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Pollution of Aquatic Ecosystem Due to Anthropogenic Activities: A Review

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ABSTRACT *With the rapid pace of development, there has been a rapid growth of pollution of aquatic environment, mostly form anthropogenic sources. Water pollution is now considered to be one of the most dangerous hazards affecting both developing and developed countries. The large scale dumping of hazardous substances in the water bodies have taken its toll of aquatic fauna. The present work is an attempt to review the existing literature on significant works being done on the effects of various anthropogenic activities on fish. In this review, the anthropogenic activities were classified as heavy metal/metalloid, oils and hydrocarbon, pesticides, combination of substances as industrial discharges and municipal or sewage discharges and discussed with emphasis on their effects in fish.*

KEYWORDS : Metals, Pesticides, Effluent, Fish

INTRODUCTION:

Pollution of aquatic environment has become a major cause of concern in the 21st century. With the rapid pace of development, there has been a rapid growth of pollution of aquatic environment, mostly form anthropogenic sources. Water pollution is now considered to be one of the most dangerous hazards affecting both developing and developed countries. The large-scale industrialization and production of variety of chemical compounds has led to global deterioration of the environmental quality. Major water bodies such as the Nile [1], Ganges [2] and Pearl [3], amongst others, were reported to be highly polluted. Even, apparently pristine water bodies and small water bodies such as lakes and ponds are highly polluted [4, 5]. The chief sources of aquatic pollution are either direct dumping of industrial effluents or spills or indirect, via leaching or runoff (pesticides). Barring a few natural means, most aquatic pollution is attributed to anthropogenic activities. Anthropogenic activities can be defined as the action of man which can be in the form of any compounds or substances that are released in any compartment of environment and thereby occur in concentrations higher than natural, leading to pollution. While, pollutants can be classified as heavy metal/metalloid, oils and hydrocarbon, pesticides, combination of substances as industrial discharges and municipal or sewage discharges. Several anthropogenic activities are listed as separate heads and their adverse effects to aquatic organisms were reviewed in this paper.

POLLUTION FROM HOUSEHOLD DISCHARGE/ DETERGENT CHEMICALS

Household discharges include a number of chemicals that are used in domestic purposes and are released regularly into municipal sewage system. These include detergents, napthalein, ammonia, chlorine, pharmaceuticals and pesticides. Linear alkyl benzene sulphonate (LAS) is a detergent chemical that is commonly released into water as detergent industry effluent or via domestic sewage. LAS altered the testis histology of fresh water fish, Heteropneustes fossilis with extensive cytotoxic damage, general inflammatory response, inter-tubular vacuoles, condensation of spermatogenic cells [6]; while, cationic detergent effected the gills and blood chemistry of rainbow trout Salmo gairdneri [7]. The intestine Catla catla showed oedema, atropy and mild lymphocyte infiltration due to of naphthalene [8] while, the exposure to a pharmaceutical mixture of acetaminophen, carbamazepine, gemfibrozil and venlafaxine and diluted wastewater effluent in zebrafish (Danio rerio) caused significant decreased in embryo production, kidney pathology, oocyte atresia and developmental abnormalities [9].

POLLUTION DUE TO PESTICIDES:

