



BIOMAGNIFICATION POTENTIAL OF POLLUTANTS IN THE AQUATIC ECOSYSTEM

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ABSTRACT

The term "biomagnification" refers to the process by which contaminated materials or hazardous chemicals become more prevalent in food chains. These substances frequently originate from contaminated or drunken environments. The contaminants include pesticides, heavy metals like mercury and arsenic, and compounds known as polychlorinated biphenyls (PCBs), which are ingested by organisms through their food or absorbed from their surroundings. Numerous industrial and household chemicals contain significant amounts of these materials. Substances that are detrimental then accumulate within the cells of the organism. Toxins progressively accumulate in the higher food chain when organisms higher up the food chain eat those lower on the trophic scale that contain them. The higher organisms will accumulate most of the toxins because this is a recurring process in the ecosystem and throughout the entire food chain. The primary purposes of monitoring the toxicity and accumulation of metals in the aquatic biota or sediment are to evaluate the quality of the surface water and guarantee food safety, respectively, and to ensure that the directives are being followed. The toxicity and accumulation parameters are used to determine the source of metal contamination and for a variety of environmental monitoring programs, including those that monitor wastewater discharges and risk assessments of both natural and man-made events, such as floods and dredging operations.

KEYWORDS: Biomagnification, causes and effects, pollutants, heavy metals, accumulation potential, food chain, aquatic ecosystem.

1. BIOMAGNIFICATION

Biomagnification stands for Biological Magnification, which means the increase of contaminated substances or toxic chemicals that take place in the food chains. These substances often arise from intoxicated or contaminated environments. The contaminants include heavy metals namely mercury, arsenic, pesticides such as DDT, and polychlorinated biphenyls (PCBs) compounds which are then taken up by organisms because of the food they consume or the intoxication of their environment. These materials are highly present in a variety of household and industrial chemicals. The harmful substances then build up inside the organism's cells. When organisms in the higher food chain consume the organisms containing the toxins below their trophic levels, the toxins gradually become concentrated in the higher food chain. Because this is a repetitive process in the ecosystem and throughout the entire food chain, the higher organisms are the ones that will accumulate most of the toxins.

1.1 Causes of Biomagnification

The release of toxic chemicals and pollutants into the environments such as the seas, air, and land results in the

accumulation of toxins and harmful substances in the environment[Shukla D.P, 2018]. The concentration of these toxic chemicals and pollutants seems to be very low when released in different environments, it eventually accumulates and gets absorbed by lower organisms in the food chains such as fish, earthworms, and plants. When the lower organisms are eaten by other organism and the process goes up the trophic levels, biomagnification occurs.

1.1.1 Agriculture

Agricultural pesticides, fungicides, herbicides, and chemical fertilizers, among other agricultural chemicals are highly toxic and often find way into the soils, rivers or lakes and the seas through surface storm water runoff. The primary agricultural inputs including pesticides, industrial by-product wastes, some fertilizers, and specific agrochemical products contain traces of heavy metals such as arsenic, cadmium, mercury, copper, and lead. These substances cause severe health impacts to humans and aquatic animals such as fish when indirectly ingested and accumulate in the body tissues.

1.1.2 Industrial manufacturing activities and pollution

The manufacturing processes of industries indirectly or directly release toxic and harmful substances which find a way to the soils, rivers, lakes, and oceans. Industrial processes pollute the environment in several ways by emitting or discharging toxic pollutants into the environment which find their way into the food chain, leading to biomagnification.

1.1.3 Mining activities in the ocean

Mining activities in the deep sea is to extract minerals and metal ores like zinc, cobalt, silver, aluminum, and gold destroy the oceans and the coastal regions as the mining processes generate scores of sulphide and selenium deposits in the waters. The toxicity levels build up and are absorbed by ocean creatures which are then consumed by organisms in the higher trophic levels of the food chain.

1.2 Effects of Biomagnification

1.2.1 Impact on human health

Humans become more susceptible to cancers, liver and kidney failure, respiratory disorders, birth defects in pregnant women, brain damage, and heart diseases are a result of mercury, cadmium, lead, cobalt, chromium and other chemical poisoning. For instance, diseases like hepatitis and cancer have been attributed to consuming seafood that has been poisoned by mercury and polycyclic aromatic hydrocarbons (PAHs).

