HOSTED BY
ELSEVIER
Contents lists available at ScienceDirect
Asian Pacific Journal of Tropical Disease
journal homepage: www.elsevier.com/locate/apjtd

Parasitological research doi:10.1016/S2222-1808(16)61110-6 ©2016 by the Asian Pacific Journal of Tropical Disease. All rights reserved.

Parasitic diseases and heavy metal analysis in *Parachanna obscura* (Gunther 1861) and *Clarias gariepinus* (Burchell 1901) from Epe Lagoon, Lagos, Nigeria

Akinsanya Bamidele[1*], Minasu Pentho Kuton[2]

[1]*Department of Zoology, University of Lagos, Lagos, Nigeria*

[2]*Department of Marine Sciences, University of Lagos, Lagos, Nigeria*

ARTICLE INFO

Article history:
Received 28 Mar 2016
Received in revised form 9 Apr, 2nd revised form 18 Apr 2016
Accepted 20 May 2016
Available online 19 Aug 2016

Keywords:
Heavy metals
Parasites
Clarias
Parachanna
Procamallanus
Wenyonia

ABSTRACT

Objective: To evaluate the bioaccumulation of heavy metals in *Parachanna obscura* (*P. obscura*) and *Clarias gariepinus* (*C. gariepinus*) and the use of their parasites as accumulation indicators from Lekki Lagoon.
Methods: Samples of fish were procured from Oluwo market, a landing site of fish of artisanal fishermen in Epe. Metal accumulation, and intestinal parasites and protozoan of *P. obscura* and *C. gariepinus* were investigated. Sediment and water samples were examined for selected heavy metals (Cu, Cr, Ni, Pb and Fe) while nematode parasite from infected fish were also analysed for heavy metal content.
Results: Absolute morphometric parameters had low correlation with single independent morphometric index (total length and standard length) but increased when correlated with combined indices. The prevalence of parasitic infections in *P. obscura* and *C. gariepinus* were 35% and 36% respectively. The metal concentrations accumulated in the fish's liver were more than that found in the water and sediment. There was strong correlation in metal accumulated in the parasites relative to the water medium (r = 0.968 - 1.000, P < 0.01). *Procamallanus* spp., a nematode accumulated 2 times more Cu, Cr, Ni, Pb and Fe than *Wenyonia* sp. There was higher heavy metal level observed in intestinal nematode *Procamallanus* sp. than *wenyonia* sp. in the infected fish in this study.
Conclusions: This suggests that *Procamallanus* sp. may be used as a potential sink of metal pollution in an aquatic environment and also a good sentinel in the environment.

1. Introduction

The escalating contamination of the environment by toxic substances has perturbed many all over the world[1]. There are a lot of toxic substances that are poured into the aquatic environment as a result of increased technologies, over population, exploration and exploitation of oil, and agricultural and domestic activities[2].

Among these contaminants, the most dangerous of them is trace metals as a result of being non-biodegradable, poisonous, bioaccumulation and biomagnification potentials in organisms[3]. Heavy metal contaminants released from the industries are in soluble form which settle down at the bottom of the aquatic environment then ingested during feeding by the organisms which leads to bioaccumulation in aquatic organisms resulting into diseases as a result of long exposure because of their toxic nature, and these process affect the aquatic fauna and other organisms through biomagnifications[4,5]. Akinsanya and Otubanjo[6,7] reported several species of parasites from freshwater fishes of Lekki Lagoon, Lagos, Nigeria. Vincent *et al.*[8] on parasitic infections on some freshwater fishes reported different parasitofauna in a particular freshwater ecosystems in Nigeria.

The link between these toxic substances and parasitism in aquatic fauna as well as the ability of parasitic organisms acting as indicators of water quality have received rapt attention in the past twenty years[9]. The concentration of these metals should be monitored in water, sediment and aquatic fauna as well as in the different water level. Sediment most especially depicts the extent of pollutant in that water body as well as their sources[10,11].

Parasites are very important in the aquatic environment and represent a high proportion of aquatic biomass. Marcogliese *et al.*[12] indicated that parasites are found wherever life exist and that they provide information as a result of their bioaccumulation potentials on polluted ecosystems[8] and damaged food webs[12].

*Corresponding author: Akinsanya Bamidele, Department of Zoology, Parasitology Unit, University of Lagos, Lagos, Nigeria.
Tel: +2348079766494
E-mail: mpkuton@yahoo.com
The journal implements double-blind peer review practiced by specially invited international editorial board members.

