International Journal of Aquatic Science
ISSN: 2008-8019
Vol 12, Issue 02, 2021

Helminths and their fish hosts as bioindicators of heavy metal pollution: A review

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Abstract: Pollution in aquatic biotopes has lately have much attention of many investigators. In addition to those studies concern chemical water, which primarily reports the total concentration of a particular pollutant, bioindicators are useful instruments for assessing levels of biologically accessible contaminants. The study of fish parasites is important not only for fish health but also for understanding ecological concerns. Investigations into the environmental factors that influence metal intake have revealed that parasites are more constant and dependable markers of metal contamination than host tissues. Many parasite species, especially helminthes, were used with their hosts to investigate the accumulation of heavy metals. Therefore, this review highlights what is currently known about heavy metals, parasite species, organs of fish and fish species as bioindicators. Finally, this paper discusses possible responses to the question of whether new, more sensitive indicators for ecological monitoring might be beneficial.

1. INTRODUCTION

Aquatic parasites have piqued ecological interest in recent years as a result of their relations with their definitive or intermediate hosts and the environment. The viability and longevity of parasites are influenced by external environmental circumstances, among other things. This straight effect of some environmental factors on parasite lifetime might be employed in bioassays in the laboratory (Morley *et al*., 2001). These negative alterations are frequently linked to physiological reactions that could be employed as biomarkers (Fatima *et al*., 2000). From a pathogenic standpoint, host-parasite interactions are in the spotlight. From a morphological, immunological, and pathological perspective, numerous articles addressing the host-parasite interface have resulted from pathological studies of host-parasite interactions. Various methods for detecting environmental pollution via host-parasite associations come from this interdisciplinary field. Recent research has looked into the use of parasites as environmental quality indicators (MacKenzie *et al*. 1995; Sures, *et al*., 1997; Valtonen *et al*., 1997). Fluctuations in the functioning or behavior of test organisms can be documented in the occurrence or lack of ecological contaminants in the case of effect indication with free living animals (Jacquin *et al*., 2020). Examination of the changes occurred within the community and population of parasites (Galli *et al*., 2021) is one potential technique to show the effect indication with parasites. Although the procedure is time consuming, the toxic effects (Sures *et al*., 1994; Sures *et al*. 1997; Szefer *et al*. 1998; Barus *et al*. 1999; Tenora *et al*. 1999; 2000) indicated that these parasitic helminths are inappropriate as bioindicators because metals are found at low levels. Tapworms, on the other hand, found to be a more promising bioindicator for metal accumelation. Because of their excellent metal collection capacity, Acanthocephalans are arguably the most studied helminths (Sures, 2001). Sures and Siddall (2003) presented a good collection of field data (Sures and Reimann, 2003), and they also have some finings based on experimental studies. A growing number of articles deal with metals in the endoparasites of some mammals, owing to the necessity for sentinel animals in terrestrial settings, especially urban (Beeby, 2001). However the majority of the studies cited above focus on metal bio concentration in parasites from fish. Experiments on the uptake and accumulation of metals by helminthes of aquatic animals are easier to conduct since they absorb metals mostly through water rather than food. As a result, the proportion of metal buildup and removal by diverse fish-acanthocephalan groupings, as well as the link between exposure and steady-state organ cohesion, will be compared.

Heavy metals

Most studies that were achieved in the field of heavy metals in parasites and their host have investigated a wide range of heavy metals. These heavy elements were selected according to their importance and distribution in the studied water bodies. Also, some studies in this regard focused on heavy metals with high toxicity, which affect water bodies in general and the diversity of living organisms, especially fish. Because fish is one of the most important living organisms that are of great economic importance, the concentration of pollutants in them and in the parasites that live inside has become a matter that requires further investigation~~s~~. The most common heavy metal screened in these kind of researches were Copper (Cu), Iron (Fe), Zinc (Zn), Manganese (Mn), Chromium (Cr), Lead (Pb) and Cadmium (Cd) (Tekin-Özan and Kir, 2007; Keke *et al*., 2020). While the less common heavy metal screened were Mercury (Hg), Nickel (Ni), Aluminium (Al), Silver (Ag), Barium (Ba), Bismuth (Bi) and Tin (Sn). (Bergey *et al*., 2002; Thielen *et al*., 2004).

