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Assessment of Difference Between Heavy Metals Concentrations in Water and Zooplankton

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ABSTRACT

Heavy metals are among the most dangerous pollutants in the natural environment due to their persistent toxicity and bioaccumulation problems, and hence they are considered a global problem. Additionally, they are stubborn, and most of them are poisonous to aquatic organisms when they reach a particular concentration. Zooplankton can continue serving as a monitor for the water situation, depending on how highly responsive they are to various contaminants. Zooplankton's ability to accumulate metals was assessed based on the categories of the bioaccumulation factor (BAF). There was no probability since all heavy metal BAFs were less than 1000 (BAF< 1000), however iron (Fe) in zooplankton samples from the two drains and aluminum (Al) in drain one sample fell into the 1000< BAF< 5000: bio-accumulative category. The metal pollution index (MPI) was calculated to compare the levels of the overall metal pollution in zooplankton. In the studied drains, the values were 16.902 and 17.924. The zooplankton can therefore be widely used in the biological monitoring and assessment of safe environmental levels of heavy metals.

INTRODUCTION

Declining water quality has become a serious risk to the aquatic life in Egypt. Untreated wastewater discharge into aquatic environments has emerged as a significant problem. Metal pollution in the aquatic environment is a serious global problem that is growing rapidly **(Aiman *et al.*, 2016)**. Metals can be found in the environment as free ions, solid colloidal particles, or solid phases. Heavy metals are an essential type of element when it comes to aquatic contaminants due to their strong effects on the balance of aquatic systems, capacity to accumulate over time in water and sediments, long-term persistence, and bioaccumulation in living organisms **(Monroy *et al.*, 2014)**. Air deposition, geological matrix erosion, industrial effluents, domestic sewage, mining wastes, and agricultural practices are the primary ways through which metals reach the water **(Elkady *et al.*, 2015)**. Some of these metals include As, Cd, Pb, and Hg, which are toxic to biota, even at low quantities, whereas others, like Cu, Zn, Fe, and Mn, are physiologically essential elements of aquatic ecosystems and only become toxic at extremely high concentrations **(Biswas *et al.*, 2012)**.

For higher trophic levels, they may act as the carriers of minerals and metals that are both necessary and optional **(Yılmaz *et al.*, 2010)**. Heavy metals can directly affect organisms by accumulating in the body or indirectly by migrating up the food chain to the next trophic level. In the food chain, heavy metals are accumulating from both bioaccumulations from the food source and buildup from the environment, such as water or sediment **(Ali *et al.*, 2021)**. This has led to the extensive use of aquatic biota in the biological detection and assessment of safe environmental levels of heavy metals. The species diversity and/or quantity of plankton can be used as a measure of water quality since they are sensitive to a variety of pollutants. Many constituents including toxic pollutants from the ambient matrix can be effectively absorbed or adsorbed by zooplankton due to its significant surface to volume ratio. As a result, a plankton chemical examination could reveal the presence of contaminants such as heavy metals **(Ibrahim & Joseph, 1995)**. Living organisms absorb and concentrate chemicals from their surroundings and diet, storing them inside their bodies through a process known as bioaccumulation. When an organism absorbs a chemical substance through its skin and respiratory surface, it distributes, transforms, and releases it back into the environment (elimination). This process affects the internal concentration of the chemical within the organism **(Ernawati, 2014)**.

In this study, the concentration of heavy metals accumulated in zooplankton was estimated, and its levels were compared to those in the water. Another objective was to determine how different sources of contamination with heavy metals would accumulate in zooplankton in two different aquatic ecosystems.

