

Impact of Heavy Metals in Environment: A Review

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ABSTRACT: The quality of water is a major environmental concern due to dispersal of industrial and urban waste generated by human activities by large scale production of variety of chemicals, energy and other developmental activities including agriculture, urbanization and other health care activities during the past four decades, in the modern world have lead to release of huge quantities of waste in the form of solid , liquid and gases. Generally it has been noticed that heavy metals (Pb, Zn, Cd, Hg, Mn, Cr, Cu, Fe, Co, Ar, Ni) are the major component and at times the sole component of industrial discharge. Permissible limits have been set by many countries and organizations like USEPA, WHO, discharge level exceeding these limits increases the toxicity level of aquatic environment causing maximum damage to both aquatic life and finally affecting humans reaching them through different routes. This review is about different studies on heavy metal exposure and its impact on fishes causing bioaccumulation and histopathological alterations in the tissues further leading to DNA damage and other toxic effects. Humans consume fish as a dietary uptake also gets exposed to these metals and indirectly expose themselves to deadly diseases like cancer and other health ailments.

KEYWORDS: Heavy metals, USEPA, WHO, Bioaccumulation, Histopathological studies, DNA.

I. INTRODUCTION

The quality of water is of vital concern for mankind since it is directly linked with human welfare. Water is one of the most important natural resource that exists on our planet and is essential for survival of both aquatic and terrestrial organisms. Rapid industrialization is responsible for increasing water pollution as the untreated excessive waste thrown in the water bodies has dreadful effects on its physiochemical properties. Oxygen concentration, CO₂ levels, hardness, pH, Total dissolved solid concentration are widely affected by presence of high concentrations of pollutants, primarily Heavy metals. Heavy metal contamination have devastating effects on ecological balance of the recipient environment as its wide occurrence in almost every industry whether it is fertilizer, distillery, pharmaceutical, hardwares, steel, chemicals and power plants besides these daily life products like detergents, shampoos, tubelights, cosmetics and batteries also contain heavy metals which when turned waste are poured into the local water bodies contaminating them. It is clear that the anthropogenic input of heavy metals is much higher than natural input. For example, anthropogenic input is almost double the natural input of mercury, and copper, lead and zinc it is greater by an order of magnitude. Anthropogenic sources of cadmium include cigarette smoking and food is the most important source of cadmium exposure in general the non- smoking population [27,37]. This is typical for the global distribution of heavy metals in the hydrosphere. Thus, compared to the other toxicants, they are of prime interest, particularly in view of their toxicity in relation to aquatic organism (hydrobionts). In the list of animal species dwelling in the water bodies' detrimental effect of pollutants can never be negligible for fishes. Poor water quality has a marked impact on decreasing fish number and early death of sensitive fish species due their inability to cope up with the polluted waters. Species which tend to survive also have poor growth patterns, low reproduction and disturbed body physiology. Many different countries have set up guidelines for heavy metals and exceeding levels cause changes in physiochemical properties of water.

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Table I: PERMISSIBLE LIMITS OF SOME HEAVY METALS BY DIFFERENT COUNTRIES

| Heavy Metals | WHO | EU | Canada | Australia | NZ | Japan | USA |
|--------------|------|------|--------|-----------|------|-------|-----|
| Cu | 2 | 2 | 2 | 1 | 2 | 1 | 1.3 |
| Ni | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | - | - |
| Co | - | - | - | - | - | - | - |
| Cr | 0.05 | 0.05 | 0.05 | - | 0.05 | 0.05 | 1 |

(Mg/L-1)

In India, various studies have been conducted on bioaccumulation of heavy metals in different organs of fish. A study by Javed M, Usmani N. [24] for bioaccumulation of heavy metal in *Channa punctatus* showed the exceeding levels of metal concentration in muscle tissue and also in water following the pattern Fe>Mn>Zn>Co>Ni>Co=Cr. These heavy metals producing toxic effects should be analyzed for the upper and lower occurrence levels in the environment and techniques to remove the undesirable quantity should be setup..