1.2.2 Effects on reproduction and development of marine creatures

The various toxic chemicals and elements accumulate in the vital organs of the various aquatic creatures affecting their reproduction and development. For instance, seabird eggs are laid with thinner shells than normal, and can result in the birds crushing their eggs instead of incubating them. Selenium and heavy metals such as mercury also affect the reproduction of aquatic creatures such as fish as it destroys their reproductive organs. Besides, PCB'S (polychlorinated biphenyls) also biomagnifies and impairs reproduction and is considerable high in aquatic systems.

1.2.3 Destruction of the coral reefs

The coral reefs are destroyed by cyanide which is used in leaching gold and in fishing. The reefs provide spawning, feeding, and dwelling grounds for numerous sea creatures. When destroyed, the survival of aquatic creatures is highly compromised.

1.2.4 Disruption of the food chain

Many sea creatures depend on the natural food chain for survival. When chemicals and other toxins are carried into the soils, rivers, lakes, or oceans and taken up by various organisms, it disrupts the interconnected relationships within the food chain. It happens when small animals ingest, or plants absorb the toxic elements after which they are eaten by bigger animals,

consequently, affecting the entire natural food chain. The creatures or plants intoxicated with substances such as mercury, copper, chromium, selenium and cobalt may also be consumed by humans and top animals in the food chain leading to susceptibility to diseases, reproductive disorders, and even deaths.

1.3 Process of Biomagnification

Biomagnification process occurs when certain toxic chemicals and pollutants such as heavy metals, pesticides or polychlorinated biphenyls (PCBs) compounds go up the food chain by working their way through the environment and into the soil or the water systems after which they are eaten by aquatic animals or plants, which in turn are consumed by animals, humans, and large birds. Eventually, these substances increase in concentration in the organisms as they move up the food chain because they are slowly excreted or metabolized/broken down. Here is an explanation showing the process of biomagnification.

1.3.1 Release of toxic chemicals and pollutants into the environment

The process begins with the release of toxic chemicals and pollutants into the environment and eventually works their way into soils, rivers or lakes, and the seas. The concentration of these toxic chemicals and pollutants seems to be very low when released in different environments. They are very minute even in terms of weight.

1.3.2 Phytoplankton

Phytoplankton refers to small plants that float in the seas that normally absorb 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.

1.3.3 Zooplankton

Zooplankton refers to small marine animals that float in the seas. They consume phytoplankton and thus take in the toxin. 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 represents about a ten-fold increase over the previous concentration.

1.3.4 Small fish consume the zooplankton

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

1.3.5 Large fish graze on the smaller fish

Again, when the large fish graze on the smaller fish 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 a four-to-five-fold increase in the toxic levels.

1.3.6 The top food chain organisms consume the fish

The organisms at the top of the food chain including marine mammals such as dolphin, sea birds, and humans gradually build up the toxins in their tissues such as their liver when they consume the large fish. The levels of concentrations here increase to the highest ranges of 10,000 to 15,000 parts per billion. The results impact the animal's fertility and make them vulnerable to diseases as they interfere with the normal functioning of vital organs.

1.4 Aquatic ecosystem affected by Metal contamination

Metals are constantly released in aquatic systems from natural and anthropic sources such as industrial and domestic sewage discharges, mining, farming, electronic waste, anthropic accidents, navigation traffic as well as climate change events like floods. Moreover, metals are easily dissolved in water and are subsequently absorbed by aquatic organisms such as fish and invertebrates inducing a wide range of biological effects, from being essential for living organisms to being lethal, respectively [Shukla D.P, 2013 and 2017]. Although some metals are essential at low concentrations for living organisms, such as (i) micronutrients (Cu, Zn, Fe, Mn, Co, Mo, Cr, and Se) and (ii) macronutrients (Ca, Mg, Na, P, and S); at higher concentrations, they could induce toxic effects disturbing organisms' growth, metabolism, or reproduction with consequences to the entire trophic chain, including on humans [Vaghela K., 2023 and Stankovic S. et al, 2014]. In addition, the non-essential metals such as Pb, Cd, Ni, As, and Hg enhance the overall toxic effect on organisms even at very low concentrations. High levels of metals in the environment could be a hazard for functions of natural ecosystems and human health, due to their toxic effects, long persistence, bio accumulative properties, and biomagnification in the food chain. In this context, metal pollution is a global problem; therefore, the international regulations demanded for water quality compliance with the quality standards both in surface water or groundwater and in biota [WFW Directive 2000/60/EC, Directive 2008/1/EC, Directive 2008/56/EC and Commission Regulation (EC) No 629/2008]. Currently, in accordance with the European Water Framework Directive (EU-WFD, 2000/60/EC), the ecological status of water bodies is assessed based on five biological indicators such as phytoplankton, macrophytes, phytobenthos, benthic invertebrates, and fish alongside with chemical and hydromorphological quality elements. Since biota has the ability to accumulate various chemicals, it has been extensively used to measure the effects of metals on aquatic organisms as an essential indicator of water quality [Mishra A. 2019].

