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RESEARCH

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Modulation of Trace Metal Accumulation in the Liver and Intestine of Amphibian Host *Sclerophrys regularis* by the Enteric Parasite *Cosmocerca* spp. Sampled in Lagos Metropolis, Nigeria

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Abstract

Background: Recent studies have shown parasites as accumulation indicators that give critical information about the bioavailability of pollutants. To further buttress parasites in the assessment of metal sink potentials, the parasite *Cosmocerca* sp. was analyzed in a total of 168 host toads, *Sclerophrys regularis*, from three (3) study stations sampled around dumpsites and natural habitats in selected parts of Lagos Metropolis.

Method: Concentrations of Zn, Ni, Co, Cu, and Pb in the soil, parasite, intestine, and liver of toads at each location were analyzed using flame atomic absorption spectrometry.

Results: Comparison based on the concentrations of metals in *S. regularis* liver regardless of the collection site (dumpsite and natural habitat) showed that the most accumulated metal was zinc. Zinc significantly accumulated in the liver of the uninfected toad at the dumpsite, followed by the infected counterparts. There was also significant bioaccumulation of lead in the liver of the uninfected toads followed by the infected toads at the dumpsites. The accumulation of lead in the toads in their natural habitats was insignificant. The significant biota-sediment accumulation of copper in the liver was in the order of infected toad at dumpsite > infected toad at natural habitat > uninfected toad at habitat. Copper accumulation in the uninfected toad at the dumpsites was insignificant. As for cobalt, the significant biota-sediment accumulation in the liver was in the order of uninfected toad at dumpsite > infected toad at dumpsite > infected toad at habitat. Insignificant bioaccumulation occurred only in the uninfected toad at the natural habitat. A strong positive correlation (0.9546) between the concentrations of metals in the liver and the intestine indicated a common source of contamination and relatively proportional accumulation rates. Although there was a significant positive correlation between the concentrations of metals in the intestine and the parasites, a significantly negative correlation relationship, however, occurred between the concentrations of metals in the liver and the parasites.

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Conclusions: This current study has demonstrated the possibility of employing *Cosmocerca* sp. as a bio-sink and bioindicator for zinc contamination. The parasites may therefore be promising in protecting *S. regularis* and safeguarding the health of the associated populace.

Keywords: Metal sinks, Bioaccumulation, Contamination, Dumpsite

Background

Several studies have revealed a marked accumulation potential of various parasite groups and have established them as useful sentinels for xenobiotics. Other studies have also demonstrated the potential of parasites to depurate toxicants (Isibor et al., 2020). They can bioconcentrate contaminants in environmental media that are present in extremely low concentrations and make them observable and quantifiable using traditional analytical procedures. Furthermore, studies have shown wide variability intolerances among various taxa of parasites as sentinels for polluted habitats (Sures et al., 2017). Parasites could also be used as diagnostic tools for assessing the toxicodynamics in the environment and to what degree they are available for uptake by the biota because they can serve as accumulation indicators that provide important information about the biological availability of pollutants (Al-Quraishy et al., 2014; Čadková et al., 2014; Courtney-Hogue, 2016; Leite et al., 2017). Trace metals are persistent and bioaccumulative. They traverse phospholipid cell membranes, causing harm at all levels of organization in the exposed biota (Walker et al., 2001). Ecologically unacceptable concentrations of trace metals in the Lagos metropolis in Nigeria have been earlier reported (Akinsanya et al., 2020).

Sclerophrys regularis also known as the square-marked toad or the African bouncing toad is a member of the family Bufonidae. It is considered a good source of protein for humans in many parts of sub-Saharan Africa (Adediran et al., 2014), particularly in Nigeria and Burkina Faso. Frogs and toads account for over 90% of all amphibians (Santos & Amato, 2010). They represent a vital link between the terrestrial and the aquatic ecosystem (Hayes et al., 2002; Unrine et al., 2007). The majority of adult frogs and toads eat insects, making them a key energy-efficient trophic link between invertebrates and vertebrates (Sparling et al., 2000). Amphibians are sentinel species because they have highly semipermeable moist epidermis and diverse lifecycle stages in both aquatic and terrestrial ecosystems (Alford & Richards, 1999). Hence, they qualify as indicators of environmental conditions. *S. regularis* may accumulate metals in their cells, higher than the background level in the ambiance due to the relatively higher permeability of their moist skin (Akinsanya et al., 2020). This notable susceptibility qualifies them as bioindicators in pollution studies (Johansson et al., 2001; Loumbourdis et al., 2007; Khattab et al., 2021).

Cosmocerca sp. is a gut-dwelling parasitic nematode of *S. regularis*. In their free-living stages, they inhabit moist soil and dry areas where this *S. regularis* spend most of its time. The larvae pierce the epidermis of the host before moving to the large intestine in a direct terrestrial life cycle (Saad et al., 2009).