II. HEAVY METAL TOXICITY

The universal problem is the environmental pollution and most important pollutants are the heavy metals in aquatic environment because of their toxicity, accumulation and biomagnifications by aquatic organisms. Metals in general terms are essential to be present for healthy functioning of the body. They play a critical role in maintaining structures of proteins and enzymes. Deficiency and excess of certain metals causes inappropriate functioning and toxicity. Heavy metals are defined as any metal which exceed the permissible limit or is present in undesired quantity in the body affecting the body's functioning and leading to its damage acting as a pollutant. A pollutant is any substance in the environment, which causes objectionable effects, impairing the welfare of the environment, reducing the quality of life and may eventually cause death [14]. Many metals are reported to be toxic in low levels e.g. lead (Pb) and mercury (Hg). The eight most common pollutant listed heavy metals by Environment Protection Agency (EPA) are: As, Cd, Cr, Cu, Hg, Ni, Pb and Zn [6]. In list of heavy metals lead, mercury and cadmium are considered to cause public health hazards [21]. Heavy metals are found to have toxic, carcinogenic and mutagenic effects on organisms which get directly or indirectly get exposed to them. It has been speculated that heavy metals disturb the metabolism, ionic balance and cell division [38]. Inhalation of cadmium fumes or particles are life threatening, exposure may cause kidney damage. Animal experiments have suggested that cadmium may be a risk factor for cardiovascular disease. Cadmium may also enter into the atmosphere from zinc, lead and copper smelters [42]. Mercury in urine is primarily related to (relatively recent) exposure to inorganic compounds, whereas blood mercury may be used to identify exposure to methyl mercury. Acute mercury exposure may give rise to lung damage. Chronic poisoning is characterized by neurological and psychological symptoms. A high dietary intake of mercury from consumption of fish has been hypothesized to increase the risk of coronary heart disease. Lead poisoning is disturbance of haemoglobin synthesis, and long-term lead exposure may lead to Anaemia. Arsenic has long-term neurological effects, and cancer at sites other than lung, bladder, kidney and skin. Chromium compounds are known to produce chronic effects on liver, lungs, kidneys and gastrointestinal cramps in humans. Studies on various fish species showed that heavy metals accumulated mainly in liver, a metabolic organ that stores metals causing their detoxification by producing metallothioneins [23]. Excess of Copper causes hypertension, anemia and is responsible for specific diseases of bone. The intestine is potentially the most important organ for Zn absorption, but very little is known about the mechanism of its uptake in fish. In contrast to Copper and Iron Zn does not form free- radicals and it has anti-oxidant properties [6]. Metals permissible limits set by various organizations like for Cu (30 ppm, WHO/FAO 1989), Ni (70-80 ppm, USFDA 1993), Mn (0.01 ppm WHO) and Zn (40 ppm, WHO/FAO 1989) in tissues of fish. Metals present beyond these values cause detrimental effect in

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(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 9, September 2016

tissues and further increase may also cause death. Recent studies by Omar W. A. *et al* [39] found species specific bioaccumulation pattern in fishes collected from both farm and natural water body, they also conducted human health risk assessment and concluded that exceeding concentrations cause adverse effect to humans upon consumption.