1.5 Metal bioavailability to aquatic organisms

Unlike organic chemicals, most metals cannot be easily metabolized into less toxic compounds, a characteristic of them being the lack of biodegradability. Once introduced into the aquatic environment, metals are redistributed throughout the water column, accumulated in sediments, or consumed by biota [Frémion F. et al, 2016]. Due to desorption and remobilization processes of metals, the sediments constitute a long-term source of contamination to the food chain. Metal residues in contaminated habitats can bioaccumulate in aquatic ecosystems— aquatic flora and fauna, which, in turn, may enter the human food chain and result in health problems. Metal accumulation in sediments occurs through processes of precipitation of certain compounds, binding fine solid particles, association with organic molecules, co-precipitation with Fe or Mn oxides or species bounded as carbonates according to the physical and chemical conditions existing between the sediment and the associated water column [Equeenuddin SM et al 2013]. Metal bioavailability is defined as the fraction of the total concentration of metal which has the potential to accumulate in the body. The factors that control the bioavailability of metals are the following: the organism biology (metals assimilation efficiency, feeding strategies, size or age, reproductive stage); metal geochemistry (distribution in water sediment, suspended matters, and metal speciation) physical and chemical factors (temperature, salinity, pH, ionic strength, concentration of dissolved organic carbon, total suspended solids) [Fu J et al 2014]. Metal bioavailability controls their accumulation in aquatic organisms. The metals uptake paths are through the permeable epidermis if metals are in dissolved forms or through the food ingestion if metals are in particulate forms. Metal speciation, the presence of organic or inorganic complexes, pH, temperature, salinity, and redox conditions are the main factors that could modulate metal toxicity. The ingestion uptake depends on similar factors, plus the rate of feeding, intestinal transit time, and digestion efficiency. Many studies have shown that the free hydrated metallic ion is the most bioavailable form for Cu, Cd, Zn, and Pb [Wojtkowska M et al, 2016], but some exceptions have been reported. Thus, the importance of other chemical forms of dissolved metals and complexes formed with suitable organic ligands with low molecular weight should not be neglected. It has been found that the presence of organic binders increases the bioavailability of Cd in mussels and fish, by facilitating the diffusion of the hydrophobic compound in the lipid membrane. The organic compounds of metals could be more bioavailable than the ionic forms. For instance, organic mercurial compounds are lipid-soluble and quickly penetrate the lipid membranes, increasing the toxicity compared to mercuric chloride which is not lipid-soluble. The absorption on suspended solids affects the total concentration of metals present in water. The association between solid particles and metals is also critical for the metal uptake into organisms through food ingestion

[Eggleton J, Thomas KV., 2004]. The suspended solids accumulate the insoluble metal compounds, but under certain conditions, the metal reached the interstitial water being dissolved. Heavy metal concentrations from sediments or suspended solids are much higher than in water, so a small fraction of them could be an important source for bioaccumulation in planktonic and benthic organisms [Adams WJ, Chapman PM., 2007]. The dynamics of different forms of metals in the aquatic environment is not fully understood, so new studies are required to analyze the different accumulation/bioaccumulation pathways based on dissolved or suspended metal forms. Other studies highlighted that bioavailability of metals in bivalve mollusks depends on sediment particle size due to their filter feeding behavior. If the particles were coated with bacterial extracellular polymers or fulvic acids, the Cd, Zn, and Ag bioavailability was significantly increased. Overall, the binding of metal decreased the bioavailability of metals from the sediment [Rosado D et al., 2016].

