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Review Article

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Effects of Aquatic Pollution on Fish Health: A Review

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Abstract Water covers about 70% of earth surface and it is a valuable natural resource that is very vital for the existence of fishes and other aquatic organisms. In contrast to high water quality, contaminated water has adverse effects on fishes which include diseases, oxygen depletion, mutagenic defects, blockage in the digestive system, secretion of toxins and reduction of respiratory potential of fishes. There are many sources of water pollution causing threat to aquatic organisms, these include: oil spillage, agricultural, domestic and industrial waste. These pollutants affect the physico-chemical characteristic of water and its biological components. Thus, negatively affecting the quality and quantity of fish stocks. Chemical and biological indicators are used to screen the health of aquatic environment. Measures such as financial penalty, imprisonment to act as deterrent, enacting water discharge permit law may reduce perpetual deterioration of aquatic environment. To protect aquatic environment and fishes that are affordable and cheapest source of animal protein from pollution, water bodies should be freed from contaminations so that fishes and human who depend on them can remain healthy.

Keywords Aquatic environment, pollution, fish, health

Introduction

Water is not only one of the most valuable natural resources but also one of the vital resources required by living organisms. It is the most essential basic component of all living organisms, as most of the biochemical reactions that take place involve water. Without water no life is possible to exist on this planet and it is termed as 'Natural liquid Gold'. Water pollution occurs when undesirable substances are disposed into aquatic system leading to change in water quality. Human activities are majorly responsible for water pollution and this tends to affect the fish severely and proves lethal to them. The most important and vulnerable freshwater system is the river which plays a critical role in the sustenance of all life. Venkatesharaju *et al.* [1] reported that the decrease in freshwater quality threatens its sustainability and has become a global concern**.** Aquatic pollution is a global problem which is capable of giving rise to diseases, metal poisoning and even death of fishes. Pollutants find their ways into water bodies almost every day, of these, heavy metals are regarded as one of the most serious pollutants of aquatic environment because of their environmental persistence and tendency to accumulate in the tissues of aquatic organisms **[2]**. Inorganic pollutants mainly contain heavy metals as major component which is different in the case of organic pollutants [3]. Mercury is a known human toxicant and the first sources of mercury contamination in man are fishes. Biotransformation of mercury and methyl mercury formation constitutes a dangerous problem for human health [4]. The sources of water body contamination of heavy metals are majorly domestic, industrial and anthropogenic activities [5]. Aquatic pollution is a major worldwide problem which calls for evaluation and revision of water resource policy at all levels. Fish and marine mammals that are at the top of the aquatic food chain are exposed to higher levels of toxins either directly from the polluted water or by feeding on other fishes who are already exposed to high levels of toxins in water [6]. Ganguly *et al*., [7] reported that hot water effluent from factories and power plant raises the temperature of

water bodies thereby leading to the death of fishes and also marine life to migrate for relocation in other to search for water with more conducive thermal condition. According to Kivi [6] wastes generated from radioactive activities in industries and militaries enter the aquatic systems and are absorbed by fish and may cause genetic, mutagenic and teratogenic in fishes. Oil spills from industrial sources runoff into the water bodies which coat the skin of fish and kill them. High levels of certain pollutants, e.g. from oil spillages, may be directly responsible for deaths of large numbers of aquatic animals. It was observed by Ajoa *et al.*, [8] that crude oil and its refined products exert negative effects on eggs and young fingerlings of fishes. The use of hematological studies as noted by Omoregie [9] in fisheries is growing for toxicological research, environmental monitoring and fish health conditions. Water pollution has serious implications on the exploitation of fishes for food security in terms of animal protein source for the rural community. Hence the objectives of this article is to throw light on water resources on earth, pollution, aquatic pollution, sources of water pollution, types of water pollutants, freshwater pollution, marine water pollution, biomagnification in water body, bioaccumulation in fishes, method of water pollution diagnosis, relationship between polluted water and fish diseases, effects of water pollutants on fish health, and measures for controlling water pollution.

Water Resources on Earth

Water is essential for the existence of all life forms. In addition, to household uses, water is also vital for agriculture, industry, fishery and tourism etc. As it is known that about three fourths of our planet earth's surface is covered by water; however, very little of it is available for consumption. Most (about 97%) of the water on earth is present in the seas and oceans; in spite of this, it is too salty to be of any use for drinking, agriculture and industrial purposes. The remaining 3% is fresh water. 68.7% of freshwater is locked up in the polar ice caps and glacier while ground and surface water take 30.1% and 0.9% respectively. Lakes account for 87% of all surface water where fishes and other aquatic animals inhabit leaving 11% and 2% for swamps and rivers.

