, thyroid issues, diabetes, and cancer are all potential health risks to people and wildlife [28]. As a bacterial indication of water pollution, disease-causing microbes classified as pathogens can induce water-borne diseases in human or animal hosts. Political surfaces frequently include coliform bacteria, which are widely utilized but not the real cause of disease. Other microorganisms that have been linked to human health issues *Salmonella*, *Norovirus, Giardia lamblia, Burkholderia pseudomallei, Cryptosporidium parvam,* and other viruses, parasitic worms, and *Schistosoma* type are among the microorganisms found in water [28]. According to Javed and Usmani [29], the emergence of industrialization and globalization has increased waste in commercial organizations by which water quality was directly influenced. Increased pollution has already degraded river water and groundwater has begun to suffer as a result. Furthermore, increased trash has increased heavy metals in water bodies, affecting the health and survival of fish that live in these bodies [30].

EFFECT OF POLLUTION ON SURVIVAL AND BEHAVIOUR OF SPECIES

High concentrations of suspended water pollutants can disrupt fish populations, causing species like perch and brown trout to exhibit strong avoidance responses. Turbid water environments may cause obstructions, damage to gill apertures and decreased immunity to infections and parasites [31]. Pollutants effect on a given fish population, influences the adult organisms in several ways, in spite of not causing any lethal effect in fish [32]. which are;

- Nutrition and food chain
- Physiological progression
- Migration
- Genetic effects
- Alteration in morphology
- Life cycle
- Incidence of diseases

Behaviour of Fish Specie

A large portion of a species behavior in the modern day can also be mediated by camouflage-toxic responses. For example, gathering food and searching for a during the bleeding season are considered activities, Additionally, pollutants that interfere with an organisms camouflage receptor can disrupt behavioral patterns that are crucial to the population survival [33]. Pollutants affect aquatic organisms behavior both directly and indirectly [34,35] especially in fish species [36, 37]. Both inorganic and organic pollutants have an impact on a variety of behavior, including feeding, socializing, aggression (Table 1) [38]. Some pollutants can also change the levels of neurotransmitters and hormones, which can affect fish species colonies and behaviors [39]. A variety of unique behaviors are exhibited by aquatic organisms that spend the most of their lives in metal-polluted environments, with high blood (lead and cadmium) concentrations. Due to the expenses of detoxification and the stress response, additional behavioral alterations may be indirectly caused by shifts in the energy balance [40].

Due to the expenses of stress response, additional behavioral alterations may be indirectly caused by shifts in the energy balance [41,42]. For instance, goldfish *Carassius auratus* showed reduced activity in response to modest doses of pesticides, most likely as a result of higher detoxifying and physiological defense costs. To completely comprehend the neurological and physiological bases of pollution driven changes in behavior and cognition, more research is necessary [43.44,45]. Potential link between pollution, behavior and cognition, and proposed research perspectives depicts in the (Figure 2).

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HISTOPATHOLOGICAL CHANGES IN SENSORY ORGANS OF FISH

According to the structural changes occur in histopathology due to any alterations, the changes can indicate the existence of different diseases and the impact of harmful chemicals, the liver of *Tilapia nilotica* raised in heavy metal polluted water had a variety of histopathological abnormalities, including alterations in the vacuolar and hydropic variations, and noticeable coagulative necrosis [50]. Further in-depth research by clarifying the ways in which mercury pollution can harm fish organs, including alterations in the histology of the fish tissues. The research conducted by the protective mechanism against pollutants in fish exposed to mercury was the lamellar fusion that occurred in their gills tissues damage [51]. In addition, fish exposed prolonged mercury exposure on regular bases which typically have a greater death rate as a result of damage to their gills epithelium [52].

IMPACT OF POLLUTION ON VARIOUS TISSUES OF FISH

Nervous System

There is a correlation between behavioral states and brain neurotransmitter levels and enzyme function [53, 54, 55]. Höglund *et al* [56] suggested that behavioral alterations are probably the consequence of neurologic damage brought on by exposure to toxicants. Brain acetylcholinesterase (AChE) activity is often measured indirectly using brain acetylcholinesterase (ChE) activity, which is one of the most often seen markers of altered neuronal function. AChE, which is found on post-synaptic membranes, is in charge of cholinergic neuronal transmission termination by breaking down the neurotransmitter acetylcholine [56]. Some of the Brain and sense organs of a fish tissue are depicted in Figure 3 & Table 2.