Table II: STUDIES ON HEAVY METAL EXPOSURE OF FISHES WITH VARYING PARAMETERS FOR ASSESEMENT

| COUNTRY | YEAR | WATER BODY | HEAVY METALS | FISH | ORGAN | PARAMETERS | REFERENCES |
|-----------|------|---------------------------------|--------------------------------|------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|------------------------------------------------------------------------------------|------------|
| TURKEY | 2003 | NORTH MEDITERRANEAN SEA | Cd, Cr, Cu, Fe, Pb, Zn | <i>Sparus auratus, Atherina hepsitus, Mugil cephalus, Trigla cuculus, Sardina pilchardus, Scomberesox saurus</i> | LIVER, GILL, MUSCLE | BIOACCUMULATION | [10] |
| ITALY | 2005 | LAKE VERDE | As, Fe, Cd, Pb, Hg | <i>Laurata</i> | GUT | APOPTOSIS, CELL PROLIFERATION, SEROTININ IMMUNOREACTIVITY IN GUT, HISTOMORPHOLOGY. | [43] |
| POLAND | 2006 | POLLUTED WATERS | Fe, Zn, Pb, Cu, Cd, Hg | <i>Salvelinus alpinus</i> | LIVER, KIDNEY | BIOACCUMULATION, GSI, ENZYME ACTIVITY | [8] |
| LITHUANIA | 2006 | POLLUTED WATER BODY | Co, Zn | <i>Oncorhynchus mykiss</i> | DNA | GENOTOXICITY, MNT BIOACCUMULATION | [7]. |
| JORDON | 2008 | NORTHERN JORDEN VALLEY | Cd, Cu, Zn | <i>O.aureus, C. carpio, C. Lazera</i> | MUSCLES, BONES,SKIN, SCALES, GILLS | BIOACCUMULATION | [3] |
| INDIA | 2008 | EXPOSURE STUDY | Cr, Ni, Cd, Pb | <i>Cyprinus carpio</i> | GILLS,LIVER, KIDNEY, FLESH | BIOACCUMULATION | [40] |
| INDIA | 2009 | TAMIL NADU RESERVOIRS | Pb | <i>Cyprinus carpio</i> | BLOOD, PLASMA | BIOACCUMULATON, CORTISOL LEVELS | [41] |
| EGYPT | 2009 | ROSETTA BRANCH NILE RIVER | | <i>O. niloticus</i> | GONADS | REPRODUCTIVE BIOLOGY, HISTOPATHOLOGY | [32] |
| TURKEY | 2009 | AVSAR DAM | Cd, Cr, Cu, Fe, Ni, Pb | <i>Cyprinus carpio</i> | HEART, MUSCLE, STOMACH-INTESTINE, GILL, LIVER | BIOACCUMULATION | [31] |
| INDIA | 2011 | KOLKATA WETLANDS | Cu, Zn, Mn, Fe, Cd,Ni, Hg, As | <i>Hypophthalmichthys molitrix, O. niloticus, L.rohita,O.mossambicus, C.mirgala, C.catla, Punctius ticto</i> | MUSCLE TISSUE | BIOACCUMULATION | [28] |
| MALAYSIA | 2011 | PONDS OF BESTARI JAYA PENINSULA | As, Cu, Pb, Sn, Zn | <i>Cyprinids</i> | LIVER, GILLS, MUSCLES | BIOACCUMULATION, HAZARD INDEX, HEALTH EFFECT | [5] |
| IRAN | 2011 | KOR RIVER | Pb | <i>Cyprinids</i> | GONADS, MUSCLES, KIDNEY, LIVER ,BRAIN | HORMONAL ASSAY | [15] |
| EGYPT | 2011 | DRAINAGE CANAL, FISH FARM | Zn, Pb, Mg, Cu, Se, Fe, Ni, Cd | <i>O. niloticus, C. Gariepinus</i> | BLOOD, KIDNEY | ENZYME ASSAY, CLINOPATHOLOGICAL STUDIES | [18] |
| EGYPT | 2012 | FRESH WATERS | Zn, Pb, Mn, Cu, Cd, Se, Hg, Fe | <i>O.niloticus, C.gariepinus</i> | BLOOD | BIOCHEMICAL ANALYSIS: AST, ALT | [30] |
| INDIA | 2011 | RASALGANJ, ALIAGRH | Cu, Ni, Fe, Co, Mn, Cr, | <i>C.punctatus, gariepinus, L.rohita</i> | C. MUSCLE, KIDNEY, LIVER | BIOCONCENTRATION | [25] |