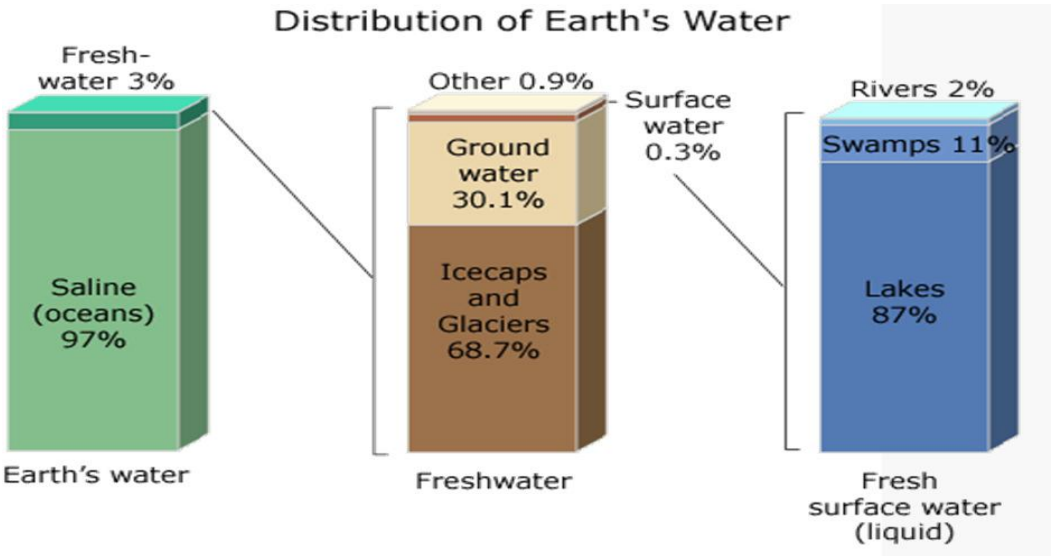

Figure 1: distribution of earth water [10]

The freshwater that can be used comes from two sources:

- Surface water
- Ground water

Surface Water: Rain and snow are good natural sources of freshwater. It is estimated that of all the precipitation (rain water and snow) that falls on the earth, about one-third is absorbed by the plants and another one-third seeps down into the soil and the remaining one third runs off the surface into streams and rivers. This part of precipitation, which runs off to form streams, rivers and lakes, is called the surface water. The small fraction of usable surface water is continuously replenished by means of the hydrological cycle. The hydrological cycle involves evaporation of water from oceans, rivers and other sources to form clouds. The

cloud on saturation with water vapour causes precipitation falling back on earth's surface. On surface, the water runs off to rivers and finally to oceans. The water again evaporates and the cycle continues.

Ground Water: The part of precipitation that seeps into the ground as a result of gravity and fills the pores between soil particles and rocks under it is called ground water. The water bearing layers of soil and rocks are called aquifers. Ground water is very important for agricultural and industrial purposes. Ground water in the form of wells and springs is often the only source of water supply especially in villages and small towns. In spite of a good number of water resources, we have shortage of usable water. This is due to increasing population, urbanization and industrialization. There is a need to optimize use of water and also conserve surface run off of water by means of rainwater harvesting, groundwater conservation, and making use of recycling methods etc.

Pollution

Pollution comes from Latin word **'***polluere***'** which means to contaminate. So, pollution is something that contaminates the environment. The term pollution generally refers to the alteration of the natural physico-chemical characteristics of an entity, medium or matter as a result of harmful substances present or that are present in quantities and qualities that would alter the natural balance of the particular entity, medium or matter. Pollution is one of the signs that human have exceeded their limits and our environment is in serious danger due to pollution whose damage is irreversible [11]. For this reason, awareness of the harms caused by several pollutants to the natural environment has led political and legislative authorities of the industrially developed countries to nail down regulations to protect the environment. We can classify pollution in terms of medium of occurrence, such as aquatic or water pollution (marine or freshwater pollution), air or atmospheric pollution and land or soil pollution. Furthermore, pollution can be classified in terms of the causative matter or compound, such as Chemical Pollution, Noise Pollution, Industrial pollution and Domestic Effluent Pollution. In this review, discussion will be centered on the aquatic pollution which is the topic of contention