Parasites respond quickly to environmental changes and they are more tolerant to these metals than their hosts and also increase in numbers in polluted conditions[13]. They are now regarded as a useful indicator of aquatic health. Intestinal parasites accumulate a number of metals than those found in host tissues[13-15], thus render parasites more sensitive metal accumulation biomonitors than their fish host. Parasites are affected by environmental changes in different ways, thus information on parasites can indicate anthropogenic impacts especially when the equilibrium between host and parasites is no longer available[16]. They often have an effect with other stressors in the same aquatic environment[17]. Pollution can reduce parasitic infections if infected host suffer as a result of bioaccumulation of contaminants rather leaving the uninfected hosts. There is variation on these effects which depend on the species of parasite and the magnitude and nature of the pollutant they interact with. Pollution can also increase parasitism if host is immunodeficient, thereby leading to their susceptibility to the particular disease linked to that contaminants. This could simply increase the population densities of suitable intermediate or final hosts in that water body. Svobodova *et al.*[18] reported that many fish species are also used as bioindicators of pollutant. Adams and Nowak[19] emphasised that the gills of many fish species are susceptible to accumulation of heavy metals due to the acidic nature of the aquatic environment which cause the movement of free divalent ions. Farkas *et al.*[20] also opined that heavy metals concentrations in fish organs like that in the parasite tissues is also an indication of pollution of the particular aquatic ecosystems. Ravera *et al*.[21] reported that availability of trace metals in the aquatic organisms in a particular water body is an indication that such contaminants have been there in the past and also currently. Parasites of fish are highly sensitive to contaminants as a result of their prompt physiological response to polluted ecosystems[22].

High concentrations of trace metals have been reported in acanthocephalans but also to a lesser degree in adult cestodes[23,24]. Vulnerability of parasites is as a result of their ability to accumulate metals[25]. Some spiny-headed worms were found to accumulate high levels of heavy metals than that found in their host. They can therefore provide information on the level and magnitude of pollution in the water body[26]. Parasites can also act as metal sinks for its fish host[27]. It is apparent that any changes to metal concentration in the fish tissues are likely to alter metal effects and presence in the hosts. Verrengia-Guerrero *et al*.[28] reported that prompt response of organism depends on the toxicokinetic and toxico-dynamic processes that occur once a metal toxicant has entered the organism. Similarly, Obodo[29] reported that catfish have the highest bioaccumulation potential as a result of the bioaccumulation factor of 350 for manganese and 219 for lead. Tilapia fishes, on the other hand, are more susceptible to accumulate lead and manganese as a result of the bioaccumulation factor of 224 for lead and 210 for manganese.

2. Materials and methods

2.1. Study area

Lekki Lagoon in Epe, Lagos State is centred on large fisheries activities. It lies between longitudes 4°00' and 4°15' E and latitudes 6°25' and 6°37' N. The surface area is about 247 km^2 with a depth of 6.4 m. There are some parts of the lagoon that are shallow and less than 3.0 m deep. This lagoon and creeks are along the coast of South Western Nigeria from the Dahomey border to the Niger Delta stretched through a distance of about 200 km. The Lagoon is connected with River Oni. The flora around the lagoon is characterized by shrubs and *Raphia sudanica* (raphia palms), and *Elais guineensis* (oil palms). Phytoplankton around the lagoon are found on its side. This includes: *Cocos nucifera* (coconut palms which are widespread in the surrounding villages. Both dry and rainy seasons are experienced in the lagoon. The fish fauna of the lagoon includes: *Heterotis niloticus, Gymnarchus niloticus, Clarias gariepinus* (*C. gariepinus*), *Malapterurus electricus, Synodontis clarias, Chrysichthys nigrodigitatus, Parachanna obscura* (*P. obscura*), *Mormyrus rume, Calamoichthys calabaricus, Tilapia zillii, Hemichromis fasciatus* and *Sarotherodon melanotheron*[30]. Figure 1 shows vividly the map of the study area indicating the Lagos Lagoon systems.

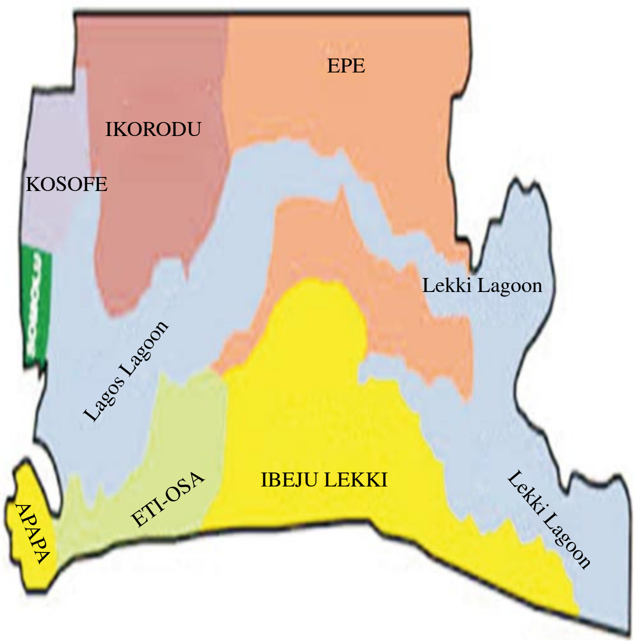

Figure 1. Typical map of Lekki Lagoon.