MATERIALS AND METHODS

The study areas were chosen based on how human activity, home sewage effluents, industrial waste, and agricultural activation affect the water quality. The study selected two drains where there are many activities. The first one is 47km long and has 13 branch drains. Each year, these branches discharge into the Rosetta branch about 290 million m^3 of agricultural wastewater. Six towns that release their waste into the drainage system supply the sewage water that fills this drain, while two active companies generate the industrial wastewater. At its discharge point to the Rosetta branch, a recommended maximum discharge of 0.97 million m^3 was planned for the first drainage system and its branches. Discharges from industrial operations were 0.0002 million m^3 per day, those from sewage treatment were 0.16 million m^3 per day, and those from agricultural activities were 0.81 million m^3 per day **(Abdel-Khalek *et al.*, 2020)**. The second main contaminant along the Rosetta branch is the discharge from the second drain. Waste from untreated housing is also drained into the second drain from the dairy and agricultural sectors. This drain transfers a daily water flow of approximately 450,000m^3 (118,877,400 gallons) **(Mostafa, 2014)**. Four neighborhoods dump about 200,000m^3 of untreated sewage into the second drain. The industry produces approximately 5500m3 (or 1,452,946 gallons) of effluent every day. This drain furthermore receives agricultural drainage water on a daily average of 250,000m^3 (66,043,000 gal) **(Mostafa, 2015)**.

Fig. 1. A map of the Nile Delta showing studied drains

Standard techniques for examining water and wastewater were used to investigate the water sample **(APHA, 2005)**. The pH, electric conductivity, and dissolved oxygen were measured *in situ* using the multi-probe system, a model Hydra Lab-Surveyor, and rechecked in the laboratory using the following bench-top equipment to ensure data accuracy. To preserve the samples for metal analysis, strong nitric acid was injected to lower the pH below 2 and stop any microbial responses. The samples were analyzed by inductively coupled plasma-optical emission spectroscopy (ICP-OES) with the ultra sonic nebulizer (USN) model Perkin Elmer Optima 3000. The final metal concentrations were expressed as mg/ l for water and as µg/ g dry weight for zooplankton. Collecting zooplankton (30L) was passed through a plankton net with a mesh size of 55 micrometers to retain zooplankton and exclude the majority of phytoplankton. The filtered volume was divided into two halves, one of which was preserved with 4% formaldehyde until it was processed in the lab, and zooplankton was examined and identified by the Sedwgwish Rafter counting method using an olympus binocular compound microscope. The remaining filtered samples were kept in plastic jars and kept frozen. Then, using Whatman GF/C filter paper that had been pre-weighed under a light vacuum, the zooplankton samples were filtered in the lab. The filter paper was weighed using a balance with 0.001mg accuracy after being dried in a desiccator to a constant weight. The dry weight of the plankton was estimated by subtracting the initial weight of the filter paper from the end weight. The filter paper and dried plankton were wet ached to determine the presence of heavy metals. Samples were heated in a (1:10, V/V) solution of concentrated sulfuric and nitric acids while in reflux. After around 4 hours of reflux, 4ml of hydrogen peroxide was added to clean the solution. The digest was filtered and then chilled. The filtrate and the water samples were tested for the presence of heavy metals using inductively coupled plasma-optical emission spectroscopy (ICP-OES), (Perkin Elmer Optima-3000 Redial). A reagent blank was made in the same way on ordinary filter paper **(Ibrahim & Joseph, 1995)**.

RESULTS

Due to the quantity of sewage discharges from commercial, industrial, and residential establishments that the two drains receive, they are the primary causes of water contamination along the Rosetta branch and connected drains. Table (1) displays the mean value for the effective physicochemical characteristics that were measured. Water's electric conductivity is defined as its capacity to carry an electrical current. The average EC values that were recorded were as follows: the second drain reported an average EC of 1.6ms/ cm, while the first drain reported an average EC of 1.3ms/ cm. In case of dissolved oxygen concentration, the average concentration during the study ranged between 1.5 and 2.1mg/ l in the two drains.