Toxicants such as metals may confer immune suppression on exposed organisms, which renders the organism more susceptible to parasitic infections (Gilbertson et al., 2003; Luebke et al., 1997) and triggers lymphocyte proliferation (Christin et al., 2004) and eosinophilic granulocytes (Kiesecker, 2002), especially in the young amphibians such as tadpoles (Carey & Bryant, 1995; Milston et al., 2003; Pina-Vazquez et al., 2012). For example, Budischak et al. (2008) demonstrated that tadpoles, when exposed to toxicants during early development, suffered increased parasite susceptibility which continued long after exposure was discontinued.

Conversely, the concentration of metals in a host can be reduced through the metal sink functions of parasites (Akinsanya et al., 2020; Griggs & Belden, 2008; Koprivnikar et al., 2007). Complex interactions between pollutants and parasites have been observed, demonstrating parasites' potential to reduce pollution levels in infected hosts when compared to uninfected conspecifics (Sures, 2007, 2008; De Donato et al., 2017; Sures et al., 2017; Gilbert and Avenant-Oldewage, 2017). Some authors have recently reported the contaminant sink functions of parasites to outstrip their pathogenic effects (Akinsanya et al., 2019, 2020). *Sclerophrys regularis* are exotic species that are hunted as a scrumptious delicacy by subsistence and commercial hunters within the Lagos metropolis (Akinsanya et al., 2020). Contamination of the organs in the toads may be deleterious to the animals, as well as the consumers, and ultimately the entire linked organisms in the food chain.

The goal of the study was to evaluate the metal sink potentials of the parasites *Cosmocerca* sp. in its host toad, *Sclerophrys regularis* sampled around dumpsites and natural habitats in selected parts of Lagos Metropolis, Nigeria. The varied bioaccumulation capacities of the liver and the intestine of the infected and uninfected toads may shed light on the roles of the parasite in the biosequestration of the metals. The outcome of the study may

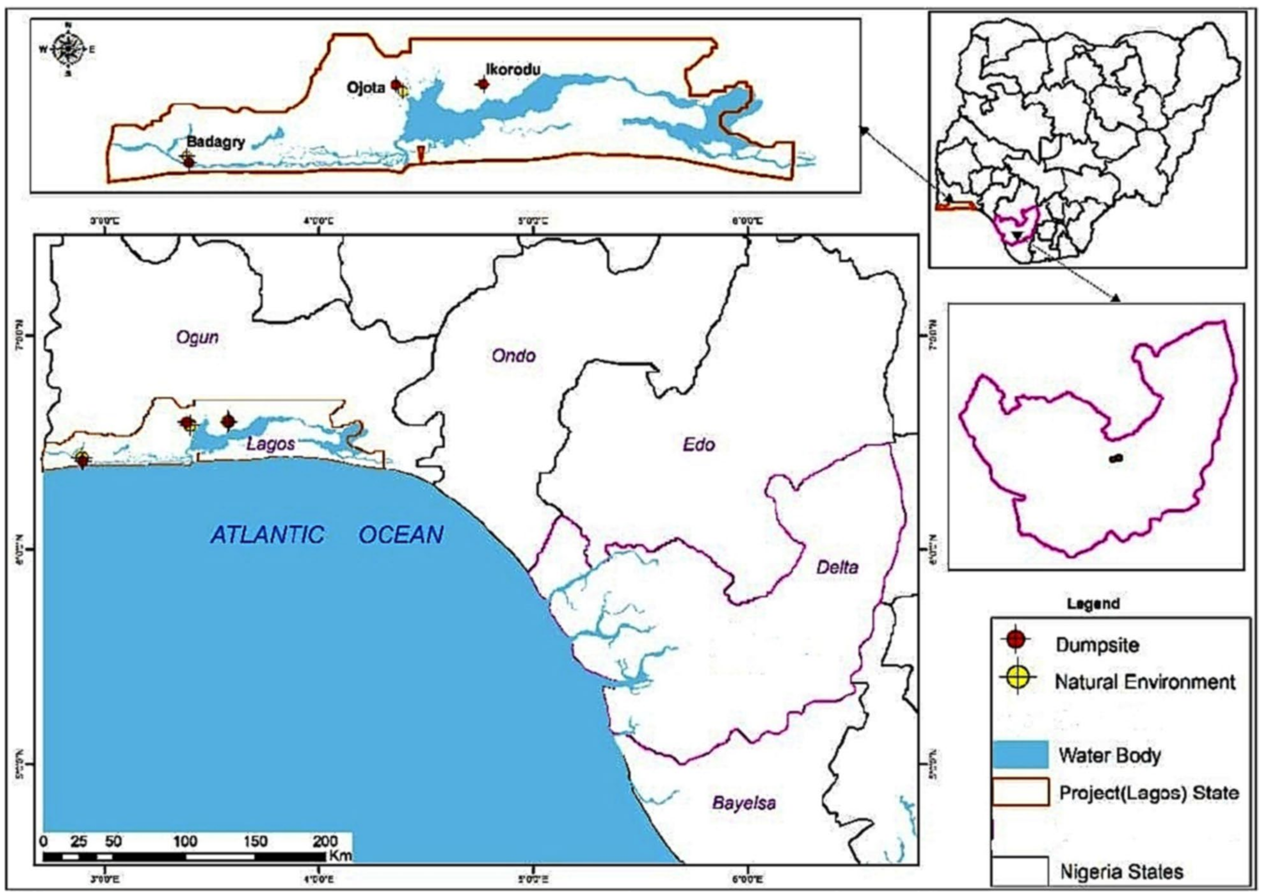

Fig. 1 Map showing sampled stations

advance the scientific knowledge on the complex interactions of parasites and pollutants in the host.