Gills

The gill system is an intricate organ that performs various functions such as gas exchange [58] and osmoregulation, that is the regulation of acid-base balance, excretion of nitrogenous waste and detoxification [59]. Additionally, it provides a pathway for fish contaminated water with inorganic mercury, which can alter water quality in extremely sensitive ways [60]. Gill lesion patterns can be categorized according to their location, changes in blood vessels, mucous/chloride changes and terminal stages [61].

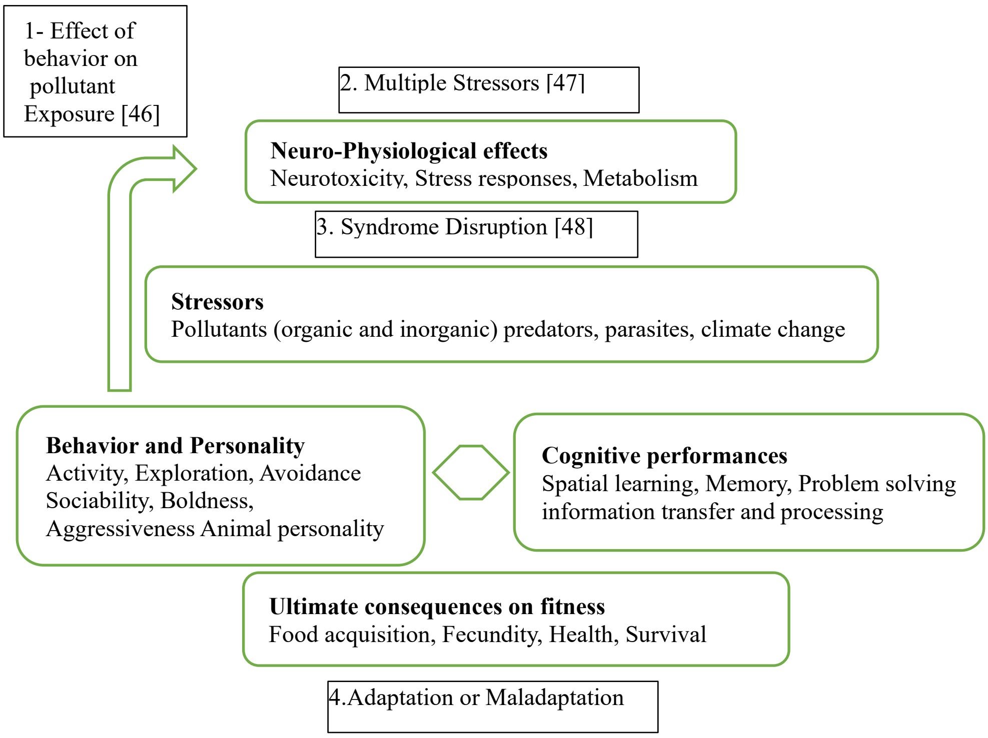

Figure 2. Potential link between pollution, behavior and cognition, and proposed research perspectives. (Adopted from Jacquin *et al* [49].

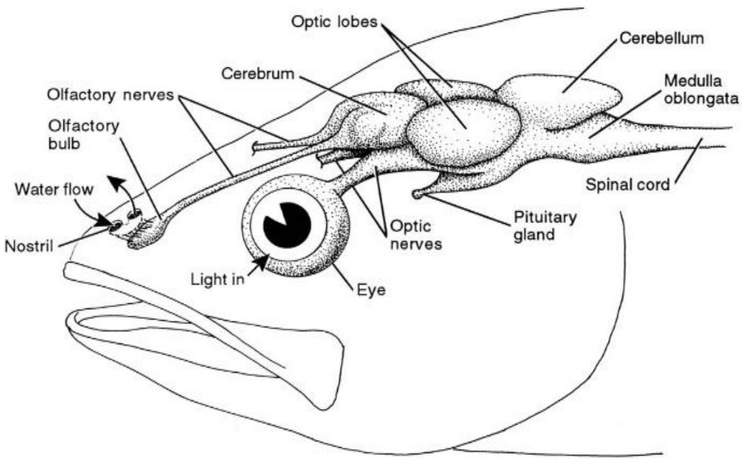

Figure 3: Brain and sense organs of a fish Image adopted from Living Ocean, CRDG, University of Hawaii at Manoa [57]