Table 1. Average of physicochemical parameters of water from the studied sites

Parameter	First drain	Second drain	Law 48 item (51) for 2013
pH	8	7.8	6.5-8.5
EC	1.3	1.6	--
Dissolved oxygen (DO mg/l)	1.5	2.1	--

Although EC and DO have no recommended limits, law (48) for the year 1982 and its updated law (51) for 2013 both state that the pH value for surface drainage water was within legal limits. Poor zooplankton variety and density in the study area were a result of anthropogenic effects, as well as discharge quantity and quality. Among the Rotifera species, *Brachionus* and *Philodina* species prevailed. The dominance of these large species within the Rotifera group explains the low numbers of other Rotifera species like *Horaella*, *Trichocerca*, and *Polyarthra*, Protozoa species (*Vorticella* and *Arcella*), and the disappearance of other groups. The extremely low or disappearing of zooplankton density of Copepoda may be due to changes in abiotic factors (temperature, pH, and food availability).

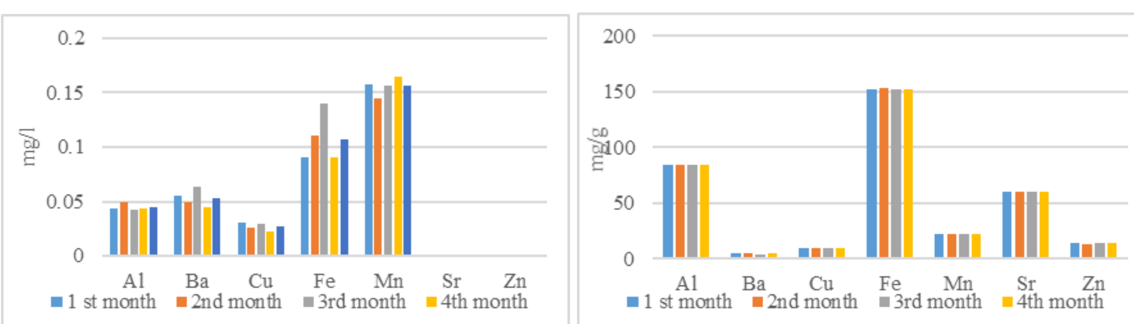
As best as we can tell, no previous research has been done on the concentrations of heavy metals in zooplankton in the study area. Table (2) summarizes the levels of heavy metals found in water samples taken from the two drains, whereas Table (3) shows the levels found in zooplankton. According to the results, zooplankton contained a disproportionately higher amount of heavy metals than water.

Table 2. Heavy metals concentrations in water samples

	Water heavy metals of 1st drain					Water heavy metals of 2nd drain					Law 48 item (51) for 2013
	1st month	2nd month	3rd month	4th month	Average	1st month	2nd month	3rd month	4th month	Average	
Al	0.044± 0.004	0.05± 0.115	0.042± 0.002	0.043± 0.003	0.045	<0.007	<0.007	<0.007	<0.007	<0.007	--
Ba	0.055± 0.002	0.049± 0.001	0.064± 0.002	0.045± 0.003	0.053	0.056± 0.002	0.048± 0.002	0.066± 0.004	0.042± 0.003	0.053	--
Cu	0.031± 0.002	0.026± 0.002	0.03± 0.002	0.022± 0.004	0.027	0.029± 0.002	0.032± 0.003	0.04± 0.003	0.031± 0.002	0.033	< 1
Fe	0.09± 0.002	0.11± 0.010	0.14± 0.002	0.09± 0.003	0.107	0.056± 0.003	0.064± 0.001	0.058± 0.003	0.061± 0.003	0.06	< 3
Mn	0.158± 0.002	0.145± 0.003	0.157± 0.082	0.165± 0.005	0.156	<0.004	<0.004	<0.004	<0.004	<0.004	< 2