Methods

Description of the study area

Three (3) study stations, namely Ojota, Ikorodu, and Badagry, were located within the Metropolis of Lagos State, Nigeria (Fig. 1). These stations were selected based on the degree of anthropogenic activities within their vicinity and sampling logistics with the local toad hunters. At each station, two (2) locations were selected, namely a location with minimal anthropogenic activities was designated as natural habitat and another was designated as a dumpsite at strategic locations of anthropogenic activities. Therefore, six (6) sampling locations were designated; thus, Badagry dumpsite (06° 25′ 42″ N, 02° 53′ 25″ E), Badagry natural habitat (06° 24′ 49″ N, 06° 53′ 52″ E), Ojota dumpsite (06° 35′ 40″ N, 03° 22′ 39″ E), Ojota natural habitat (06° 34′ 47″ N, 03° 23′ 37″ E), Ikorodu dumpsite (06° 35′ 8042″ N, 03° 34′ 8016″ E), and Ikorodu natural habitat (06° 35′ 46″ N, 03° 34′ 34″E). The stations at the dumpsite were chosen for this study based on our observations of tremendous refuse dumped at these locations by the locals.

The research area's seasonality is defined by rainy and dry seasons typical of Nigeria's southern region.

Sample collections

A total of 168 specimens of *Sclerophrys regularis* were procured fresh but lifeless from toad hunters. At these locations, toads were hunted by a fragment of the populace for livelihood and/or consumption as an animal protein requirement. The hunters employed hand nets and perforated buckets for toad hunting, which spanned the periods of March 2020 and February 2021. The fresh toads were conveyed to the University of Lagos Zoology department's laboratory in ice chest coolers labeled according to stations for further investigations.

Afterward, the toads were dissected, and the intestine and liver were excised for trace metal analysis. The intestine of each toad was inspected for enteric parasites and stored in saline solution, identified using identification instructions such as those published by Colombo et al. (2005), Xing et al. (2005), Sures (2007), and Akinsanya et al. (2008). The sex of the source toad and the stations were then used to label the parasite samples. Soil samples were collected from 5 scattered spots at each sampling site with the aid of a Van Veen grab (30 × 15 × 28 cm) for 12 months, totaling 60 samples from each site. Samples collected/months were transported in ice-laden chest cooler, to the laboratory of the Department of Zoology, University of Lagos, where they were refrigerated at 4 °C pending analyses.

Morphometric and sex determination in toad

Sex was determined in the toad through physical observation of the throat area and then confirmed using Kobayashi et al. (2018) as an identification guide. Using an electronic digital weighing scale (model EK-1A SERIES), the weight of each toad was measured to the nearest 0.01 g. Using a vernier caliper, the morphometrics of the toads were determined and recorded; thus, HDL = head length, SVL = snout to vent length, LF = length of the forelimb, LH = length of the hind limb, TD = tympanic diameter. All lengths were taken to the closest 0.1 cm.

Tissue analysis

Two (2) gram wet weight samples of preserved intestine and liver were weighed individually into a PTFE beaker and digested with 25 ml of ratio 1:1 hydrogen peroxide and nitric acid on a hot plate in a fume cupboard. This was heated till the volume was reduced to about 5 mL. They were allowed to cool before being filtered and made up with distilled water in the 50-mL volumetric flask for the trace metals concentration analysis. Flame atomic absorption spectrometry (Philips model PU 9100) was used in analyzing the concentrations of Zn, Ni, Co, Cu, and Pb with detection limits of 0.05 μg g^{-1}, 0.05 μg g^{-1}, 0.01 μg g^{-1}, 0.05 μg g^{-1}, and 0.03 μg g^{-1}, respectively. All procedures were guided by SW-846 Test Method 7000B: Flame Atomic Absorption Spectrophotometry (USEPA, 2007). The limits of quantification (LOQ) for the metals were estimated as the mass fraction for which certainty and uncertainty were achieved, based on outputs of the computed ratios between the calculated and the reference mass fractions (i.e., calculated value/ reference value) in the calibration curves. The LOQs for Zn, Ni, Co, Cu, and Pb were 0.014, 0.012, 0.013, 0.011, and 0.014 mg. kg^{-1}, respectively. Results obtained were validated using material Buffalo River Sediment certified reference material (NIST 2704). The adequacy of trueness was evaluated using z scores, which indicated 6% SDs from the CRMS at a 95% confidence interval (ISO13528:2015, 2015).