Aquatic Pollution

The phrase **"**aquatic pollution**"**is also refered to as water pollution. Aquatic pollution can be defined as the contamination of streams, lakes, seas, underground water or oceans by substances, which are harmful to living organism. Water pollution is an important and essential issue in the world posing a grave threat to fishes which requires immediate evaluation and revision of water resource policy at all level. In almost all cases, the effects of water pollution is damaging not only to natural biological communities but also individual species and populations. Zaidi [12] stated that polluted water causes serious problems for human health as well as hampers ecological and environmental agents**.** According to UN WWAP [13] every day, 2 million tons of sewage, industrial and agricultural waste is discharged into the world's water, the equivalent of the weight of the entire human population of 6.8 billion people. WHO [14] mentioned that Worldwide infectious diseases such as waterborne diseases are the number one killer of children under five years old and more people die from polluted water annually than from all forms of violence, including war**.** Polluted water causes 4 billion cases of diarrhea each year, and results in 2.2 million deaths, mostly of children under five. This means that 15% of child deaths each year are attributable to diarrhea, a child dying every 15 seconds. In India alone, the single largest cause of ill health and death among children is diarrhea, which kills nearly half a million children each year [15]. In some regions, more than 50% of native freshwater fish species are at risk of extinction, and nearly one-third of the world's amphibians are at risk of extinction [16]. Water pollution is responsible for outbreak of diseases worldwide. In each year about 250 million people contract water borne diseases from drinking contaminated water. These diseases include cholera and typhoid fever along with others [17]. It was predicted by **(**"10 interesting water pollution facts", [17]**)** that in 2025, 3.5 billion population of the world will experience water shortages. This prediction was based on the fact that the world's population continues to increase, while land water declines as pollution levels continue to rise. According to(" water pollution fact and statistics", n. d.) , a string of lead poisoning cases in Zamfara state (Nigeria) between March to June 2010 led to the death of more than 163 people. Poisoning incidents occurred as a result of illegal extraction of ore by villagers, who were poisoned when they came into contact with heavy metals polluted water. Aquatic pollution is indeed a serious problem causing scores of death of not only fishes but also other aquatic animals.

Sources of Water Pollution

When pollutants enter a stream, river or lake it give rise to surface water pollution. The surface water pollution has a number of sources. These are categorized as:

- Point and Non-Point Sources
- Natural and Anthropogenic Sources

Point and Non-point Sources: The well-defined sources that emit pollutants or effluents directly into different water bodies are called **point sources**. Domestic and industrial wastes are examples of this type. The point sources of pollution can be effectively checked. On the other hand, **Non-point sources** of water pollution are scattered or spread over large areas. These types of sources deliver pollutants indirectly through environmental changes and account for majority of the contaminants in streams and lakes. For example, the contaminated water that runs off from agricultural farms, construction sites and abandoned mines enter streams and lakes, therefore it is quite difficult to control non-point sources.

Natural and Anthropogenic Sources: an increase in the concentration of naturally occurring substances is also termed pollution. The sources of such increase are called natural sources. Siltation (which includes soil, sand and mineral particles) is a typical example of natural source. It is common natural phenomenon, which occurs in most water bodies. Indiscriminate deforestation makes soil loose and flood waters bring silt from mountains into streams, rivers and lakes. On the other hand, the human activities that result into the pollution of water are called anthropogenic or man-made sources of water pollution**.** For example, domestic (sewage and waste water), industrial and agricultural wastes that goes into the rivers, lakes, streams and seas are anthropogenic sources. Certain materials that are leached from the land by Run-off water and enter the various water bodies also belong to this category.

Types of Water Pollutants

The biodiversity of freshwater is threaten by the availability of various kinds of pollutants (chemical, physical, radioactive and pathogens) from different sources (industrial effluents, agricultural run-off, domestic sewage, construction and mining activities) [18]. It causes a large number of diseases and deaths worldwide, mostly in Africa and Asia [19]. Physical pollutants (temperature change and large objects) cause visual water pollution e.g. plastic bags released into water bodies by human activities [19]. Pathogens are exuded from untreated sewage [20] and radioactive matters are released from nuclear power plants [21]. Water pollutants getting into water bodies are also caused by urban runoff containing toxins from land areas, impurities from street, dirt, debris, pesticides, and adulterant from vehicles [22]. In Africa, according to 1992 assessment, major causes of pollution are industrial effluents, mining, and feces exude from land. Whereas in Asia major causes are eutrophication, heavy metals, pathogens, sediments from deforestation and organic matter. While in Europe, eutrophication, nitrates, pathogens, organic matter, acidification and pesticides are major causes of water pollution [23]. There are many types of pollutants such as Oxygen demanding wastes; disease-causing agents; plant nutrients; organic chemicals; inorganic chemicals; sediments; radioactive substances and heat. In most situations, the waste treated is a mixture of the preceding types of pollutants, thus greatly complicating treatment and control procedures [24]. Water pollutants can be broadly put under the following types:

- Sewage Pollutants (Domestic and Municipal Waste)
- Industrial Pollutants
- Agricultural Pollutants
- Physical pollutants (Radioactive and Thermal Pollutants)

Sewage pollutants (Domestic and municipal): The sewage contains garbage, soaps, detergents, waste food and human excreta and is the single largest sources of water Pollution. Pathogenic (disease causing) microorganisms (bacteria, fungi, protozoa, algae) enter the water system through sewage making it polluted. Typhoid, cholera, gastroenteritis and dysentery are commonly caused by drinking infected water. Water Polluted by sewage contains disease causing organisms which make aquatic environment unfit for habitations by fishes. It may carry certain other bacteria and viruses that cannot grow by themselves, but reproduce in the cells of host organisms. They are responsible for deoxygenation of water-bodies which is harmful for aquatic life.

Industrial Pollutants: Many industries are located near rivers or fresh water streams. These are responsible for discharging their untreated effluents into rivers like highly toxic heavy metals such as chromium, arsenic, lead, mercury, etc. along with hazardous organic and inorganic wastes (e.g., acids, alkalines, cyanides, chlorides, etc.). River Ganges in India receives wastes from textile, sugar, paper and pulp mills, tanneries, rubber and pesticide industries. Most of these pollutants are resistant to breakdown by microorganisms (called non-biodegradable), therefore harming fishes and other aquatic lives. Factories manufacturing plastic, caustic soda and some fungicides and pesticides release mercury (a heavy metal) along with other effluents in nearby water bodies. Mercury enters the food chain through bacteria, algae, fish and finally into the human body.

Agricultural Wastes: Manure, fertilizers, pesticides, and wastes from farms, slaughterhouses, poultry farms, salts and silt are drained into water bodies as run-off from agricultural lands. The water body receiving large quantities of fertilizers containing phosphates and nitrates or manures becomes rich in nutrients which lead to eutrophication and consequent depletion of dissolved oxygen for fishes. Consumption of water rich in nitrates is bad for human health especially for small children.

Physical Pollutants: Physical pollutants can be of different types. Some of them are discussed below:

Radioactive Wastes: Radionucleides found in water are radium and potassium-40.These isotopes originate from natural sources due to leaching from minerals. Water bodies are also polluted by accidental leakage of waste material from uranium and thorium mines, nuclear power plants and industries, research laboratories and hospitals which use radioisotopes. Radioactive materials enter fish body through water and food, and may be accumulated in blood and certain vital organs.

Thermal Wastes: Various industries, nuclear power plants and thermal plants require water for cooling and the resultant hot water is often discharged into rivers or lakes. This results in thermal pollution and lead to the imbalance in the ecology of the water body. Higher temperature lowers the dissolved oxygen level (which is very essential for fishes) by decreasing the solubility of oxygen in water. Fish and other aquatic organism can get affected by a sudden change in water temperatures.

Sediments: Soil particles carried to streams, lakes or oceans form the sediments. The sediments become pollutants due to their large amount. Soil carried by flood water from farm land, is responsible for sedimentation. The sediments may damage the water body by introducing a large amount of nutrient matter.

Petroleum Products: Petroleum products are widely used for fuel, lubrication, plastics manufacturing, etc. and happen to be poisonous in nature. Crude oil and other related products generally get into water by accidental spillage from ships, tankers, pipelines etc. Oil slick which floats on the water surface causes death of fishes and severely affects the ecosystem of the water body.

Biomagnification in water body

Biomagnification stands for Biological magnification which means the increase of contaminated substances or toxic chemicals that take place in food chains. These substances often arise from contaminated environment. The contaminants include heavy metals namely mercury, arsenic, pesticides such as DDT which are then taken up by organisms because of the food they consume. When organisms in the higher food chain consume the organisms containing the toxins below their trophic levels, the toxin gradually become concentrated in the higher food chain. Because this is a repetitive process in the ecosystem, the higher organisms are the ones that will accumulate most of the toxins. Below is an explanation showing the process of biomagnification.