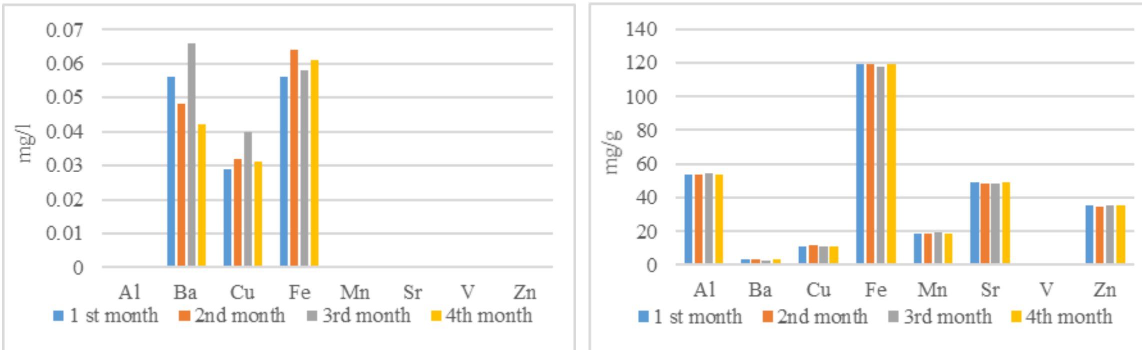
Table 3. Heavy metals concentrations in zooplankton (µg/ g)

	Zooplankton heavy metals of 1st drain					Zooplankton heavy metals of 2nd drain				
	1st month	2nd month	3rd month	4th month	Average	1st month	2nd month	3rd month	4th month	Average
Al	84.854± 0.041	83.989± 1.000	84.855± 0.330	84.859± 0.384	84.643	53.769± 0.194	53.798± 0.306	54.297± 0.213	53.658± 0.254	53.881
Ba	4.944± 0.354	4.856± 0.514	3.988± 0.188	4.785± 0.830	4.643	3.561± 0.359	3.521± 0.103	2.97± 0.045	3.681± 0.205	3.433
Cu	9.885± 0.142	9.979± 0.152	9.87± 0.385	9.791± 0.166	9.881	11.349± 0.122	12.102± 0.517	11.281± 0.017	11.241± 0.076	11.493
Fe	151.981± 1.501	152.867± 0.870	151.889± 0.635	152.788± 0.053	152.381	118.926± 0.130	118.839± 0.126	117.948± 0.036	118.913± 0.054	118.657
Mn	21.748± 0.502	22.019± 1.511	22.361± 0.389	21.967± 0.306	22.024	18.501± 0.172	18.911± 0.056	19.214± 0.227	18.298± 0.004	18.731
Sr	60.459± 0.871	60.399± 0.761	59.998± 0.612	60.095± 1.049	60.238±	48.789± 0.196	48.398± 0.146	48.487± 0.086	48.955± 17.307	48.657
V	<	<	<	<	<	0.815± 0.052	0.828± 0.045	0.839± 0.039	0.801± 0.059	0.821
Zn	13.894± 0.231	12.999± 0.639	13.696± 0.517	13.697± 0.407	13.571±	35.275± 0.742	34.869± 0.369	35.574± 0.130	35.477± 0.177	35.299



(a) (b)

Fig. 2. The heavy metals concenteration in (a) water and (b) zooplankton of first drain



(a) (b)

Fig. 3. The heavy metals concenteration in (a) water and (b) zooplankton of second drain

In the first drain water sample, the highest concentrations of metals were found to be Mn> Fe> Ba> Al> Cu, while other elements were below the detection thresholds. Fe> Ba> Cu were the metals that were most abundant in the second drain, with the remaining metals being below detection thresholds. Al and Ba are exempt from the law's recommended limitations under law (48) for the year 1982 and its edition no. 51 (2013), while Cu, Fe, and Mn were below the law's recommended and acceptable limits. In the second and first drains, respectively, the discovered metals were in the following order according to the zooplankton samples: Fe> Al> Sr> Mn> Zn> Cu> Ba and Fe> Al> Sr> Zn> Mn> Cu> Ba> V. This shows that these metals' abundance in water does not follow the same trend as zooplankton's.