It was estimated that the world-wide deaths and chronic diseases due to pesticide poisoning number about 1 million per year [10]. Pesticides alone contribute a bulk of the water pollution. The major sources of environmental contamination by these chemicals are agricultural practices, usage in public health programmes and industrial discharges. Other than targeted pests, pesticides affect a wide range of non target organisms, such as invertebrates and fish inhabiting aquatic environment [11]. Pesticide induces a variety of responses in fish such as reproduction [11]. Effects of organophosphorous pesticide, malathion was studied on teleost fish Indian flying barb, Esomus danricus [12] and Glossogobius giuris [13]. G. giuris showed structural changes of the gill lamellae organization, epithelial detachment, necrosis, hyperplasia, loss of the microridges, altered morphology of pillar cells and mucous cell diameter at different sub lethal concentrations. E. danricus showed respiratory distress, histopathological alterations of gill, liver and intestine and changes in the chromatophore colouration from the scales [12, 14, 15, 16, 17]. The effects of malathion on hepato-renal and reproductive organs of Heteropneustes fossilis were most prominent [18]. The parenchymal architecture of the liver was disturbed and hepatocyte swelled, cytoplasm became granular and finally, dissociated and apoptotic. Blood capillary endothelium ruptured and blood was spilled into the liver tissues. The kidney lesions were characterized by degeneration in the epithelial cells of renal tubule, pycnotic nuclei in the hematopoietic tissue, dilation of glomerular capillaries, degeneration of glomerulus, intracytoplasmatic vacuoles in epithelial cells of renal tubules with hypertrophied cells and narrowing of the tubular lumen. In oocytes, cytoplasmic degeneration and increased number of atretic cells, along with the partial destruction of the ovigerous lamellae and vitellogenic membrane were observed. Organochlorine pesticide, endosulfan can change gill morphology, subsequently leading to disruption in oxygen consumption, are found to be early warnings for endosulfan stress in fish [19]. In E. danricus, endusulfan at chronic doses caused respiratory distress, histopathological alterations of gill, liver and intestine and change the chromatophore colouration from the fish scales [20, 21, 22, 23, 24]. Other pesticides such as dichlorvos [25], deltamethrin [26], chlorpyriphos [27] and lindane [28] also cause adverse health hazards to fish by targeting multiple targets in fish.

POLLUTIONS DUE TO HEAVY METALS/METALLOIDS:

Aquatic system may also be polluted by heavy metals/metalloids such as Cd, Cu, Pb, Zn, Hg, Cr, Se, As. The effects of heavy-metal contamination on freshwater fish include changes in their biochemical, physiological, and morphological characteristics. Cu, Zn, and Cd ions mainly enter the fish with food [29]. However, uptake from water also plays a considerable role, especially under conditions of deficiency of trace elements in food and their high concentrations in water [30]. Chronic toxicity of Cu and Cd induced changes in chromatophores of Indian flying barb, Esomus danricus [31, 32]. Cu was found to be a stressor even in very less, sublethal amounts. Pb toxicity in Puntius altus via histopathological analysis was also studied in detail [33]. Pb caused gill alterations, glomerulus atrophy and increase in the number of lymphocytes in parenchyma. Cloudy swelling, tubular narrowing and hyaline droplet were also found in renal tubule. The main lesions of liver were hepatocyte hypertrophy, nuclear pyknosis, cytoplasmic vacuolation and moderate melano-macrophages aggregation [33]. Toxicity of Hg to immune system of fish is well recognised [34]. Hg exposure in a wild fish species, largemouth bass (Micropterus salmoides) showed that Hg caused immune suppression in fish, which became susceptible to trematode infections [35]. In a study undertaken to assess the state of the gibel carp Carassius auratus gibelio in the Amur River Basin, several metal/metalloids such as Zn, Cu, Ni, Pb, Mn, Hg, As, were detected in the water as well as the fish tissues. Numerous histopathological changes, such as, vacuolisation, karyopyknosis, and necrosis of hepatocytes, necrotic changes, accumulations of pigments, nuclear polymorphism, hyperplasia of bile ducts, disturbances in blood circulation and inflammation were found. Fish gills showed hyperplasia, and gross abnormality of the reproductive system was detected in male carp. The study also confirmed that an unusual proportion of the sexes (gynogenesis) exist in carp from Amur River, with female fish dominating among the sample [36]. Channa punctatus exposed chronically to hexavalent Cr showed retarded growth and development of the ovary. The gonado-somatic index was lower and the growth of the ovigerous lamellae were stunted in chronic exposed group. The diameters of all the three stages of oocytes of the preparatory phase ovary, previtellogenic non-yolky stage I oocytes and vitellogenic oocytes of stage II, III were reduced which resulted in a less compact arrangement and necrosis. A lower percentage of vitellogenic oocytes were observed and such oocytes had disrupted yolk platelets. Disruption of ovarian stroma and increase in atretic oocytes was also pronounced. The Cr mediated toxic effects may disrupt vitellogenesis by directly acting on the liver. Hepatic damage, such as, localized degeneration, hepatocellular vacuolization and atrophy was well demonstrated histologically [37]. The tilapia, Oreochromis niloticus, exposed to dietary Pb resulted in the accumulation in tissues of the digestive system in the following order: intestine > stomach > liver. Livers of tilapia exposed to dietary lead presented an evident degeneration of hepatic tissue, irregularly arranged hepatocytes, cell hypertrophy, ambiguous cell outline, and obvious vacuolation in cytoplasm. Amylase activity decreased in stomach and trypsin activity in intestines decreased [38]. Thus, the long-term exposures to these heavy metal might pose a potential risk to fish populations in the vicinity of polluted waters.