Soil analysis

The soil samples were air-dried at room temperature and then sieved through a 2-mm mesh size. One gram of soil sample was homogenized and transferred into PTFE conical flask. A 25 mL of ratio 3:1 hydrochloric and nitric acid (aqua regia) was added to the soil sample in a fume cupboard. The mixture was then heated at 45 °C on a hot plate until the volume was reduced to about 5 mL. The mixture was filtered and made up with distilled water in a 50-mL volumetric flask. Zn, Ni, Co, Cu, and Pb were then analyzed using the flame atomic absorption spectrometry, and the concentration was expressed in μg/kg dry weight. The detection limits of zinc, nickel, and cobalt were 0.05 μg kg^{-1}, while that of lead was 0.03 μg kg^{-1}. All procedures were conducted in conformity with the guidelines of Jones (2001) and Estefan et al. (2013).

Quality control and assurance

All QC data were maintained and are available for easy reference and inspection. All standards, replicates, and blanks were prepared at the same time, covered during non-use, and used immediately to prevent contamination. The laboratory reagent blank was run to account for any interference or contaminant. Analar-grade reagents were obtained with their certificate of analysis. Each sample analysis batch was done with a certified reagent from the same lot/batch, with the lot number accurately documented.

Calibration of equipment

Before analysis of samples, the instrument was calibrated by injecting a series of calibration standards with a volume of 1 μL at an R^2 value of ≥ 0.995. A five-point calibration curve was prepared using the calibration standard that was commercially obtained. The response factor (RF) for each analyte/component in the calibration standard was calculated using the area response and the amount of standard material. The relative standard deviation percentage (%RSD) of the RF was calculated for each analyte across the calibration curve. The value was maintained at $\pm 15\%$ for the curve to be deemed valid. The calibration curve was verified at the end of each analysis batch and after every 20 samples by the use of continuing calibration verification (CCV) standard and a continuing calibration blank (CCB). The CCV was made from the same material as the initial calibration standards at or near mid-range. Samples following the last acceptable CCV/CCB were re-analyzed. The analysis data for the CCV/CCB were kept on file with the sample analysis data.

All glassware was treated with chromic acid and cleaned by washing with detergent and hot water and rinsed with tap water, distilled water, and acetone. The glassware was oven-dried at 150 to 200 °C for 30 min. The volumetric flask was rinsed with deionized water. After drying and cooling, glassware was sealed and stored in a clean environment to prevent any accumulation of dust or other contaminants. Before use, the glassware was rinsed once with chromic acid and twice with deionized water. Glasswares were oven-dried before.

Statistical analysis

The descriptive statistics (mean ± SE) of the trace metal concentrations in the soil and toad tissues were subjected to analysis of variance (ANOVA). The values were then subjected to the Duncan multiple range test (DMRT) to determine the precise locations of significant differences. To determine data homogeneity at 95 percent confidence intervals, the standard normal homogeneity (SNH) test was performed among the various groups.

Results

Comparison based on the concentrations of metals in the toad liver's regardless of the locations (dumpsite and natural habitat) showed that the most accumulated metal was zinc (Fig. 2). Furthermore, based on zinc concentrations, a comparison of the liver and intestine tissues among infected and uninfected *S. regularis* showed the order uninfected liver > infected liver > uninfected intestine > infected intestine.

This trend is more statistically buttressed in Table 1, with emphasis on the locations. As expected, dumpsites accumulated significantly higher concentrations of zinc than their counterparts in the natural habitats ($p < 0.05$).

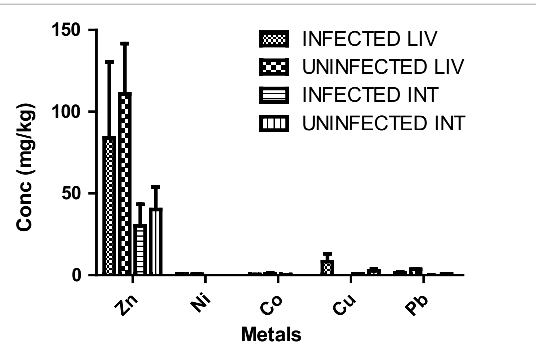

Fig. 2 Comparative concentrations of metals in the biological samples. Liv. = Liver. Int. = Intestine

The concentration of zinc in the liver of the uninfected toads was significantly higher than those of the infected counterparts ($p < 0.05$). This trend was consistent in both the natural habitat and the dumpsite. The concentrations of zinc in the liver of *S. regularis* at the dumpsite were higher than the limit set by FEPA (2003). It is, however, noteworthy that the concentration in the liver of the infected toad was lower (Table 1). Conversely, as for the intestines of the toads on the other hand, no significant difference occurred among the trace metals across the locations and the infected and uninfected groups ($p > 0.05$) (Table 1).