Metals' bioaccumulation factor (BAF)

When a chemical substance is consumed by an organism by any exposure route, including dietary and environmental sources, the process is referred to as "bioaccumulation." Additionally, bioaccumulation is the end consequence of chemical absorption into the organism at the respiratory surface and from the diet, as well as chemical removal from the organism by procedures, such as respiratory exchange, fecal digestion, metabolic bio-transformation of the parent molecule, and growth dilution **(Arnot & Gobas, 2006)**. The bioaccumulation factor (BAF), which was used to evaluate an aquatic organism's capacity to absorb chemicals from its surroundings, provided general details on how a substance develop rich in biota in relation to the environment **(Arnot *et al*., 2022)**.

Arnot and Gobas (2006), **Authman *et al.* (2013)** and **Ernawati (2014)**, respectively, used the following equation:

BAF= Metal concentration in the organ (µg/ g)/Metal concentration in water (mg/ 1).

Aquatic species have the ability to bioaccumulate environmental toxins up to a million times their reported water column concentrations. The zooplankton of the first drain accumulated extremely high levels of Al (1880.952), followed by Fe (1424.121), Cu (365.961), and Mn (141.178), and only mild levels of Ba (87.601), Sr (60.238), and Zn (13.571), according to the calculated BAF from the locations. The second drain's BAF showed significant accumulation of Fe (1977.612) and Cu (348.259), as well as intermediate accumulation of Ba (64.770), Al (53.881), Sr (48.657), Zn (35.299), Mn (18.731), and V (0.821) (Fig. 4). The substantial ability of zooplankton to accumulate huge amounts of heavy metals is confirmed by these findings.

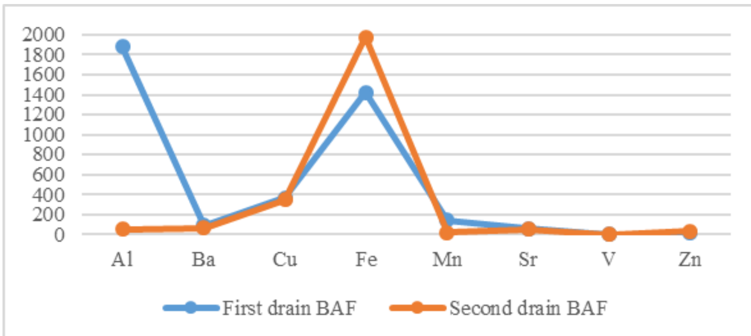


Fig. 4. Bioaccumulation of heavy metals

Metal pollution index (MPI)

According to the following formula, the metal pollution index (MPI) was developed to compare the total metal load in zooplankton among different sites **(Usero *et al*., 1997)**:

MPI= (M1×M2 × M3 ×….. Mn)$^{1/n}$

Where, Mn is the concentration of metal in (µg/g dry weight) that is present in a particular tissue. This index was assessed in order to ascertain the total amount of metals contained in the samples of the target zooplankton species obtained at the study sites. The findings show the absence of appreciable variations between the two drains' zooplankton level of heavy metals. First drain's MPI value was 17.924, as opposed to second drain's 16.902 MPI. This may be due to the zooplankton's levels of metal accumulation, which depend on parameters, such as pollution levels, assimilation potential, life cycles, zooplankton density and elimination/uptake rates, at the two sites having essentially the same factors.

Statistical analyses

The SPSS 20 statistical program was used to analyze the data from this investigation. In order to identify the significant differences between locations in the concentrations of heavy metals in water and zooplankton, a two-way ANOVA was used. The Pearson correlation was additionally used to evaluate the connections between the heavy metals in zooplankton and the water in the two drains. In addition, several study's figures were designed using Microsoft Excel.