1.6 Metal bioaccumulation/biomagnification

Monitoring the toxicity and accumulation of metals into the aquatic biota or sediment is mainly performed for assessing both the surface water quality and ensure food safety, respectively, as well as for the compliance with the directives. The toxicity and accumulation parameters are used for various environment monitoring programs such as wastewater discharges or various risk assessments of natural and anthropogenic events (floods or dredging activities) and for identifying the source of metal contamination. According to the European document COM (2011)—876 final—2011/0429 (COD) (2012/C 229/22) amending the Directive 2000/60/EC and 2008/105/EC on priority substances in the field of water policy, new concentration limits of several harmful chemical compounds were allowed for the aquatic biota (fish, mollusks, or crustaceans). For instance, diphenyl brominated, fluoranthene, hexachlorobenzene, hexachlorobutadiene, benzene compounds, dicofol, perfluorooctane sulfonic acid and its derivatives, dioxins, and dioxin-type compounds, cyclo-hexa-bromo-dodecane, heptachlor epoxide, and heptachlor have a concentration value in the range 6.7×10^{-3} to 167 mg/kg wet weight. The rest of the chemical compounds were not yet amended, which represents a considerable research opportunity to assess their chronic toxicity, bioaccumulation, and subsequently to set their maximum permissible concentration limits in aquatic organisms. Furthermore, the Directive 2008/105/EC of Environmental Quality Standards (EQS) entails values for various chemicals in biota. More and more studies of various organic and inorganic chemical bioaccumulation/bioconcentration in freshwater organisms revealed induced harmful effects, especially of heavy metals (Hg, As, Cd, Zn, Fe, Pb, Fe, Mn, etc.) [Schneider L et al 2009 and Salazar MJ et al 2012] and metal nanoparticles. Bioaccumulation remains to be an ongoing highly debated subject. According to United States Geological Survey (USGS) Toxic Substances

Hydrology Program, the bioaccumulation represents “the biological sequestering of a substance at a higher concentration than that at which it occurs in the surrounding environment or medium.” Pollutants can be uptake by organisms directly from the environment or through ingestion of particles, and the accumulation occurs when an organism absorbs toxic chemical with a rate faster than the chemical is metabolized. On the contrary, bioconcentration refers to the chemical uptake from the water only, which could be assessed in the laboratory conditions. The value of the concentration factor index gives information if there is a bioaccumulation (the concentration factor of 1) [Vadineanu A., 1990]. The understanding of the bioaccumulation process is important because persistent pollutants (such as metals) could increase the toxic potential risk by bioaccumulation in the ecosystem, triggering a long-term effect on the ecosystem which cannot be assessed by laboratory toxicity tests. It is considered that a high bioaccumulation potential does not necessarily imply a high potential for toxicity, and as a result, the toxic effects should be estimated separately. In addition, it was made a distinction between accumulation in a small concentrations range, which occurs due to physiological needs (e.g., Zn) and apparently uncontrolled accumulation (e.g., Cd) [Iordache V. 2009]. It was observed that the mollusk's from the Black Sea have shown a great tendency to accumulate in high concentration Cd and Cu from sediments as well as Cd, Ni, and Cu from water. Data showed that the highest concentrations of heavy metals were found in the digestive tract of fish [Jitar O et al, 2015]. Also, the fish *Cyprinus carpio* could differentially bioaccumulate metals from one organ to another: Zn > Cr > Pb > Cu in muscle; Pb > Cr > Zn > Cu in gills; Pb > Cr > Zn in liver. Moreover, for the same species, it has been shown that gills and liver or kidney were accumulating the following metals: Pb > Cd > Cr > Ni and Pb > Cd > Ni > Cr. On the other hand, bioaccumulation of Pb and Cd was significant in all C.

carpio tissues [Vinodhini R, Narayanan R. 2008]. Metal transfer in the aquatic food chain is another interesting environmental topic for many reasons such as the accumulation of metals in aquatic organisms that could transfer up to humans, leading to a potential risk of public health through consumption of contaminated fish [Baby J et al 2010]. It is known that aquatic organisms can be exposed to high or low concentrations of metals as a result of continuous or accidental release, causing long-term effects. The main uptake pathways of metals in aquatic organisms are direct through the food or sediment particles ingestion and water via epidermis and gills then they are transported inside the cells through biological membranes and ionic channels [Ashish T, Amitabh CD., 2014]. Bioconcentration and bioaccumulation of metals into the trophic chain occur if metals are excreted into the water or the contaminated organisms are food for some predator's organisms [David IG et al 2012]. The study named "Ecotoxicology