Release of toxic chemicals and pollutants into water body: The process begins with the release of toxic chemicals and pollutants into the water body, the toxic chemicals seem to be very low when released in the water body.

Phytoplankton: Phytoplankton refers to small plants that float in the water bodies that normally absorbed toxins. Once absorbed, the toxins stay in their tissues without being excreted or broken down. With time, the toxins accumulate to high concentrations up to 200 parts a trillion which represents a toxin accumulation increase by about four fold.

Zooplankton: Zooplanktons refer to small animals that float in the water bodies. They consume the phytoplankton and thus take in the toxins. The toxins stay locked in the organism's tissue without being

excreted or broken down. Over time the toxin concentration increases up to two parts per billion which represent about ten-fold increase over previous concentration.

Small fish consume the zooplankton: Whenever the small fishes feed on the zooplankton, they consequently take up the toxins which get absorbed in their fatty tissues. As a result, accumulation occurs and the concentration builds up to 20 parts per billion which is another ten-fold increase.

Large fish graze on the smaller fish: Again, when the large fishes graze on the smaller fishes for food, they consume the toxins that accumulate in their fatty tissues. The concentrations become higher up to ranges of 80 to 100 parts per billion. This is about four to five fold increase in the toxic levels.

The top food chain organisms consume the fish: The organisms at the top of the food chain gradually build up the toxins in their tissues such as their liver when they consume the large fish. The levels of the concentrations here increase to the highest ranges of 10000 to 15000 parts per billion. The result affects the animals' fertility and makes them vulnerable to diseases as they interfere with the normal functions of vital organs.

Bioaccumulation in Fish

The term bioaccumulation is defined as uptake, storage, and accumulation of organic and inorganic contaminants by organisms from their environment. Fishes are major part of the human diet due to high protein content, low saturated fat and sufficient omega fatty acids which are known to support good health therefore, various studies have been carried outs worldwide on the contamination of different fish species by heavy metals. For fish, the bioaccumulation process includes two routes of uptake: aqueous uptake of water-borne chemicals and dietary uptake by ingestion of contaminated food particles. Accumulation of heavy metals in fishes leads to biomagnifications. Bioaccumulation is the gradual build up over time of a chemical in a living organism. This occurs either because the chemical is taken up faster than it can be used or because the chemical cannot be broken down for use by the organism (that is, the chemical cannot be metabolized). Chemical pollutant that bioaccumulates comes from many sources. Pesticides are an example of a contaminants that bioaccumulate in organisms. Rain can wash freshly sprayed pesticides into creeks, where they will eventually make their way to rivers, estuaries, and the ocean. Once a toxic pollutant is in the water or soil, it can easily enter the food chain. For example, in the water, pollutants adsorb or stick to small particles, including a tiny living organism called phytoplankton. Because there is so little pollutant stuck to each phytoplankton, the pollutant does not cause much damage at this level of the food web. However, a small animal such as a zooplankton might then consume the particle. One zooplankton that has eaten ten phytoplankton would have ten times the pollutant level as the phytoplankton. As the zooplankton may be slow to metabolize or excrete the pollutant, the pollutant may build up or bioaccumulate within the organism. A small fish might then eat ten zooplankton. The fish would have 100 times the level of toxic pollutant as the phytoplankton.

Bioaccumulation versus Biomagnification

- Bioaccumulation is increasing the concentration of a substance in one organism whereas biomagnification is increasing the level as you go up in a food chain.
- Bioaccumulation occurs within a tropic level and biomagnification occurs between tropic levels.

Method of Water Pollution Diagnosis

Some forms of water pollution are obvious while some are less obvious and much harder to detect. There are two main ways of measuring the quality of water:

- Chemical indicator
- Biological indicator

Chemical indicator: in this method one is to take samples of water and measure the concentrations of different chemicals that it contains. If the chemicals are dangerous or the concentrations are high, the water is regarded as polluted.