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 9, September 2016

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|-------------------|------|--------------------------------------------------|------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|------------------------------------------------------------------------------------------------------------|------|
| MALAYSIA CHINA | 2012 | MARKET PLACE, SELANOGOR | Zn Cd, Zn, Pb, Ni, Co | <i>Oreochromis niloticus</i> | INTEGUMENTS LIVER, GILL, MUSCLE | BIOCONCENTRATION | [46] |
| | 2012 | YANGTZE RIVER | Cu, Zn, Cd, Hg, Pb, Cr | <i>Hypophthalmichthys molitrix</i> , <i>Ctenopharyngodon idellus</i> | MUSCLE | BIOACCUMULATION | [49] |
| IRAN | 2012 | SOUTH WEST PARTS OF CASPIAN SEA | Cu, Zn, Cd, Pb, Hg | <i>Rutilus frisii</i> | LIVER , MUSCLE | BIOACCUMULATION, CONDITION FACTOR,HIS AND GROWTH | [35] |
| NIGERIA | 2012 | REVER BENUUE | Cu, Zn, Co, Mn, Fe, Cr, Cd, Ni, Pb | <i>Tilapia zilli</i> , <i>C. angullaris</i> , <i>Synodontis budgetti</i> , <i>Oreochromis niloticus</i> | GILLS, LIVER, STOMACH, KIDNEY, BONES, FLESH | BIOACCUMULATION | [1] |
| SAUDIA ARABIA | 2012 | MARKET PLKACE IN RIYADH | Fe, Mn, Cu, Zn, Pb, Cd, Hg | Blackspot emperors, Groupers, sardines common fishes | MUSCLES | BIOACCUMULATION | [2] |
| INDIA | 2012 | SEWAGE FED POND | Cu, Ni, Fe, Co, Mn, Cr, Zn | <i>C.punctatus</i> | GILLS, LIVER, MUSCLE BAND INTEGUMENTS | BIOACCUMULATION | [24] |
| TURKEY | 2012 | BLACK SEA | Zn, Cu, Cd, Pb | Mediterranean horse mackerel, Stripped mullet, Atlantic bonito, Flathead mullet, Black scorpion fish, Sea bream, Shi drum, Picarel, Common sole | MUSCLE | BIOACCUMULATION | [9] |
| IRAN | 2013 | SISTAN'S CHAHNIMAH RESEVIOR | Pb, Ni, Cu, Fe, Zn | <i>Paracობitis rhadinaea</i> | LIVER, MUSCLE, TISSUES | BIOACCUMULATION | [47] |
| FRANCE | 2013 | LANDFILL LEACHATES RECEIVING WATER BODY | As, Cd, Cu, Mn, Ni, Zn, Pb | <i>Rutilus rutilus</i> | DNA | RAPD | [44] |
| EGYPT | 2014 | RED SEA | Cu, Zn,Pb, Cd,Fe, Mn | <i>Benthic and pelagic fishes</i> | LIVER, GILLS, MUSCLES | BIOACCUMULATION | [16] |
| INDIA | 2014 | KALAMBI VILLAGE RESERVIOR | Hg, Pb | <i>C. mrigala</i> | LIVER , GILLS | BIOACCUMULATION, HISTOPATHOLOGY | [13] |
| MALAYSIA | 2014 | KELANTAN RIVER | Cd, Ni, Pb | | MUSCLE | BIOACCUMULATION | [22] |
| EGYPT | 2015 | NILE | Pb | <i>Rutilus frisii</i> | LIVER | BIOACCUMULATION | [17] |
| INDIA | 2015 | KOLKATA WETLANDS | Pd,Cu,Cd | <i>O. niloticus</i> , <i>Glossogobius sp.</i> | STOMACH INTESTINE | HISTOPATHOLOGY, HISTOCHEMICAL, ULTRASTRUCTURAL AND ENZYMOLOGICL STUDIES | [34] |
| INDIA | 2015 | LOCAL PONDS | Hg,Cd, Zn | <i>Tilapia mossambica</i> | LIVER, INTESTINE | PROTEIN CONCENTRATION, BIOCONCENTRATION | [11] |
| INDIA | 2016 | EFFLUENT LOADED CANAL | Mn, Fe, Co, Ni, Cu, Zn | <i>M.armatus</i> | MUSCLE | BIOACCUMULATION, DIETARY INTAKE, TARGET HAZARD QUOTIENT, CARCINOGENICITY,H UMAN HEALTH RISK | [26] |