Organs

All studies that tested the capability of fish and their parasites to accumulate the heavy metals used specific organs of the fish. The selection of the studied organs came according to the type and size of fish, the nature of the study, the aim of the study and the collection of samples. Most researchers in this field use more than one organ to study the accumulation of heavy elements. The majority of them studied the liver, muscles and intestines. Most of the organs studied were the liver (Sures, *et al.*, 1994; Tekin-Özan and Kir, 2005; 2007; Al-Niaeemi *et al*., 2020) followed by muscles (Bergey *et al*., 2002; Keke *at al*., 2007), intestines (Malek *et al*., 2007; Popiolek *et al*., 2007) and gills (Shahat *et al*., 2011). The reason for choosing the liver in this type of study is likely because the liver is the organ that deposits most of the highly toxic elements. While the muscles are considered as the suitable tissue to trap heavy elements, in addition muscles are being considered as the large proportion of the biomass of the fish's body. Gonads and kidneys were less common used (Shahat *et al.,* 2001; Thielen *et al*., 2004; Malek *et al*., 2007), probably due to its small sample size.

Accumulation of heavy metals in fish species and their parasites

In this part, some studies conducted on fish and their parasites and their susceptibility to the accumulation of heavy metals will be reviewed. All reviewed papers were summarized in table (1). *Esox lucius* and its endoparasite *Raphidascaris acus* were surveyed by Tekin-Özan and Kir (2007) for heavy metals accumulation. Heavy metal concentrations (Fe, Zn, Cu, Mn, and Cr) in the livers of these fishes were investigated. Only Fe and Zn were found in *R. acus* and fish livers, while Cu, Mn, and Cr levels were below the detection limit. *Clarias gariepinus*, *Raiamas nigeriensis* and *Coptodon zillii* (Reported as *Tilapia zilli*) were analyzed with their endoparasite (*Eustrongylides* sp.) by Keke *et al*. (2020) for heavy element concentration (copper, lead, manganese, iron, zinc, and chromium). Fish muscle and parasite samples from three different fish species were used in this study. Metal levels in *Clarias gariepinus* parasites were Fe > Zn > Cr > Mn > Pb > Cu; *Coptodon zillii* (Reported as *T. zilli*) parasites were Fe > Zn > Mn > Cu > Cr > Pb; and *Raiamas nigeriensis* parasites were Fe > Zn > Cr > Mn > Cu > Cr > Pb. Fe, Zn, Mn, Cu, Cr, and Pb levels in parasites of all fish species were consistently greater than those in the muscles of the host. While, Pb was not found in *Raimas nigeriensis* fish muscles, but it was found in the helminthes parasitized in the fish, representing that the parasites have a high bioaccumulation capacity. Because of the intimate relationship between *Eustrongylides* sp. and zinc. *Eustrongylides* sp. could be a good surrogate for zinc pollution. Intestinal helminthic parasites were found to be excellent surrogates for both the effects and accumulating bioindication of heavy metal pollution in this investigation. *Perca fluviatilis* and its parasite *Acanthocephalus lucii* were studied by Sures *et al*. (1994) for Pb, Cd and Hg accumulation. The acanthocephalans detected in the fish's intestines had substantially greater lead concentrations than their fish's organs.

A population of *Tinca tinca* and its cestode *Ligula intestinalis* were examined for some heavy elements (Cd, Cr, Cu, Fe, Mn, Pb, and Zn) accumulation by Tekin-Özan and Kir (2005). The plerocercoid contained higher amounts of four elements than other fish tissues (liver, gills and muscles). The amount of heavy elements in water and tissues of were found to have significant positive for Cu and negative for (Fe, Zn, and Mn) associations. There were substantial positive for (Cu and Zn) and negative for (Fe and Mn) associations in *L. intestinalis* plerocercoids.