Biological indicator: Bioindicators are living organisms such as plants, planktons, animals, and microbes, which are utilized to screen the health of the natural ecosystem in the environment. Each organic entity inside a

biological system provides an indication regarding the health of its surroundings such as plankton responding rapidly to changes taking place in the surrounding environment and serving as an important biomarker for assessing the quality of water as well as an indicator of water pollution. The presence of variant organisms in an aquatic environment implies the water body is devoid of pollution. For instance, in many water bodies, such as, seas, lakes, streams, and swamps, significant biological production is carried out by plankton. Planktons are composed of organisms with chlorophyll (i.e. phytoplankton and animals such as zooplanktons). These planktons consist of communities that float along currents and tides, yet they fuse and cycle important quantities of energy that is then passed on to higher trophic level. The changes that occur within the communities of planktons provide the platform to determine the trophic state of water bodies. Since planktons are profoundly sensitive to natural change they are best markers of water quality and particularly lake conditions. One of the reasons planktons are being considered in lakes is to monitor the water quality of the lake when there are high centralizations of phosphorus and nitrogen; these centralizations may be indicated by certain planktons reproducing at an increased rate. This is evidence of poor water quality that may influence other organisms living in the water body. In addition to being a health indicator, planktons are also the fundamental sustenance for many larger organisms in the lake. Thus the plankton is key to the aquatic organisms, as both an indicator of water quality and as the main food source for many fish.

Relationship between Polluted water and fish diseases

Pollution of aquatic environment has an influence on the prevalence and intensity of fish infection or infestation caused by bacteria, fungi and parasite. Pollutants in water bodies can either affect fish directly or affect its associated defense mechanisms. When a water body is polluted and there is disease outbreak, there often is a strong relationship between this disease and high parasite prevalence. However, it should be stressed that not every outbreak of fish disease is caused by pollution. Other factors, such as overcrowding or the increase in the number of disease causing organisms may be the primary cause. Although, the severity of the disease get increased when the water body is contaminated with pollutants. Changes due to pollution in water bodies may decrease the ability of fishes to maintain an effective immunological response system leading to susceptibility to different diseases. It was reported by Zdenkich *et al.,* [25] that acute or chronic pollution of surface waters can cause a reduction in the level of unspecific immunity to diseased fish. For example, a significant decrease in the concentration of total proteins, globulins and lysozymes in the blood plasma of carp can occur after a long-term exposure to sublethal zinc concentrations. Also a decrease in the number of leucocytes and significant changes in their differential count are typical effects caused by a number of pollutants (e.g. phenols, metals, pesticides etc.) .A characteristic decrease in the percentage of lymphocytes and an associated increase in granulocytes can occur. Such a decrease in the number of small lymphocytes which are active in the increase and transfer of globulins is followed by a decrease in antibody production and thus a decrease in resistance to disease.
Below are the fish diseases having close relationship with polluted water.

Bacterial diseases

Some bacterial agents such as *Aeromonas punctata, Aeromonas salmonicida* inhabit the digestive tract of clinically healthy fish, with weakening in fish immune system due to pollutants in water bodies these bacterial agents can act as causative factors in the outbreak of a bacterial disease. Presence of organic pollutants in water brings about decrease in dissolved oxygen content which creates a favorable environment for bacterial growth ultimately leading to fish diseases. A direct relationship between the organic pollution of surface waters and outbreaks of *furunculosis* is well established, so that this disease may at times serve as a positive indicator of poor water quality.

Fungal diseases

A direct relationship between *branchiomycosis* and organic pollution of water is well known in fish culture practice. Usually, the disease is endemic in ponds and reservoirs; cyprinid fish species, whitefish, pike, and rainbow trout can be affected. The outbreak and duration of the disease depend on ambient environmental factors, the most important of which is water temperature. The disease occurs most frequently when the water

temperature is above 20°C (with an optimum of 26°C) and is accompanied by organic pollution and associated fluctuations in the dissolved oxygen concentrations. Mechanical (i.e. physical) and/or chemical damage of the protective mucus layer of the skin, fins and gills are prerequisites for the disease outbreak. Such damage is also a precondition for the secondary development of *saprolegnia*; fungal spores develop to form greyish-whitish woolly growths on the damaged surfaces, particularly in weakened fish.