Liver

The liver is crucial for both the storage of glucose in all fish species and for digesting activity during filtration. Since the livers primary job is to remove any harmful substances from the blood [62]. Tayel *et al* [63] noted that the liver also produces bile, which is subsequently stored in the gallbladder. As a result, the liver of a fish is a useful indicator of aquatic pollution [63]. Fish in contaminated environments had a greater frequency of lymphocystis and liver damage leading to hepatic neoplasia when compared to clean system fish, but there was no discernible difference in the development of epidermal disease. These findings indicated a health risk associated with long-term exposure to pollutants at levels comparable to those found in the aquatic environment. In a separate study, the polluted waters of Bhopal's lower lake were blamed for the occurrence of fibrous tumours in catfish *Heteropneustes fossils* [64].

Kidney

The kidneys are an essential component of the fish body, performing vital functions such as preserving homeostasis, eliminating waste from the bloodstream, selective reabsorption, volume preservation, and preserving the pH of blood and other fluids [65]. One of the first organs to be impacted by pollutants in the contaminated water, according to Thophon *et al.*, [66] investigation, was the kidney.

In 2006, Capkin [67] saw several necrotic spots strewn across the hematopoietic tissue and renal tubules of the rainbow drought. These spots were caused by changes in the water quality, such as elevated pH levels, temperature changes, hardness, and so on. Renal tubule formation is visible in these damaged kidneys.

Table 2. Effect of lesions on different vital organs of Fish due to mercury contamination. **(**Adopted from Zulkipli *et al* [72].

Organs	Effect on Fish
Gill	Respiratory lamellae undergo significant structural changes that reduce their capacity for gas exchange, resulting in reddish gills and breathing difficulties [68].
Liver	Severe stress as a component of the mortality event connected to the cold, malnutrition, and immediate symptoms of hypothermia [69].
Kidney	An increase in the rate at which the kidneys filter out toxins, build up mercury in the blood, and cause damage to cells [70].
Brain	Damage to the posterior region of the brain caused astrocytes to proliferate and Purkinje cells and pyramidal cells to disappear [71].

Reproduction

Numerous investigations discovered deviations in behaviour from the typical impact on reproduction, such as reductions in the number of viable eggs and intervals between reproductions because of the thermal and other effects of pollution on reproduction [73]. A substantial amount of empirical data on a wide range of taxa has backed life cycle theory, which contends that allocating resources to a particular reproductive bout should come at a cost to the organism's ability to survive, grow, or reproduce in succeeding bouts [74, 75, 76].

According to Partridge and Harvey [77], if this were not the case, animals could invest enormous sum of money on procreation forever. A case study with male bluegill sunfish is that when exposed to bigger broods in an experimental setting, they were trained to ventilate their eggs by spraying water over them more often [78]. Choudhury and colleagues (1982) reported decreasing GSI, water, and lipid contents of the ovary with increasing pesticide exposure [79]. Decreased ovarian phospholipids, inhibition of the conversion of esterified cholesterol to free cholesterol, suppression of testosterone, estradiol, and 17 a-hydroxyprogesterone in ovarian tissue and plasma [80] and enhanced reduction in ovarian hormones at higher pesticide doses, and impaired steroidogenesis by inhibiting gonadotropin secretion [81] are among the effects of pesticide exposure on ovarian tissue and plasma.

Fish Parasite

Parasites can reveal a variety of biological characteristics about their hosts, such as phylogeny, recruitment, migration, and feeding excellent direct indicators of the state of the environment's quality [82]. Specifically, by artificially recording the existence of intermediate, paratenic and definitive hosts, parasites with complex life cycles [83, 84,85,86]. The presence of parasitic infections in fish affected by aquatic pollution, the presence of poly chlorinated biphenyls, heavy metals, hydrocarbons, pesticides and sewage all have opposite effects on internal indefinitely on external parasites and on parasites themselves [87].