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 9, September 2016

III. BIOACCUMULATION STUDIES AND BIOMARKERS USED

Fish has turned into an important indicator due to its increased sensitivity towards temperature, natural surroundings, water quality deterioration, additionally aquatic contamination antagonistically affecting the fish health which might bring mortalities and ecosystem degradation. Fish biomarkers including the assessments of biomolecular cellular, and physiological alterations that are utilized for biomonitoring the biological effect of toxicants especially metal exposure. Potential biomarkers include DNA and protein adducts, mutations, chromosomal aberrations etc. Quantification of fish metallothionein transcript levels in absolute units has recently been presented [19]. The prolong exposure of heavy metals can lead to bioaccumulation and bio-magnification in the food chain affecting fish feeding and reproductive behavior with other alterations such as changes in histology of stomach, intestine, kidneys, gills, brain and muscles, and also nutrient profile. Limited information is available on the disorders of morphological and functional characteristics of fish digestive tract exposed to pollutants as hydroplasia, destruction of intercellular contacts and mitochondria, increase cellular proliferation and formation of crypts, edema in mucosal and sub mucosal layers are studied [33]. No doubting all living creatures, immune system and immune response come about as a protective mechanism and although fishes are most primitive vertebrates, but they too had to develop an immune system proficient enough to react and protect them from attack by various microorganisms and parasites [4, 48]. Suppression of immune system and immune response may results from the action of several pollutants including heavy metals which provide opportunities for invasion of many pathogens, but till now the effect of heavy metals on the immune system and immune response is not fully understood [12, 45, 29]. The inhibitory effect of heavy metals on humoral immune response and antibody formation may result in the damaging effects of metals on hematopoietic tissues in liver, spleen and kidneys. Histopathological studies of fish tissues of different organs have shown degeneration in muscle bundles with focal areas of necrosis, atrophy of muscle bundles and edema between muscle bundles. The liver showed vacuolar degeneration and aggregations of inflammatory cells in the hepatocytes, focal areas of necrosis and fibrosis, dilation and congestion in blood sinusoids and thrombosis formation in the central veins. In the gills, the pathological alterations included proliferative, degenerative and necrotic changes in the epithelium of gill filaments and secondary lamellae, edema in secondary lamellae, dilation and congestion in blood vessels of gill filaments and mucous cells proliferation. Kidney showed vacuolar degeneration in the epithelium of renal tubules, focal areas of necrosis, hemorrhage between the renal tubules and edema in Bowman's capsules with atrophy in the glomeruli. In the intestine, degenerative and necrotic changes in submucosa and mucosa with edema between them, dilation in blood vessels of serosa and atrophy in the muscularis and submucosa are noticed [33]. The changes reported include atrophy of epithelial cells, detachment of intestinal layers flattening and degeneration of the villi. The combined PAS-AB stain depicts the change in the intensity of localisation of acid and neutral mucopolysaccharides in the epithelial and mucous cell content in the tissues. Micro anatomical studies have revealed the disarrangement of gastric folds, degeneration and scattered microvilli in the stomach. Different degrees of inhibition of digestive enzymes (viz. protease, amylase and lipase) are exhibited in stomach and intestine [34]. Similarly changes in liver such as enlargement were observed in few cases. Histopathological changes are sensitive and they provide better assessment for biochemical parameters [36]. Mechanism of action of these heavy metals causing bioaccumulation in fish tissues is undertakes different pathways many are yet to be studied. Most commonly acting, by forming free radicals and leading to oxidative stress. The excess free radicals not removed by anti-oxidants present in the body which causes oxidative stress leading to poor growth and organisms remains in a stressed state and are not able to perform normal body functions. Hydroxyl radicals, Superoxide radicals and hydrogen peroxide which deplete organism's intrinsic defense mechanism were also studied and severe effects on tissues were observed [20]. Fish is considered as an important protein source and also known to contain essential amino acids required for healthy functioning of body. The most important source of unsaturated fatty acids Omega-3 and Omega-6 (USEPA 2004) makes it more popular food source and many countries like China, Peru, India, Indonesia, USA etc are some of the largest fish producing countries in the world. Due to increasing number of fish consuming population there is a need to assess the risk factor which comes along when a contaminated or a heavy metal loaded fish is consumed by the people and it may causes health issues and even produce cancer causing agents in human body. Studies on human health risk assessment by Javed M, Usmani N [26] showed a potential risk to both Human males and females consuming fish and also Target Hazard Quotient (non- carcinogenic risk factor) Calculated by using the equation:

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 9, September 2016

$$THQ = \frac{(M_c \times IR \times 10^{-3} \times EF \times ED)}{(RfD \times BW \times ATn)}$$

EF is the exposure frequency of the person exposed to the metal via intake of contaminated food (fish), also ED which is the exposure duration stating how long the individual is been exposed to such intake during life period. RfD is the reference dose for metal estimated and ATn the average time for non-carcinogens.(USEPA 2011,USEPA 2012), dietary intake were also taken as measures to see the impact on individuals consuming the fish, and they found Co had the highest target hazard quotient followed by Ni> Cu> Zn> Fe. According to USEPA human health risk assessment includes four basic steps including planning and research, identification of hazardous substances, dose response and exposure assessments and finally characterization of risk factors telling details about the risk from environment factors.

IV. CONCLUSION

Aquatic organisms particularly fish is studied most for heavy metal exposure as it serves as the best protein source for humans and also for its ecological importance. Uncontrolled discharges have disturbed the organism so much so that continuing effect may cause death and finally extinction of some important species of fish. Bioaccumulation and biomagnifications has caused detrimental effect on the organism's body and also on several organs including digestive and reproductive health. It also makes it more susceptible to diseases and parasitic attack due to poor defense mechanism of the system. Information provided by this review gives a better understanding towards the causes, routes and effects of heavy metal exposure. The collection of fishes from polluted water bodies and studying the impact on their morphological changes and physiological alteration has helped in understanding different accumulation patterns and also the time of exposure that may vary from place to place also the biomarkers used in different studies by workers (tissues from gills, intestine, liver, muscle, gonads and also DNA/RNA) gives the clear picture of where the actual damage is been done. Further, human health studies are helpful to identify routes of pollutant entry and effect it is liable to cause. Industries should follow the guidelines and check their discharges before the uncontrolled release of chemicals which can be cause of extinction of an important food source from water bodies in the coming future.

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Vol. 5, Issue 9, September 2016

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