The freshwater fish, *Silurus glanis*, and its tapeworm were surveyed by Al-Niaeemi *et al*. (2020) for the accumulation of heavy metals (Mn, Fe and Cr). Metal concentrations in catfish tissues were in the following order: Mn > Fe > Cr. The metal concentrations of the tapeworm *P. armata* were in the following order: Fe > Mn > Cr. Furthermore, infected catfish had lower mean concentrations of the three heavy metals (Cr, Fe, and Mn) in their bodily tissues than uninfected fish. The presence of the intestinal tapeworm may be linked to a decrease in a metal buildup in infected fish. It also emerged that the three metals are largely collected in the catfish's liver, followed by the gills and, to a lesser extent, the muscles.

Popiolek *et al.* (2007) investigated the accumulation of some heavy elements (Zn, Cd, Ni and Cu) in some tissues (gills, liver and intestine) and the endoparasite of *Perca fluviatilis*, the distribution of Ni, Cd, and Zn concentration was similar. The liver had the greatest mean concentration of metals among all the tested fish organs, followed by the gut, while the gills had the lowest mean concentration. Metal concentrations in tapeworm tissues were 6 to 74 times greater than in the gills, 537 times higher in the intestine, and 2.528 times higher in the liver. Cu concentrations were likewise highest in tapeworm tissues, but they were almost the same in the fish gut and liver; they were lowest in the gills.

Liver, muscle and the endoparasitic nematode *Anguillicola crassus* were analyzed by Palíková and Baruš (2003) for mercury concentration. The definitive host's mercury concentrations were higher in the liver, but not statistically different from those in the muscle. According to regression research, mercury contents in the liver and the total body length of the fish have a positive relationship. Only one fish specimen from the study reservoir had mercury levels in its muscles that exceeded the sanitary limit.

Mercury uptake was also estimated by Bergey *et al*. (2002) in *Fundulus heteroclitus* and its endoparasitic nematode *Eustrongylides* sp. *Fundulus heteroclitus* parasitized by the worm *Eustrongylides* spp. accumulated lower mercury amounts than unparasitized fish, and the parasite accumulated less mercury than the host, because parasites occupy a trophic level above

their hosts, their decreased uptake of methyl mercury contradicts the common idea of methylmercury biomagnification.
Both *Anthobothrium* sp. and *Paraorigmatobothrium* sp. along with their host *Carcharhinus dussumieri* were analyzed for Cd and Pb by Malek *et al*. (2007). Lead and cadmium concentrations in both parasite species were many times greater than in host tissues, according to the findings. The findings significantly support the notion that helminth parasites are exceptionally sensitive early warning bioindicators, especially in vulnerable areas with low pollution levels.
Leite *et al*. (2021) conducted a study for heavy metals (Al, As, Cd, Cr, Cu, Fe, Mn, Ni, and Pb) analysis in both *Hysterothylacium* sp. and *Phyllodistomum* sp. and their fish host (*Hoplias malabaricus*). The parasites, both nematodes and digeneans, had statistically larger concentrations of all elements than the host tissues, however *Hysterothylacium* sp. showed higher concentrations than *Phyllodistomum* sp. We also discovered that uninfected fish had significantly greater metal concentrations than infected fish.
Levels of some heavy elements (As, Al, Ag, Ba, Bi, Cd, Co, Cu, Cr, Fe, Ga, Mn, Mg, Ni, Pb, Sn, Sb, Sr, Tl, and Zn) were studied by Thielen *et al*. (2004) in the fish *Barbus barbus* and its intestinal acanthocephala *Pomphorhynchus laevis*, the acanthocephalan had larger quantities of ten of the twenty-one elements studied than other barbel tissues (muscle, gut, liver, and kidney). When it came to fish tissues, the liver had the highest amounts of most of the elements, followed by kidney, gut, and muscle. The parasites and the host are competing for metals, according to Spearman correlation analysis, this notion is supported by the negative correlations between parasite number and metal conentrations in barbel̓s tissues. The bioconcentration factors for Ag, As, Ba, Bi, Cu, Ga, Mn, Pb, Sr, Tl, and Zn revealed that parasites concentrated metals more than fish tissues.