Control of parasites infections:

- Eliminate the root sources of pollution.
- Meticulous and strict hygiene.
- Applying particular counter dotes.
- The hazards of pollution on health were alerted by the outliers.
- General anti-pollution use of humic acid

Their culpability encompasses the following: direct livestock mortality, deceleration of growth rate and feed conversion ratios, incurred treatment expenses, and product rejection duringg processing [88]. Apart from causing direct losses, parasites can also significantly affect fish behaviour, fecundity, resistance to other stressors, susceptibility to infections, possible legal burdens, and fish marketability [89, 90].

CONCLUSIONS

Freshwater bodies including lakes, rivers, and wetland ecosystems provide habitat and food for a variety of organisms such as fish, algae, phytoplankton’s, zooplanktons, cyanobacteria, and birds. To avoid deterioration of freshwater quality, prevent human activities that have the possibility of introducing hazardous chemicals and environmental stresses into aquatic bodies. Heavy metal toxicity has harmed the health and quality of fish and eating them can harm the neurological system and harm delicate organisms. The consequences on the aquatic life due to water pollution showed alterations in histopathology, physiological damages, migration, embryonic and developmental modifications mainly in fish species. Several contaminants in the atmosphere, which are made up of numerous toxicant chemical compounds, are harmful to fish species. Since the HPC (the heterotrophic plate count) approach vastly underestimates the amount of heterotrophic microbial cells present in the water sample, the HPC was deleted from the WHO's most recent hygienic parameter lists. Furthermore, many parasite species require many types of vertebrate and invertebrate organisms acting as intermediate or definitive hosts to complete their life cycle; thus changes in the structure of a parasitic community reflect differences in the composition of aquatic species (i.e., macro invertebrate fauna) commonly used as indicators of water quality. These enormous benefits must be sustained by eliminating human activities that have the potential to release hazardous substances and environmental stressors into aquatic bodies in order to avoid deterioration of freshwater quality. Measures should be urged to prevent the contamination of drinking water and food, as well as adequate preparation of fish for human consumption. The impact of pollution on fish is a complex and multifaceted issue with far-reaching ecological, economic, and social consequences. Effective pollution control measures, sustainable resource management and global cooperation are essential to mitigate these effects and ensure the health and resilience of aquatic ecosystems. Future developments in the interplay of environmental, technical and socio-economic variables will probably influence some elements of the consequences of pollution on fish. To reduce the negative effects of pollution on fish and maintain the wellbeing of aquatic ecosystems for future generations, it is crucial to conduct on-going study, to keep an eye out for emerging trends and take preventative action. To carry out the effective programs for monitoring water quality, to identify patterns and possible problems early and evaluate the amounts of pollutants such as nutrients, heavy metals and contaminants on a regular basis. This makes it possible to take prompt action to safeguard fish health. To raise public understanding of the significance of clean water and its direct relationship to fish health it is necessary to educate communities on proper trash disposal, the effects of pollution on local ecosystems and the role that citizens may play in maintaining water quality. Global food security is largely dependent on the rapidly expanding industries of aquaculture and fishing. The average per capita consumption of animal protein, including fish, is predicted to rise meeting the food needs of an expanding population in the future. Regarding sustaining sustainability in production, aquaculture has recently faced grave concerns. As a result, to successfully address these issues, high-throughput advanced technologies like proteomics and genomics have been developed. To better understand disease/stress, physiology, developmental biology, and species recognition, fish biologists use proteomics.

Histopathological studies can be used to confirm whether the fish gill has already begun to exhibit damage to the lamellae as a result of fusion or excessive mucus production, which slows down the intake of oxygen. However, other internal organs including the brain, kidney, liver and intestine can also be utilized as histology indicators. This is because additional factors, like high ammonia content in the water may also have an impact on the gill's histopathology. Nonetheless, because the liver and kidney have higher concentrations of mercury than the other two internal organs, they are the most crucial organs to examine when assessing the impact of mercury contamination on tissue lesions. The nation's economy and health will continue to benefit greatly from the effective and sustainable management of its aquatic resources. The resources, production and performance of the fisheries are limited despite the vast opportunities and potential due to a number of factors, including climate change, the installation of onshore coal-based power plants, a lack of scientific knowledge, a shortage of skilled labor and the inadequate enforcement of laws and regulations pertaining to the fisheries development. Therefore, further studies are still required for the conservation of fish species and taking effective measures to eradicate or minimize aquatic pollution.

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