DISCUSSION

The primary source of metals in agriculture waste and drainage canals is the dumping of household waste flows, which include relatively high concentrations of metals derive from products, viz. toothpaste, cleansers, cosmetics and human faeces **(Stephenson, 1987)**. The low average concentrations of the dissolved oxygen during the study could result from the breakdown of the floating organic waste is consistent with the amounts seen **(Fathi & Flower, 2005)**. Transparency, temperature, pH, water exchange rates, and food availability (such as Chl a, b, and c) were found to be the main factors affecting zooplankton diversity and abundance **(Benitez-Diaz *et al*., 2014; Tahoun *et al*., 2021)**. The food chains of ecosystems are critically dependent on zooplankton, which is a source of nutrition for higher organisms such as fish. The biogeochemical cycling of metals, especially particle-reactive metals in the water column of ecosystems, depends on zooplankton, which are the primary consumers. Adsorption greatly aids in the accumulation of metals from the environment by attaching to many functional groups present in the extracellular matrix of plankton. While the majority of research has focused on determining whether trace metals can build up in organisms to levels that may be harmful to human health, there has also been a rise in interest in understanding how trace metals cycle through the aquatic environment and the potential harm that metals could do to the biota there **(Ravera, 2001)**. Although no standard quality of the heavy metal concentrations in plankton has been made so far; therefore, this data could be used as a baseline study to determine the degree of heavy metal pollution **(Widiastuti *et al*., 2023)**. Heavy metals in first drain water were found in the following order: Mn> Fe> Ba> Al> Cu, while Ba> Cu> Fe were found in that order in the second drain, but Al and Mn were below detection levels. In the zooplankton samples from the two drains Fe, Al, and Sr were nearly identical, while Mn> Zn> Cu> Ba were the concentration order for the heavy metals in the first drain, and it was Zn > Mn > Cu >V in the second drain. According to **Chouvelon *et al*. (2019)**, the variations between different sites are probably as a result of the distinctive zooplankton assemblages and dissolved metal concentrations at each site.

The distribution and behavior of the metal in the aquatic environment are significantly impacted by the emission of pollutants and other anthropogenic activities **(Willy *et al*., 1998)**. Plankton is frequently the primary food source for many predators. It may significantly contribute to the transfer of heavy metals to higher trophic levels. Therefore, studying the amounts of heavy metals in plankton is crucial. The results showed that metal concentrations in zooplankton were significantly greater than in water. This could be as a result of the broad surfaces of the two main dominating zooplankton species

(*Brachionus* and *Philodina*), which are considered as tolerant pollution species and have a large contact area that can interact with metals in the environment. Additionally, many pollutants are quickly absorbed due to their active metabolism **(Ismail & El Zokm, 2023)**. The water body's production, physical-chemical characteristics, zooplankton species makeup, and ability to absorb heavy metals are among the factors that have been reported to influence the concentration of heavy metals in zooplankton **(Isibor *et al.*, 2020)**.

Iron (Fe), which is regarded as an essential trace element for the biological requirements of zooplankton and frequently acts as a limiting parameter of growth **(Battuello *et al.*, 2016)**, was present in the highest concentrations in the study for zooplankton with a value of 152.381µg/ g dry weight in the first drain, and 118.657µg/ g dry weight in the second drain. The average concentration of aluminium (Al) varied between 84.643 and 53.881µg /g dry weight in the first and second drainage, respectively. According to **Desouky *et al.* (2002)** and **Quiroz-Vazquez *et al.* (2010)**, some species can accumulate significant levels of Al when the pH is close to neutral (between 6.0 and 8.2), which might cause serious physiological and behavioral disturbances as breathing and reproductive capabilities. Sr and Ba are frequently found together with particulate organic carbon in sediments and the water column, indicating that organisms can collect these elements **(Yan *et al.*, 2016)**. Sr is more soluble and accessible than Ba, and because of this, organisms tend to collect it more than Ba in aquatic environments, where it can be found in substantial concentrations in some species, even if it is only present in trace amounts. Ba concentrations were 4.643 and 3.433µg/ g dry wt, and Sr concentrations were 60.238 and 48.657µg/ g dry wt, respectively, in the first and second drainages. Manganese (Mn) which occurs naturally in water at specific concentrations, is bioaccumulated by the lowest trophic species **(Achary *et al.*, 2020)**. It was detected in the samples of the two drains' zooplankton at quantities of 22.024 and 18.731µg/ g dry weight, respectively. Zn recorded concentrations of 13.571µg/ g dry weight in the first drain and 35.299µg/ g in the second although Cu registered low concentrations (9.881µg/ g in the first drain and 11.493µg/ g in the second), which can be attributed to their active uptake and storage **(Isibor, 2020)**. Only the second drain zooplankton samples had vanadium (V), a trace metal that is thought to have leaked into the soil matrix, as a result of the application of fertilizers containing V in agriculture, sewage sludge, or steelmaking slag. The average concentration of vanadium in these samples was 0.821µg/ g. Vanadium compounds are currently considered a threat to the environment due to their detrimental effects on plants and animals **(Hanus-Fajerska *et al.*, 2021)**.