of heavy metals in the Danube meadow" [Iordache V. 2009] revealed that the amplification of metal concentrations in the food chains of ecosystems depends on the type of metal and the food chain. The metal accumulation in plants depends on the species, metal type, and ecosystem, especially for species which predominantly take metals from soil/sediment. Benthic gastropods tend to differentially accumulate the metals. The populations which are using the seston as energy source concentrate in many cases metals from different sources: Bivalves shell accumulate Pb, the tissue—Mn, Zn, Cd, and sometimes the amphibians in young stages accumulate Cd, Mn, and Zn. Metal concentrations such as Fe, Mn, Cu, Cr, and Pb were not amplified in the food chain (benthic fauna-fish-birds), but they were amplified for Zn and Cd. Concentrations of metals were greater at the end of the trophic chains, as follows: vegetation/detritus—terrestrial invertebrates Phyto phase/detritophag—terrestrial invertebrates' predators amphibians (Cd, Cr, Pb, and Cu in case of detritus chain and Zn in case of vegetation). The fish always accumulate metals, with some exceptions in the case of Cd, for which the transfer coefficient indicates accumulation in muscle and liver. The transfer of metals from benthic invertebrates to omnivorous fish revealed concentration of Zn and Cu in the liver and Zn in muscle. The Mn, Cr, and Cd metals transfer from omnivorous fish (muscle) to predatory fish, more specifically in their muscles and liver. At the end, the birds that are using contaminated fish as food source will accumulate Fe, Mn,

Zn, Cu, and Cd in muscle and all metals (except Cr) in the liver [Iordache V. 2009].

1.7 Biomagnification/Bioaccumulation Potential of Pollutants in the river ecosystem

It has several important cultural, economic, and environmental values and provides water for approximately 450 million people. Moreover, the Ganga River is being used for fishing and aquaculture (Gupta et al., 2018). Fish, in addition to their important source of protein, have rich contents of essential minerals, vitamins, and unsaturated fatty acids. They can normally accumulate heavy metals from food, water, and sediments as they are situated at the top of the aquatic food chain. Due to rapid industrialization, this river is being continuously degrading due to the direct discharge of industrial wastes, agricultural run-off, and anthropogenic activity along the riverbank (Jani et al., 2018). These wastes contain health hazard chemicals like salts of chromium, copper, cadmium, arsenic, mercury, and lead which interact with the aquatic environment and affect the river ecosystem. Heavy metals containing pollutants pose serious water pollution problems due to their toxicity, persistence and bioaccumulation, also accumulate in tissues of plants and animals leading to toxicity in aquatic biota. Fish and humans being the top consumers in the aquatic ecosystem and food chain are badly affected by the accumulation of these heavy metals (Afshan et al., 2014).

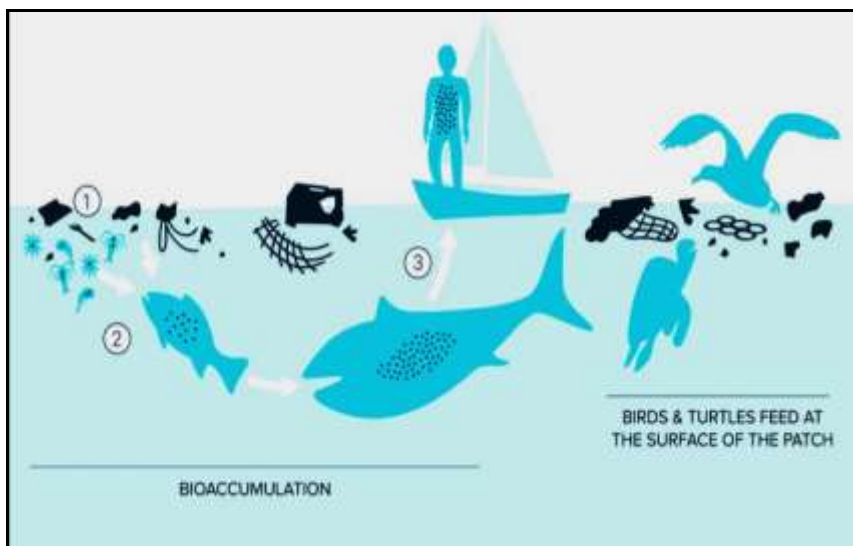


Figure 2.1: Bioaccumulation pattern of pollutant in the food chain.