As expected, the highest bioaccumulation occurred in the tissues of the toads at the dumpsite (Fig. 3A). There was significant bioaccumulation of lead in the liver of the uninfected toads followed by the infected ones at the dumpsites. The accumulation of lead in the toads in their natural habitats was insignificant. The significant biota-sediment accumulation of copper in the liver was in the order of infected toad at dumpsite > infected toad at habitat > uninfected toad at habitat. The accumulation of copper in the uninfected toad at the dumpsites was insignificant. As for cobalt, the significant biota-sediment accumulation in the liver was in the order of uninfected toad at dumpsite > infected toad at dumpsite > infected toad at habitat. Insignificant bioaccumulation occurred only in the uninfected toad in the natural habitat. Zinc only significantly accumulated in the liver of the uninfected toad at the dumpsite, followed by the infected counterparts. No significant biota-sediment accumulation occurred in all toads at the habitats, and no significant biota-sediment accumulation was recorded for nickel in the toads at all the locations.

A noteworthy pattern was apparent in the roles the parasites played in influencing the bioaccumulation of the trace metals in *S. regularis*. The liver/parasite accumulation factor indicated significant bioaccumulation of lead and zinc in the parasites from the liver of the infected toads at the dumpsite only (Fig. 3B). Interestingly, the parasites in the toads in the natural habitat did not record a significant accumulation of the trace metals from the liver. As there were no parasites in the uninfected toads, the liver/ parasite accumulations recorded zero as expected.

As for the bioaccumulation in the intestine, only a fairly significant amount of lead and zinc were accumulated in the uninfected toads at the dumpsite (Fig. 3C). No significant accumulation of lead occurred in the infected toads at the dumpsite. Lead was also not accumulated in the infected and uninfected toads in the natural habitat. Outstandingly significant bioaccumulation of copper occurred in the intestine of the uninfected toads at the dumpsite, followed by the infected toads at the same location. The order of bioaccumulation of cobalt from the sediment into the intestine of the toads was: infected toads at the dumpsite > uninfected toads at the habitat > infected toads at the habitat. Cobalt did not accumulate in the intestine of the uninfected toads

Table 1 Concentrations of trace metals (mg/kg, Mean ± SD) in the liver and intestine of *Sclerophrys regularis* uninfected and infected with the nematode *Cosmocerca* sp. within the natural habitats and dumpsites from Lagos metropolis, Nigeria (March 2020–February 2021)

	Habitat		Dumpsite		FEPA (2003)
	Infected	Uninfected	Infected	Uninfected	
Liver					
Zn	9.49 ± 6.11[D]	30.0 ± 29.22[C]	**94.5 ± 31.62[B]**	**111 ± 15.28[A]**	75
Ni	0.120 ± 0.15	0.0993 ± 0.09	0.711 ± 0.61	0.415 ± 0.05	80
Co	0.354 ± 0.51	0.0253 ± 0.04	0.378 ± 0.43	0.855 ± 0.16	–
Cu	3.23 ± 1.98	1.59 ± 1.78	9.46 ± 3.66	0.000 ± 0.00	30
Pb	0.000 ± 0.00	0.310 ± 0.54	1.27 ± 1.33	3.60 ± 1.24	2
Intestine					
Zn	23.7 ± 4.88	34.9 ± 23.70	40.2 ± 35.19	40.2 ± 4.25	75
Ni	0.0713 ± 0.03	0.301 ± 0.07	0.010 ± 0.01	0.010 ± 0.001	80
Co	0.152 ± 0.09	0.0910 ± 0.15	0.022 ± 0.01	0.022 ± 0.02	–
Cu	0.145 ± 0.06	0.683 ± 0.14	3.47 ± 0.20	3.47 ± 0.64	30
Pb	0.235 ± 0.15	0.153 ± 0.24	0.676 ± 0.09	0.676 ± 0.12	2

Numbers with superscripts are significantly different in the order of A > B > C > D at $p < 0.05$. Emboldened figures are > the regulatory limit of FEPA (2003)