POLLUTION DUE TO HYDROCARBON:

The effects of crude oil and its toxicity to larval marine fish, mummichog (Fundulus heteroclitus) was wel studied. Fish embryos exposed to complex mixtures of PAHs from petrogenic sources show a characteristic suite of abnormalities, including cardiac dysfunction, oedema, spinal curvature, and reduction in the size of the jaw and other craniofacial structures. Fish treated with other compounds such as dibenzothiophene, phenanthrene, or pyrene caused mortality. All PAH-exposed embryos showed delayed or failed inflation of the swim bladder. In embryos treated with the three-ring PAHs, dibenzothiophene and phenanthrene, the earliest observed defect was loss or reduction in circulation and the cardiac dysfunction [39].

POLLUTION DUE TO INDUSTRIAL EFFLUENT:

Industrial effluents are the discharges of industries that often contain multiples of potentially toxic chemicals in large concentrations. Often, these effluents are inadequately treated and released into the aquatic environments, where they tend to cause adverse effects on aquatic organisms. Black jaw tilapia, Sarothedon melanotheron, on exposure to industrial effluents, showed significant elevations in the values of blood glucose, WBC, MCH, neutrophils and monocytes, while the reverse was observed in PCV, Hb, RBC, MCHC, MCV, lymphocytes and thrombocytes with the increase in the level of effluents [40]. The African catfish, Clarias gariepinus, exposed to a metal finishing company effluent showed a dose–based reduction in haemaglobin, hapatocrit and red blood cell count [41]. The health effects in fish due to the long-term exposure to effluents from waste water treatment works was studied [42]. Exposure to wastewater treatment effluents containing estrogenic chemicals can disrupt the endocrine functioning of riverine fish and cause permanent alterations in the structure and function of the reproductive system. Reproductive disorders may not necessarily arise as a result of estrogenic effects alone, and there is a need for a better understanding of the relative importance of endocrine disruption in relation to other forms of toxicity. Here, the integrated health effects of long-term effluent exposure were reported (reproductive, endocrine, immune, genotoxic, nephrotoxic). Concentrations of treated effluents that induced feminization of male roach, measured as vitellogenin induction and histological alteration to gonads, also caused statistically significant alterations in kidney development (tubule diameter), modulated immune function (differential cell count, total number of thrombocytes), and caused genotoxic damage (micronucleus induction and single-strand breaks in gill and blood cells). Genotoxic and immunotoxic effects occurred at concentrations of wastewater effluent lower than those required to induce recognizable changes in the structure and function of the reproductive endocrine system. These findings emphasized the need for multiple biological end points in tests that assess the potential health effects of wastewater effluents. They also suggested that for some effluents, genotoxic and immunological end points may be more sensitive than estrogenic (endocrine-mediated) end points as indicators of exposure in fish [42]. The impact of industrial effluent on water quality and gill pathology of Clarias gariepinus from Alaro stream, Nigeria was carried out [43]. The fish showed irreversible alteration of the gill structures. Morphological examination of fish samples from upstream showed reddish gill filaments while those of fish downstream were pale and there was hypersecretion of mucus on the gill surface. The toxic effects of paper mill effluents has been reviewed [44, 45]. The fresh water fish Mystus vittatus were found to be highly sensitive to paper mill effluent during the spawning phases of the reproductive cycle [46]. Effluent when released in water has high temperature which increases water temperature. Increase in temperature reduces the solubility of oxygen in water and hence, could raise the metabolic rate (oxygen demand) of the fish, thus limiting the oxygen carrying capacity of the blood. In view of this, it may be presumed that the toxic metals present in the effluent would acquire greater toxicity during the warmer months of the year and thus contribute