The freshwater fishes *Oreochromis niloticus niloticus* and *Clarias gariepinus* along with their intestinal parasites *Acanthosentis tilapiae*, *Clarias gariepinus*, *Orientocreadium lazeri* and *Paracamallanus cyathopharynx* were studied by Shahat *et al*. (2011) to investigate the concentration of Pb, Cu and Cd. Result showed significant higher concentration of heavy metals was recorded in the parasites compared to their host fishes.
Finally, all previous studies indicated the ability of the parasite and the host to accumulate pollutants at different rates. However, most studies did not pay attention to the physiology of the parasite and what are the mechanisms that the parasite uses in accumulating these pollutants, and how these pollutants can affect the free stages of some parasitic helminthes in the water. So, more studies are required in this subject.

Table (1): Studies which conducted on fishes, their parasites, accumulated heavy metals, and countries.

Host	**Organ**	**Parasite**	**Heavy metal surveyed**	**Country**	**Reference**
Esox lucius	Liver	*Raphidascaris acus*	Fe, Zn, Cu, Mn and Cr	Turkey	Tekin-Özan and Kir (2007)
Clarias gariepinus	Muscle	*Eustrongylides sp.*	Fe , Zn , Cr , Mn , Pb and Cu	Nigeria	Keke *et al.* (2020)

Raiamas nigeriensis Tilapia zillii					
Perca fluviatilis	Muscle, liver and intestine	*Acanthocephalus lucii*	Pb, Cd and Hg	Germany	Sures *et al.* (1994)
Tinca tinca	Muscle, liver and gills	*Ligula intestinalis*	Cu, Fe, Zn, Mn, Cr, Pb and Cd	Turkey	Tekin-Özan and Kir (2005)
Silurus glanis	Gills, liver and muscle	*Postgangesia armata*	Mn, Fe and Cr	Iraq	Al-Niaeemi *et al*. (2020)
Perca fluviatilis	Gills, liver and intestine	*Triaenophorus Nodulosus*	Zn, Cd, Ni and Cu	Poland	Popiolek *et al.*, 2007
Anguilla anguilla	Liver and muscle	*Anguillicola crassus*	Hg	Czech Republic	Palíková and Baruš (2003)
Fundulus heteroclitus	Muscle	*Eustrongylides* sp.	Hg	USA	Bergey *et al*. (2002)
Carcharhinus dussumieri	Liver, muscle, intestine and gonad	*Anthobothrium* sp. *Paraorigmatobothrium* sp.	Cd and Pb	Iran	Malek *et al* (2007)
Hoplias malabaricus	Muscle, intestine and liver	*Hysterothylacium* sp. *Phyllodistomum* sp.	Al, Cr, Mn, Fe, Ni, Cu, As, Cd and Pb	Brazil	Leite *et al.* (2021)
Barbus barbus	Muscle, liver, intestine and kidney	*Pomphorhynchus laevis*		Hungary	Thielen *et al*. (2004)
Clarias gariepinus Oreochromis niloticus niloticus	Gills, intestine, liver and kidney	*Acanthosentis tilapiae, Clarias gariepinus,, Paracamallanus cyathopharynx Orientocreadium lazeri*	Ag, Al, As, Ba, Bi, Cd, Co, Cr, Cu, Fe, Ga, Mg, Mn, Ni,	Egypt	Shahat *et al.* (2011)

			Pb, Sb, Sn, Sr, Tl and Zn		
Anguilla anguilla	kidney, liver, muscle,	*Anguillicola crassus Proteocephalus macrocephalus*	As, Cd, Cr, Cu, Hg, Ni, Pb and Zn	Portugal	Eira *et al*. (2009)

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