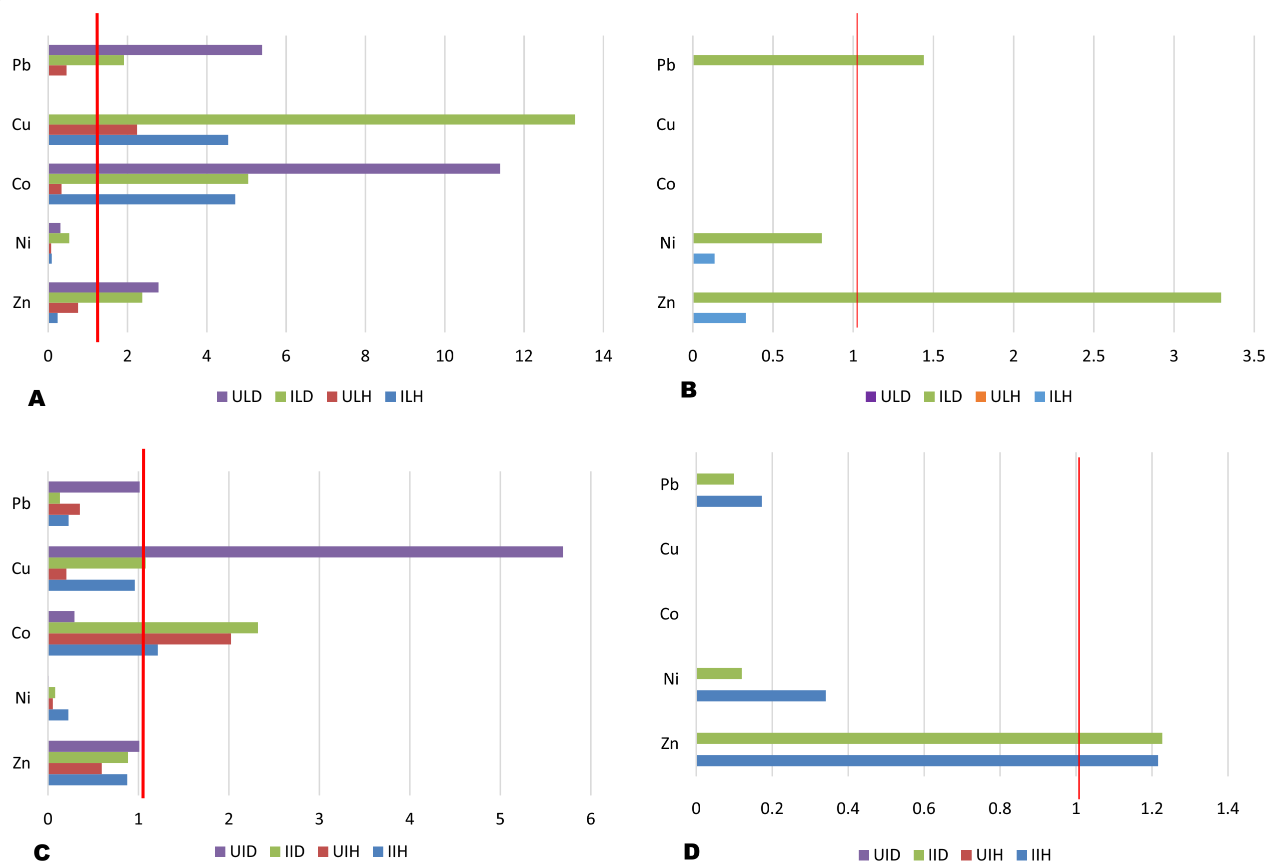

Fig. 3 Bioaccumulation of trace metals in toad *Schlerophrys regularis* and its enteric parasite *Cosmocerca* sp. A = liver/ sediment biota-sediment accumulation factor, B = liver/ parasite bioaccumulation factor, C = intestine/ sediment biota-sediment accumulation factor, D = intestine/ parasite bioaccumulation factor. Keys: ULD = uninfected liver at the dumpsite, ILD = infected liver at the dumpsite, ULH = uninfected liver at habitat, UID = uninfected intestine at the dumpsite, IID = infected intestine at the dumpsite, UIH = uninfected intestine at habitat, IIH = infected intestine at habitat

at the dumpsite, while none of the categories of toads accumulated nickel at any of the locations.

The role of the parasites in the dynamics of the trace metals revealed that the parasite significantly accumulated zinc only from the intestine of the infected toads at both the dumpsite and habitat at close rates (Fig. 3D). As expected, no significant parasite/ intestine bioaccumulation was recorded in the uninfected toads as there were no parasites present. The statistical output of data analyzed for lead, copper, cobalt and nickel in relation to the abundance of parasites was: lead: $F(1,22)=3.785$, $p=0.065$, $R^2=0.147$; copper: $F(1,22)=1.516$, $p=0.231$, $R^2=0.0644$; cobalt: $F(1,22)=0.089$, $p=0.769$, $R^2=0.004$; nickel: $F(1,22)=1.197$, $p=0.286$, $R^2=0.05$. The p values (>0.05) implied that the concentrations of these metals in *S. regularis* had no significant regression relationship with the abundance of the parasites. Also, the regression sum of squares showed that only 14% of lead, 6% of copper, 0.4% of cobalt, and 5% of nickel concentrations in the toad were influenced by the parasite abundance (Fig. 4A, B, D, E).

The regression equation of zinc $F(1,22)=0.379$, $p=0.04$, $R^2=0.682$ indicated that p-value for the relationship between the concentration of zinc in *S. regularis* and the parasite abundance was significant; being <0.05. Furthermore, the regression sum of square showed that 68% of the concentration of zinc was influenced by the abundance of the parasite in the host toad, which is an appreciable percentage (Fig. 4C). This implies that the concentration of zinc had a significant regression relationship with the parasites in the toad. A very strong positive correlation (0.9546) between the concentrations of zinc in the liver and the intestine indicates a common source of contamination and relatively proportional accumulation rates (Table 2). Although there was a significant positive correlation between the concentrations of metals in the intestine and the parasites, a significantly negative correlation