to the overall increased mortality during these months in M. Vittatus [46]. The impacts of fertilizer industry effluent upon the levels of protein and the activity of lactate dehydrogenase, a terminal key enzyme in glycolytic pathway, in different organs of a fresh water teleost fish, Channa striatus was also studied [47]. The toxicity of the effluent on the fish tissues could be attributed to the impact of certain heavy metals and ammonia present in it. The increased mortality of fish in the study due to increase in water temperature may be attributed to the increased uptake of effluent components and reduced level of dissolved oxygen in the medium. The effluent treatment caused apparent changes in the level of protein in certain tissues of the fish. The results showed the average protein concentration in various tissues of the control fish in the following order: gills> liver> brain> muscle> kidney> heart. The decreased trend in protein content may be due to inhibition of its biosynthesis or enhanced degradation of protein and metabolic utilization of the keto acid into gluconeogenesis pathway for the synthesis of glucose under the fertilizer industry effluent induced stress. The LDH activity in the tissues of C. striatus was reduced, which might be dependent on the concentration of the fertilizer industry effluent and duration of exposure. Some heavy metals such as Zn, Cr, Cu and Pb present in the fertilizer industry effluent can bind to certain proteins disrupting membrane integrity, cellular metabolism and ion-transports which may pose threat to the maintenance of homeostasis. In another study [48], in vitro impact of fertilizer industry effluent upon the levels of AChE activity and protein content in different tissues of non-target aquatic fish, Channa striatus was estimated. When AChE activity was compared for different tissues, it was observed in following decreasing order: brain>muscle>liver> gills>heart>kidney. The study also observed marked concentration dependent decrease in the protein contents from fish tissues. In another study [49], auto grafts and allo grafts were more readily rejected by the control fish than the tannery effluent effluent-exposed Cyprinous carpio, indicating immunotoxicity. Exposure of the freshwater cichlid, Oreochromis mossambicus to chrome tannery effluents and injection of chromium compounds into the body cavity resulted in spleen atrophy, and reduced leukocyte counts and antibody response on injection of bovine serum albumin. The fish developed oedema in the anterior region of peritoneal cavity, convulsions, imbalance in swimming body twisting, and protrusion of the eye-balls. With increased concentration of the effluent, the symptoms were much pronounced. Exposure to textile mill effluent caused an increase in large lymphocytes, monocytes, neutrophils and basiphil granulocytes and decrease in small lymphocytes in H. fossilis. Besides, there was an elevation of haemoglobin and hepatocrit levels. However, on long term exposure of 120 days, the red cell indices – MCV, MCH, MCHC showed a remarkable decline. These changes are in accordance with the changes observed for RBCs, haemoglobin and hepatocrit. From this study it is concluded that the sub lethal concentration of the textile mill effluent caused detrimental effect on aquatic organisms and make them susceptible to various diseases [50]. The distillery effluent diminished the rate of oxygen consumption, total carbohydrate and glycogen contents of muscle, liver and brain tissues; while, the serum glucose, lactic acid and LDH activities were elevated in Cyprinus carpio [51].

CONCLUSION:

Anthropogenic activities are responsible for rapid deterioration of aquatic ecosystems. Such activities, mostly emanating from industrial effluents, are a major cause of concern. Industrial effluents are often released in the water bodies with minimum pre treatments. Even if the treatment systems are available, often such measures are not enough to prevent damage to aquatic organisms, such as fish. It is, therefore, highly recommended that the industries should strictly comply with the existing regulatory norms. Besides, the existing regulatory norms for discharge of effluents in water bodies have to be modified from time to time.

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