2.2. Collection of samples

The test organisms are *P. obscura* (snake head) and *C. gariepinus* (African mud catfish) which belong to the family Channidae and Clariidae respectively and which constitute important proportion of the catches by artisanal or subsistence fishermen and are of high economic importance.

Samples of fish were procured monthly between May to August 2015. A total of 50 randomly (n = 100) selected specimens of *P. obscura* and *C. gariepinus* respectively were obtained from Lekki Lagoon .

2.3. Examination of samples for parasite

The fresh specimens were dissected and the samples of intestine were obtained with the aid of stainless steel scissors and forceps which has been previously cleaned with physiological saline as recommended by Sures *et al.*[31].

The intestines were cut in physiological saline and were further carefully slit open longitudinally to aid the emergence of the gastrointestinal helminth parasites. The livers were mashed in physiological saline and worms wriggling movement from the intestine was enhanced and noticeable on emergence coupled with the thigmotropic nature of the parasite. The tissue samples and parasites were frozen at –26 °C in sample bottles until further processing according to methods described by Sures[26].

2.4. Identification of parasites

All the recovered gastrointestinal helminth parasites were sorted out into their various groups (cestodes and nematodes) using standard parasitological guidelines. The parasites were preserved and fixed in 70% alcohol. Samples parasites were sealed thoroughly in ethylene diamine tetraacetic acid bottles, appropriately and labelled.

2.5. Heavy metal analysis

Individuals were also grouped based on infestation status. The intestine of some of the infected and non-infected individuals were selected for heavy metal analysis together with the identified parasites from each of the infected hosts. Using the atomic absorption spectrometer, 5 g of dried fish tissue was digested with 10 mL of nitric acid, the sample is then heated until the brown fumes disappear. The sample was left to cool and distilled water was added and make up to 50 mL in a standard volumetric flask. The filtrate was descanted and analysed using the atomic absorption spectrometer.

2.6. Stomach content analysis

Each fish was dissected and stomach was removed and transferred into a Petri dish with few drops of water. The stomach content of each fish was observed under the binocular microscope and the various food items identified are recorded on a standard proforma prepared for each dissected fish. Fullness of the stomach of each specimen was recorded in the proforma as 0/4, 1/4, 2/4, 3/4, and 4/4 representing empty stomach, quarter full stomach, half full stomach, respectively. For food analysis, various methods were employed. These include numerical, occurrence method.

Numerical method: a count was made to obtain the number of each kind of food occurring in the items found in all the fishes examined. The disadvantage of this method was that the organism occurring in the largest number may not necessarily constitute the most important food item.

Frequency occurrence method: in this method, the stomach contents were examined and the individual items were sorted, identify and recorded. This was taken as the number of stomach in which the organism occurred. The percentage of frequency of occurrence was calculated relatively to the number of stomachs containing food. The advantage of this method was that it gives information on the various types of organism fed upon. The disadvantage was that it does not give information on the quantities or the number of food items and secondly, this method did not take into consideration food items that are resistant to digestion.

2.7. Gonado-somatic index

The gonado-somatic index is a measure of the amount of the fish constituent from metabolic activities utilized to the production of eggs of the female gonad. It is the relationship of the gonad weight using the formular.

2.8. Statistical analysis

In sense of multivariate, morphometric and meristic discriminations between the two catfish species were carried out using standard discriminate function analysis and regression analysis using SPSS version 15.0.

3. Results

3.1. Prevalence of intestinal helminth parasite in relation to sex of P. obscura and C. gariepinus in Lekki Lagoon

Out of the 50 fishes of *P. obscura*, 10 were infected (20.0%) and 40 (80.0%) were not infected. The infected individuals had 3 males (6.0%) and 7 females (14.0%) while the non-infected individuals had 25 males (50.0%) and 15 females (30.0%). The *Chi*-square distribution was significant at 0.01 level [$\chi^2(2) = 2.31$, $P < 0.01$]. Out of the 50 fishes of *C. gariepinus*, 8 were infected (16.0%) and 42 (84.0%) were not infected. The infected individuals had 6 males (12.0%) and 2 females (4.0%) while the non-infected individuals had 25 males (50.0%) and 17 females (34.0%). The *Chi*-square distribution was significant at 0.01 level [$\chi^2(2) = 2.12$, $P < 0.01$]. The prevalence of parasitic infections of the fish hosts was shown in Tables 1 and 2.

Table 1

Prevalence of intestinal parasite of *P. obscura* in Lekki Lagoon. *n* (%).