A one-year biomonitoring study was conducted by Peter M. Kiffney and William H. Clements (1993) to determine the extent of metal contamination (Cd, Cu, and Zn) in a benthic community from the Arkansas River (CO), a subalpine stream impacted by discharges from historic mining operations. Elevated concentrations of metals in water were paralleled by higher concentrations in benthic organisms. Significant differences ($p < 0.05$) in metal concentrations in *aufwuchs* and benthic

macroinvertebrates among upstream (reference) and downstream (impacted) stations were observed. Metal concentrations in *aufwuchs* and benthic invertebrates remained elevated at some downstream stations, despite decreases in water concentrations. Time of year and the functional group contributed to the variation in metal bioaccumulation in benthic macroinvertebrates. Monitoring metal concentrations in aquatic macroinvertebrates was a better indicator of metal

bioavailability in the Arkansas River than ambient (water) metal concentrations. Research conducted by **P. U. Singare, R. S. Lokhande and P. P. Pathak (2011)** advocated habitat conservation and ecological studies with special reference to the pollution due to heavy metals and Physico-chemical characteristics of the soil along the creek area. A study to estimate the levels of water pollution of the Upavan, Masunda, Makhmali and Rewale Lakes situated at Thane, the city on the North-Eastern side of Mumbai, was carried out. The study was performed to understand the Physico-chemical parameters like pH, conductivity, alkalinity, salinity, hardness, chemical oxygen demand (COD), dissolved oxygen (DO) and biochemical oxygen demand (BOD) of lake water. The study was also extended to understand the level of heavy metals like Cu, Zn, Ni, Cd, Hg, As and Fe. These heavy metals have a marked effect on the aquatic flora and fauna which through biomagnification enter the food chain thereby affecting human beings. A study conducted by **M N O Ajima et al., (2015)** revealed that bioaccumulation and toxic effects of heavy metals have caused ecological damage to the aquatic ecosystem. The concentration of heavy metals including zinc, lead, cadmium, iron, and copper was determined in the sediment and water as well as in the muscle, gill, and intestine of two fish species (*Pelmatochromis guentheri* and *Pelmatochromis Pulcher*) of Mbaa River in Southeastern Nigeria. Samples were collected at three different spots from the river, and the level of heavy metals specified above was determined by atomic absorption spectroscopy (AAS) after a modified wet digestion process. The results indicated that sediment had the highest concentration of the heavy metals investigated while water had the lowest concentration. Fish tissues showed appreciable bioaccumulation of these metals as evidenced by a higher concentration profile when compared with that of water. Furthermore, the concentration of these heavy metals in water and their bioconcentration factor in the fish were above the recommended limit by WHO and FEPA, indicating that Mbaa River along Inyishi may not be suitable for drinking nor the fish safe for human consumption. The study also reveals the use **Pablo GagoFerrero M et al (2015)** presented the occurrence of eight organic UV filters (UV-Fs) was assessed in fish from four Iberian River basins. This group of compounds is extensively used in cosmetic products and other industrial goods to avoid the damaging effects of UV radiation and are ubiquitous contaminants in the aquatic ecosystem. Fish are considered by the scientific community to be the most feasible organism for contamination monitoring in aquatic ecosystems. Despite that, studies on the bioaccumulation of UV-F are scarce. In this study fish samples from four Iberian River basins under high anthropogenic pressure were analyzed by liquid chromatography-tandem mass spectrometry (HPLC-MS/MS). Benzophenone-3 (BP3), Ethyl-hexyl methoxycinnamate (EHMC), 4-methyl benzylidene camphor (4MBC) and octocrylene (OC) were the predominant pollutants in the fish samples, with