Metal deposition in organisms is in a state of dynamic balance based on a range of external and internal variables, such as the source of the pollution, accumulation methods, assimilation efficacy, life cycle, elimination rate, uptake rate, and detoxification mechanisms. **Ferrández-Severini *et al.* (2013)** found that zooplankton with higher metal bioaccumulation also had lower rates of metal metabolism and excretion. Zooplankton modify their accumulation methods by speeding up metal excretion and slowing down metal intake when the amount of metals in their bodies are too high or not needed by them **(Calbet *et al.*, 2016)**.

The bioaccumulation factor (BAF) provides a comprehensive picture of how metals are enriched in organisms **(Achary *et al.*, 2020)**. Metal concentrations in the environment are mirrored in the vital tissues' accumulation of these metals, which then accumulate in their tissues in considerable proportions that are higher than those found in their surroundings **(Homira *et al.*, 2008)**. Additionally, aquatic organisms that live in low-oxygen environments should speed up their respiration to compensate for the lack of oxygen, which will enhance the accumulation of metals **(Abdel Khalek, 2015)**. The elevated metals accumulation in the investigated zooplankton are likely caused by the high discharge activity and low measured oxygen contents (1.5 and 2.1mg/ l) in the two drains. Metal bioavailability, water's physicochemical characteristics, species, age, and physiological state are only a few examples of the numerous interactions between exogenous and endogenous factors that cause aquatic biota to absorb metals **(Moiseenko & Kudryavtseva, 2001)**. According to the average BAF from the sampling locations (Fig. 4), zooplankton accumulated extremely high levels of Al (1880.952), Fe (1424.121), Cu (365.961), and Mn (141.178), moderate levels of Ba (87.601) and Sr (60.238), and the lowest accumulation levels of Zn (13.571) in first drain zooplankton. Fe (1977.612), Cu (348.259), Ba (64.77), Al (53.881), Sr (48.657), Zn (35.299), and V (0.821) had the average BAF for second zooplankton samples. Inability to migrate away from metal sources, dissolved metals adhering to exoskeletons, and active or passive metal absorption into gastrointestinal tracts may all be factors in the increasing accumulation of heavy metals in contaminated habitats for zooplankton **(Brewer *et al.*, 2012; Ju *et al.*, 2019)**. The bioaccumulation efficiency of non-essential metals (Sr, Ba, and V) is lower than that of essential metals (Fe, Cu, and Mn), which have a high bioaccumulation efficiency. Important elements may have a much higher BAF due to their role as enzyme activators. In light of the fact that zooplankton may bioaccumulate various metals in its tissues at various concentrations, our study suggests that zooplankton may be a suitable bioindicator for monitoring metal pollution in multiple aquatic hot zones. **Arnot and Gobas (2006)** stated that the following categories are used to classify heavy metal BAFs: BAF less than 1000 denotes no risk of accumulation, 1000 <BAF <5000 suggests bioaccumulative behavior, and BAF more than 5000 indicates extremely bioaccumulative behavior. Fe and Al were classified as being in the 1000 < BAF < 5000: bio-accumulative group in zooplankton samples from both drains. The other metal BAFs were below 1000 (BAF< 1000), suggesting that there was no chance, which is consistent with the results of **Olayinka-Olagunju *et al.* (2021)**.