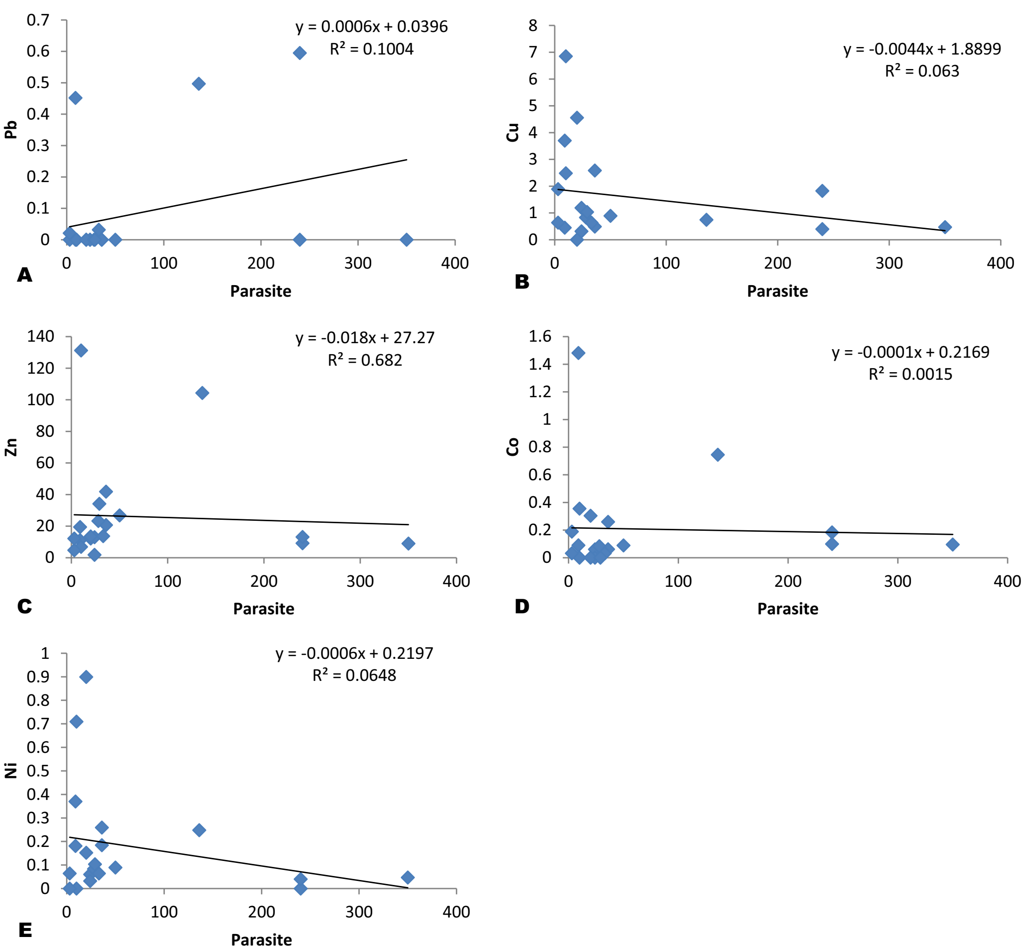

Fig. 4 Regression analysis of trace metal concentrations on the abundance of *Cosmocerca* sp. In the host toad. A = Regression analysis of lead, B = Regression analysis of copper, C = Regression of Zinc, D = Regression of cobalt, E = Regression of nickel

Table 2 Correlation of zinc concentrations in the nematode parasite *Cosmocerca* sp. and the tissues of the host *Sclerophrys regularis* in Lagos metropolis, Nigeria

	Parasite	Intestine	Liver
Parasite	1		
Intestine	**0.7164**	1	
Liver	**−0.7169**	**0.9546**	1

Emboldened figures imply a significant correlation relationship

relationship, however, occurred between the concentrations of metals in the liver and the parasites.

Discussions

Zinc was the most accumulated metal in the liver from the studied environment of *S. regularis* bioaccumulation threat to the host. Furthermore, zinc was the only metal that exceeded the FEPA (2003) established limit for biological tissues. Hence, *Cosmocerca* sp. did not only exhibit the ability to modulate the bioaccumulation of metals in the host, but it also showed responsiveness based on severity. Sures et al. (2017) stated that parasites that exhibit tolerance to high pollutant burdens are applicable as sentinels for polluted habitats. In the current study, *Cosmocerca* sp. may be a reliable sentinel species for indicating the level of metals in the host toad. Moreover, since accumulation indicators provide vital information about the bioavailability of pollutants, *Cosmocerca* sp. may represent possible diagnostic tools for assessing the toxicodynamics of zinc in the environment. The parasite also proved to be reliable in assessing the toxicokinetics of zinc in *S. regularis* (Sures et al., 2017).

This severity-based depuration potential was consistently evident in the liver and the intestine. Zinc was also the only metal that exhibited a significant regression in the abundance of the parasites whose metal concentrations also strongly negatively correlated with the concentrations of metals in the liver. These observations imply that the number of parasites influenced the concentrations of metals in the liver. Furthermore, data suggest that as the concentrations of metals increased in the parasites, there was a significant decrease in the concentration of zinc in the liver. According to Sures et al. (2017) at the steady-state concentration of toxicants, the uptake and elimination rates are balanced. In the current study, the accumulation of zinc is associated with the combined physiological responses of the toad and its parasite effects. Thus, if the steady-state concentration is lowered as a result of parasitism, the infected toads can expect less severe toxic effects than the uninfected conspecifics.