Fish parasites

Khan and Thulin [26] stated that aquatic pollution can influence the pathogenic activity of ectoparasites and endoparasites living on the body surface or in internal organs of fish. The level of pathogenic activity of ecto- and endoparasites living on the body surface or in internal organs of fish, can be influenced by water pollution [26]. Contaminating substances such as pesticides may have a harmful effect on the parasites but fish weakened by parasite infestation may be more sensitive to the toxic effects of substances in the water. For a number of fish protozooses there is a conditional dependence on organic and other pollution of the aquatic environment; for example, such a reduction in water quality can be followed by a gill invasion with *Cryptobia branchialis*. Reduced pH values of the water (e.g. to 5–6), together with unsuitable breeding conditions, can contribute to an outbreak of *ichthyobodosis*. Poor hygienic conditions in ponds and reservoirs carry a potential danger for *myxosporeoses* outbreaks; low dissolved oxygen concentrations associated with low light conditions are favourable for *chilodonellosis*. Thermal pollution can lead to lethal outbreaks of *ichthyophthiriosis*. Domestic sewage discharged into surface waters can be a source of high populations of *trichodines*. Phenol and polychloropinen can cause fish to become more sensitive to *Ichthyophthirius multifiliis*.

Effects of Oil Spillage

Oils and refined products have been responsible for many of the recently recorded pollution incidents in surface waters. Between 1970 to 1990 these substances were responsible for the majority of water pollution accidents recorded on a worldwide basis [25]. The effects of oil spill on fishes are caused by either the physical nature of the oil (physical contamination and smothering) or by its chemical components. When oils are discharged to rivers or ponds they spread on the surface, thus reducing (especially in stagnant waters) the transfer of oxygen from the air to water Whenever oil spills, it spreads almost immediately and some of the components get dissolved in water while others may become oxidized or undergo bacterial degradation. In cases of pollution of flowing turbulent waters the oil does not form an intact layer on the water surface but becomes dispersed as droplets into the water. In such cases, the gills of fish can become mechanically contaminated and their respiratory capacity reduced. Oil products may contain various highly toxic substances, such as benzene, toluene and xylene which are to some extent soluble in water; these penetrate into the fish and can have a direct toxic effect. The presence of crude oil spillage inhibits oxygen penetration into the water where fishes live thus bringing about oxygen tension [27]. Oil spills from industrial sources runoff into the water sources which coat the skin of fish and kill them. Cruickilton and Duchrow [28] stated that oil spill serves as a source of toxins for fish and can cause disease, genetic defects/alterations and death and also damages the surface protective activity of skin which keeps the aquatic animals warm**.** There are also differences in the sensitivity to oils and refined products between different fish species. The fry of predatory fishes (especially pikeperch and trout) show the greatest sensitivity to refined products [25]. In general, oils and most of the refined products have a narcotic effect on fish; acute symptoms are effects on the nervous system and respiratory activity. The main clinical symptoms include an initial increased activity and respiratory rate followed by a loss of balance (the fish lie on their side), loss of response to stimuli, reduced activity, shallow respiratory movements, and ultimately death [25]. The gills show severe dystrophic effects and necrosis and there may also be a proliferation of the respiratory epithelial cells and hypertrophy of the mucus cells. Prolonged exposure to oils at low concentrations can cause severe degenerative necrobiotic effects in the kidneys of the fish and in their eggs [25].

Effects of Sewage and Agricultural Run-off

Disposal of untreated sewage as well as run-off from Agriculture into water bodies causes increase in eutrophication of surface water which in turn leads to massive development of phytoplankton. This bloom causes the water pH to rise to a level above 10.High pH in water bodies increases the concentration of un-