concentrations in the range of ng/g dry weight. The results indicated that most polluted areas corresponded to Guadalquivir River basin, where maximum concentrations were found for EHMC (241.7 ng/g d.w.). Sediments from this river basin were also analyzed. Lower values were observed in relation to fish for OC and EHMC, ranging from below the limits of detection to 23 ng/g d.w. Accumulation levels of UV-F in the fish were used to calculate biota sediment accumulation factors (BSAFs). These values were always below 1, in the range of 0.04–0.3, indicating that the target UV-Fs are excreted by fish only to some extent. The fact that the highest concentrations were determined in predators suggests that biomagnification of UV-F may take place along the freshwater food web. **Chang-Gui Pan et al (2014)** explained that Per- and polyfluoroalkyl substances (PFASs) are used in various industries, which results in their ubiquitous occurrence in the environment. This study determined the concentrations of eighteen PFASs in muscle and liver of nine wild freshwater fish species collected from rivers in the Pearl River Delta (PRD) region, South China, and assessed their bioaccumulation and potential health risks to local people. The results showed that eight and twelve PFASs were detected in the fish muscle and liver samples, respectively. Perfluorooctane sulfonate (PFOS) was found to be the predominant PFAS both in muscle and liver with its highest concentrations of 79ng/g wet weight (WW) in muscle and 1500ng/g WW in the liver, followed by Perfluoroundecanoic acid (PFUnDA) and Perfluorotridecanoic acid (PFTTrDA) with trace concentrations. The mean PFOS concentrations in fish muscle and liver tissues of the nine collected species ranged from 0.40ng/g in mud carp to 25ng/g in snakehead, and from 5.6ng/g in mud carp to 1100ng/g in snakehead, respectively. Significant positive correlations were found among PFASs both in water and fish, indicating a similar pollution source for these PFASs. In tilapia samples, PFOS concentrations showed an increasing trend with increasing length and weight, but no significant difference between genders. Bioaccumulation factors (logBAF) in fish for the PFASs were in the range from 2.1 to 5.0. The calculated hazard ratios (HR) of PFOS for all fishes were in the range of 0.05–2.8, with four out of nine species (tilapia, chub, leather catfish and snakehead) having their HR values more than 1.0. The results suggest that frequent consumption of these four fish species may pose health risks to the local population. **P.U. Singare, R.S. Lokhande, P.P. Pathak (2010)** undertook a study and investigated the assessment of pollution status along the wetland of Thane Creek, which has been subjected to a lot of pollution from Asia's biggest Thane-Belapur Industrial Complex located at the south of Mumbai harbor along the west coast of India. The soil samples were also analyzed for their heavy metal contents like nickel, zinc, cadmium, copper, iron, arsenic, and mercury. It was observed that the concentration of these heavy metals increases gradually in dry seasons, followed by a sharp decrease during the rainy season. These heavy metals have a marked effect

on the aquatic flora and fauna which through bio magnification enter the food chain and ultimately affect human beings as well. The study conducted by **Vera Verhaert et al., 2017** investigates the trophic transfer of persistent organic pollutants (POPs: PCBs, PBDEs, OCPs and PFASs) in the subtropical aquatic ecosystem of the Olifants River Basin (South Africa) utilizing trophic magnification factors (TMFs). Relative trophic levels were determined by stable isotope analysis. POP levels in surface water, sediment and biota were low. Only Σ DDTs levels in fish muscle ($<LOQ-61ng/g$ WW) were comparable or higher than values from other temperate and tropical regions. Significant positive relationships between relative trophic level and PCB, DDT and HCH concentrations were observed so trophic levels play an important role in the movement of contaminants through the food web. TMFs were >1 , indicating biomagnification of all detected POPs. Calculated TMFs for PCBs were comparable to TMF values reported from the tropical Congo River basin and lower than TMFs from temperate and arctic regions. For p,p'-DDT, a higher TMF value was observed for the subtropical Olifants River during the winter low flow season than for the tropical Congo river. TMFs of DDTs from the present study were unexpectedly higher than TMFs from temperate and arctic aquatic food webs. The fish species in the aquatic ecosystem of the Olifants River can be consumed with a low risk for POP contamination. **Robeena Sarah (2019)** et al studied and conclude that Ganga is the largest riverine system of India with a fragile ecosystem. It's prone to anthropogenic disturbances because of its cultural, economic, and environmental values. The contamination of river Ganga by heavy metals (HM) is due to biotic (anthropogenic sources) and abiotic (pesticides, fertilizers) sources that pose a devastating health hazard to human, plant, and edible fish life. The chemical analysis with the help of atomic absorption spectrometer performed on its water samples demonstrated the accumulation of heavy metals such as Arsenic (As), Lead (Pb), Cadmium (Cd), Iron (Fe), Zinc (Zn). Moreover, the spectrophotometric analysis indicated the accumulation of heavy metals in order of occurrence ($Fe > As > Cd > Zn > Pb$) in the liver and ($Zn > Fe > As > Cd > Pb$) in the kidney of edible fish *Channa punctatus*. The present study has been used to sensitively monitor the extent of heavy metals pollution in the biotic aqua life of the river Ramganga system and it's suggested that the bioaccumulation of heavy metals in *Channa punctatus* has reached above permissible limits for human consumption, indicating potential health risks. Necessary biological steps should be taken to handle such food pollution and prevent the environmental risk and food chain disruption.

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