Akinsanya et al. (2020) earlier demonstrated the depurative potentials of the enteric parasite, *Amplicaecum africanum* on the metal burden in *Amietophrynus regularis* within selected areas compared to a dumpsite in Lagos metropolis. They concluded that when a parasitic infection is a primary factor affecting the toad, parasite prevalence may influence the net effect of parasitological harm and depuration benefit to the host. They then suggested that under controlled conditions, parasites may serve as bioremediators.

In this study, *Cosmocerca* sp. showed higher concentrations of lead and zinc from the infected toad liver at the dumpsite than the concentration found in the host. Furthermore, the parasite also had distinctively higher concentrations of zinc in the intestine of the infected toad in both the dumpsite and natural habitat. The high accumulation potential exhibited by the parasite is promising for toxicological studies. In reports cutting across limnetic, marine, and terrestrial habitats, higher concentrations of toxicants in parasites than in the host have been widely reported (Eira et al., 2005; Eira et al., 2009; Jankovská et al., 2009; Jankovská et al., 2010, Torres et al., 2010; Yen et al., 2013; Golestaninasab et al., 2014). In a field study on a limnetic habitat carried out by Barus et al. (2007), the parasite *Philometra ovate* accumulated higher concentrations of lead and zinc than its host *Gobio gobio.*

Sures and Siddall (1999) used lead as an experimental toxicant on chub infected with the acanthocephalan *Pomphorhynchus laevis*, which exhibited lower lead concentrations than uninfected conspecifics. Sures et al. (2003) later confirmed the observation by experimenting on lead isotope 210Pb. Similarly, Gabrashanska and Nedeva (1996) and Turcekova and Hanzelova (1999) found reduced metal concentrations in cestode-infected wild fish compared to the uninfected animals. They attributed the decreased metal levels in acanthocephalan-infected fish to the entero-hepatic parasite's interference within the fish host (Sures and Siddall, 1999). Successively, several types of research from various host–parasite systems have been published in the past few years, all of which reveal lower metal concentrations in tissues of infected hosts from aquatic as well as terrestrial habitats (Akinsanya et al., 2019; Isibor et al., 2020; Akisanya et al., 2020).

The current findings on the efficiency of *Cosmocerca* sp. in sinking metals in *S. regularis* corroborate the findings of Akinsanya et al. (2020) on the effectiveness of *Amplicaecum africanum* in sequestering metals from the toad host, *Amietophrynus regularis.* This indicates that potential *Cosmocerca* sp. and *A. africanum* may be combined for more promising outcomes.

The potential to reduce metal levels in different tissues of hosts has been carried out on many cestodes and acanthocephalans. This current study conforms to the majority of the previous findings, given that a nematode (*Cosmocerca* sp.) was used. But there is a need for extended study on the pollutant sink potentials of various nematodes and digeneans, as these groups are still understudied in this regard.

The feasibility of the reduction of metal concentrations in infected hosts has important implications. Pollutant accumulation in aquatic and terrestrial fauna can be attributed to a balance of distinct absorption and loss processes that vary according to the infection. The uptake of zinc by *Cosmocerca* sp. parasites in the current study may be considered as an efflux from the host *Sclerophrys regularis*, similar to the elimination routes (Le et al., 2016) and can therefore modulate the concentration of the metal in the toad host.

Conclusions

This current study has demonstrated the possibility of employing *Cosmocerca* sp. as a bio-sink and bioindicator for zinc contamination. The parasites may therefore be promising in protecting *S. regularis* and safeguarding the health of the associated populace. In controlled experiments, *Cosmocerca* sp. may be employed alongside *Amplicaecum africanum* and other efficient parasites in extracting threatening levels of metals from the host toad. Given that *S. regularis* is listed among endangered amphibians, the protection of *S. regularis* will be better captured with the data presented in this study because it will be informative to decision makers and subsequent researchers that are poised toward the protection of this unique species. The data generated from this study may be useful for further studies on the toxicokinetics of metals and decision making on the protection of the environment, which may as well ameliorate anthropogenic activities that have posed threats to the survival of this species, particularly, in the study area which is noted for overpopulation and the consequent indices associated with same.

Abbreviations
LOQ: Limit of quantification; CRMs: Certified Reference Materials; SD: Standard deviation; CI: Confidence interval; FEPA: Federal Environmental Protection Agency; MSDSs: Material Safety Data Sheets.

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Author contributions
AB, IPO, and OMO conceived and designed the experiments. OMO performed the experiments. IPO analyzed and interpreted the data. OAB and AK contributed reagents, materials, analysis tools, and ideas. All authors have read and approved the final manuscripts.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Ethical approval for this research was given by the Health Research Ethics committee of the College of Medicine of the University of Lagos. CMULHREC No: CMUL/ACUREC/03/20/729.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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