ionized form of ammonia (NH_3) and also has a significant influence on the toxic action of this form of ammonia on fish [25]. The un-ionized form (NH3) is potentially toxic to fish and other aquatic life at relatively low concentration [29]. The permeable un-ionized ammonia in the polluted water body diffuses freely across the gill epithelium to the blood and other tissues in response to the concentration gradient existing between blood ammonia and environmental ammonia [30]. It was mentioned by Zdenkich *et al.*, [25] that the first signs of ammonia toxicity include a slight restlessness, and increased respiration; the fish congregate close to the water surface. In later stages, cyprinids gasp for air, their restlessness increases with rapid movements and respiration becomes irregular; then follows a stage of intense activity. Finally, the fish react violently to outside stimuli; they lose their balance, leap out of the water, and their muscles twitch in spasms. Affected fish lie on their side and spasmodically open wide their mouths and gill opercula. Then follows a short period of apparent recovery. The fish return to normal swimming and appear slightly restless. This stage is then replaced by another period of high activity; the body surface becomes pale and the fish die. The skin of ammonia poisoned fish is light in colour, and covered with a thick or excessive layer of mucus. In some cases small haemorrhages occur, mainly at the base of the pectoral fins and in the anterior part of the ocular cavity. The gills are heavily congested and contain a considerable amount of mucus; fish exposed to high ammonia concentrations may have slight to severe bleeding of the gills. Intense mucus production can be observed on the inner side of the gill opercula, mainly at the p osterior end. The organs inside the body cavity are congested and parenchymatous, and show dystrophic changes. Also oxygen depletion resulting from phytoplankton bloom and sudden die-off of blue green algae leads to suffocation of fishes when the oxygen demand is below the optimum concentration. Furthermore, according to Claude [29] a few species of algae may be directly toxic to fishes and other aquatic animals. These algae include certain unicellular marine algae known as prymnesiophytes, and some blue-green algae, dinoflagellates, diatoms, and chloromonads. Toxic algae especially those that are responsible for the red tide phenomenon in marine waters can cause huge fish kills over wide areas. Algae and blue - green algae in particular, are known to produce compounds that can cause bad taste and odor in drinking water supplies. The two most common offensive compounds are geosmin and 2-methylisoborneol. These same compounds can be adsorbed by fish, shrimp, and other aquatic animals and impart a bad taste and odor to the flesh. Such products are deemed “off-flavor” and are of low acceptability in the market.

Effects of Plastic Wastes

The accumulation of plastic products in water bodies affects fishes adversely. Plastics that act as pollutants are categorized into macro-plastic, mega-plastic and micro-plastic. They enter the water body through litter, when waste such as plastic bags, packaging and other convenience materials are discarded. Plastics do not degrade easily and therefore remain in the same undegraded form in water bodies. Fishes mistakenly confuse plastics as food materials and ingest them which causes blockage in the digestive system and might lead to death. Plastic often causes fish to starve to death by getting stuck around their mouth making them unable to eat. Apart from plastic, metal, rope, nets and styrofoam are among other human made trash items which are disposed off in water bodies and harm aquatic life [31].

Effects of Thermal Pollution

Thermal pollution occurs when power plant and factories discharge hot water into water bodies causing rapidly changing water temperatures. Fishes are poikilothermic animals, that is, their body temperature is the same as the temperature of the water in which they live. Fishes have specific temperature needs for growth and are unable to survive sudden changes that can result in massive death of fishes. Also organic matter decomposes faster in warmer temperature depleting dissolved oxygen from water and increasing bacteria levels which consequently fishes adversely. This causes over-abundance of organic nutrients. Algal blooms occur choking fish gills and clouding the water and may die due to depletion of oxygen. Fish may be forced to migrate the area, relocating to a more suitable location giving rise to change in biodiversity. Fluctuations in water temperature from power plants and factories kill off coral and cause marine life to migrate for relocation in an attempt to find waters with a more sustainable thermal condition [7].

Effects of Radioactive Waste

Radioactive waste generated from industrial and military wastes enter the water bodies and are absorbed by fish and can cause genetic, mutagenic and teratogenic defects in them [6].

Measures for Controlling Water Pollution

- One of the strategies in controlling aquatic pollution is to enact water discharge permit law for the discharge of pollutants from point source into water bodies
- Limit should be set for the discharge of pollutants into water bodies to avoid degradation of aquatic ecosystem
- Prohibiting discharge is a possibility in some instances. But, this approach is rare, because many activities that cause water pollution are essential for society [29].
- Management practices that prevent run-off from Agricultural area into water bodies should be employed
- Municipal wastes resulting from domestic activities should undergo proper treatment prior to discharging into aquatic bodies
- Thermal effluents from power plants in industries and factories should not be directly discharged into water bodies
- Special legislation such as financial penalty, imprisonment to act as deterrent should be developed to prevent damage being caused to aquatic resources by the action of various chemicals, waste water and solid waste

Conclusion

The consequences of aquatic contamination on fish health and as well as human utilizing the polluted water directly or consuming contaminated fish for animal protein are immeasurable. Several researches have shown that water pollution is not only a strenuous threat to aquatic biodiversity inducing extinction of fishes but also degradation to aquatic ecosystem reducing the quality of water for human consumption. Hence, the choice is ours (human being), either we allow the water quality to decline by our activities and we continue living with contaminated water bodies and fishes that are the affordable and cheapest source of animal protein or we keep our water bodies free from pollution so that fishes and humans who depend on it can remain healthy.

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