Upon evaluating the correlation coefficient, keep in mind that correlation simply depicts a level of linkage and cannot establish causality **(Vucinic *et al.*, 2012)**. According to the bioaccumulated metals in the zooplankton bodies, correlation analysis was done for the metal content found in the water and zooplankton. It was found that the two aqueous metal contents had a substantial effect on the bioaccumulated metals in the zooplankton tissue. Al, Ba, Cu, Fe, Mn, and Sr were the six metals that demonstrated a significant positive strong association (p-value 0.05) in the ANOVA analysis of metal concentration in water and zooplankton, whereas V and Zn had a negative correlation ($P > 0.05$) (Table 4).

Table 4. ANOVA values represent the type of sample and ANOVA values represent sites

	ANOVA values represent the type of sample			ANOVA values represent site		
	df	F	Sig.	df	F	Sig.
Al	1	20.265	0.046	1	0.094	0.788
Ba	1	43.386	0.022	1	0.045	0.852
Cu	1	72.812	0.013	1	0.027	0.884
Fe	1	1315.357	0.001	1	0.002	0.972
Mn	1	151.661	0.007	1	0.014	0.916
Sr	1	88.415	0.011	1	0.022	0.895
V	1	1.000	0.423	1	1.000	0.423
Zn	1	5.059	0.153	1	0.330	0.624

Based on the Pearson correlation coefficient, the study provides a possible relationship between zooplankton and the average concentration of heavy metals in water drains, as represented by Fe (P= 0.001 & r = 0.999**), Mn (P= 0.007 & r = 0.993**), Sr (P= 0.011 & r = 0.989*), Cu (P= 0.013 & r = 0.987*), Ba (P= 0.022 & r = 0.978*), Al (P= 0.046 & r = 0.954*). In the case of Zn and V the (P> 0.05) indicating no correlation (Table 5).

Table 5. Pearson correlation of heavy metals in water and zooplankton

	Type of samples	Al	Ba	Cu	Fe	Mn	Sr	V	Zn
Types of samples	1								
Al	.954*	1							
Ba	.978*	.996**	1						
Cu	.987*	.892	.930	1					
Fe	.999**	.965*	.985*	.979*	1				
Mn	.993**	.982*	.995**	.961*	.997**	1			
Sr	.989*	.988*	.998**	.951*	.994**	.999**	1		
V	.577	.306	.393	.703	.545	.481	.449	1	
Zn	.847	.648	.716	.922	.825	.780	.758	.923	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The degree of metal contamination in zooplankton was described by comparing high total metal content (MPI), which implies an elevated amount of pollution in the zooplankton, between study locations **(Ju *et al.*, 2019)**. By addressing the estimated MPI, it can be seen that the zooplankton samples are not very metal-contaminated. The first drain has an MPI of 17.924 in the current research, while the second drain is 16.902.

CONCLUSION

It is well established that human activity has a substantial impact on the biological condition of many aquatic surfaces and that many types of pollution can imperil an aquatic ecosystem. According to the study, zooplankton had metal concentrations that were significantly greater than those in water. The results of this study indicate that the dominant zooplankton species (*Brachionus* and *Philodina*), due to their huge surface area in comparison to their mass unit and active metabolism, which causes the rapid adsorption of various contaminants, may be to blame for the bioaccumulation of metals in zooplankton. The results of the bioaccumulation factor (BAF) calculation were also used to determine that zooplankton exhibits a significant tendency for the accumulation of specific metals. In light of the findings, the bioaccumulation factor can be utilized to explain why heavy metals are bioaccumulating in contaminated aquatic environments. More research is necessary to investigate how much the population composition of zooplankton is changed by metal toxicity in the water column, which serves as the main food source for fish that are ultimately consumed by humans. The information provided by this study can thus be used as a starting point for further research into these aquatic systems.

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