Sex	Infected	Non-infected	Total
Male	3 (6.0)	25 (50.0)	28 (56.0)
Female	7 (14.0)	15 (30.0)	22 (44.0)
Total	10 (20.0)	40 (80.0)	50 (100.0)

Table 2

Prevalence of intestinal parasite of *C. gariepinus* in Lekki Lagoon. *n* (%).

Sex	Infected	Non-infected	Total
Male	6 (12.0)	25 (50.0)	31 (62.0)
Female	2 (4.0)	17 (34.0)	19 (38.0)
Total	8 (16.0)	42 (84.0)	50 (100.0)

3.2. Protozoan infections in the fish species

The two fish hosts recorded the protozoan parasites *Myxobolus* sp., *Schzoamoeba* sp. with an unidentified flagellate parasites. This was shown in Table 3. This implied that the fish hosts were infected with the same protozoan parasites but different helminth parasites.

Table 3

Prevalence of intestinal protozoa in *P. obscura* and *C. gariepinus*.

Protozoa		Number	Prevalence
P. obscura	*Myxobolus* sp.	20	0.35
	Schzoameoba sp.	20	0.15
	Unidentified flagellate	5	0.10
C. gariepinus	*Myxobolus* sp.	22	0.42
	Schzoameoba sp.	20	0.15
	Unidentified flagellate	8	0.21

Table 4

Shows Mean morphometric, Condition factor of *P. obscura* and *C. gariepinus* in Lekki Lagoon.

Fish	Sex	Total length	Standard length	Weight	Condition factor K	Stomach content
P. obscura	Male	23.36 ± 3.10	20.43 ± 2.62	111.00 ± 26.48	1.33 ± 0.30	1.46 ± 0.28
	Female	23.80 ± 3.45**	2.70 ± 3.26	114.00 ± 34.06**	1.34 ± 0.53	0.77 ± 0.19
C. gariepinus	Male	28.30 ± 1.30	23.40 ± 5.60	1.30 ± 109.00	0.80 ± 0.30	0.65 ± 0.21
	Female	25.20 ± 45.40**	14.83 ± 1.56	91.67 ± 24.31**	2.82 ± 0.63	0.95 ± 0.32

Data were expressed as mean ± SD; *: *P*-value significant at 0.05 level; **: *P*-value significant at 0.01 level.

Table 5

Heavy metal concentration in fish intestine and the parasite

Fish	Tissue	Number	Cu	Cr	Ni	Pb	Fe
P. obscura	Infected intestine	10	0.01 ± 0.01	0.24 ± 0.15	0.30 ± 0.25	0.20 ± 0.15	3.00 ± 2.50
	Non-infected intestine	0	0.06 ± 0.07	0.13 ± 0.17	0.14 ± 0.21	0.25 ± 0.19	3.78 ± 2.64
	Parasite *Procamallanus* spp.	3	0.06 ± 0.10	0.30 ± 0.15	0.20 ± 0.10	0.09 ± 0.05	2.95 ± 1.50
C. *gariepinus*	Infected intestine	10	0.10 ± 0.05	0.25 ± 0.30	0.00 ± 0.00	0.35 ± 0.25	4.00 ± 3.35
	Non-infected intestine	10	0.25 ± 0.24	0.35 ± 0.31	0.05 ± 0.04	0.49 ± 0.67	5.76 ± 5.95*
	Wenyonia spp.	0	3.25 ± 2.85	4.26 ± 3.75	1.00 ± 0.95	0.95 ± 0.75	4.69 ± 0.89**

*: *P*-value significant at 0.05 level; **: *P*-value significant at 0.01 level.

3.3. Morphometric of P. obscura and C. gariepinus in Lekki Lagoon

Randomly-selected specimens were measured to obtain their length and weight parameters. The total length of *P. obscura* in male female and male were mean ± SD, 23.36 ± 3.10, $P < 0.01$, mean ± SD, 23.8 ± 3.45, $P < 0.01$, respectively. Also the total length of *C. gariepinus* in male and female are mean ± SD, 28.30 ± 1.30, $P < 0.01$, mean ± SD, 25.20 ± 45.40**, $P < 0.01$, respectively. The morphometrics of the fish hosts was shown in Table 4.

3.4. Metal concentration in fish intestine and parasite of P. obscura and C. gariepinus

Bioaccumulation directions of contaminants in the tissue of the fish can be utilized as effective indicators of environmental metal contamination. The ANOVA of the trace metals in the water and organs (intestine) of *P. obscura* and *C. gariepinus* showed that there was a significant difference ($P < 0.05$) which was an indication that the trace metal concentrations were significantly impactful and the aquatic ecosystem was polluted. The contaminant analysis in the fish hosts as well as in the helminth parasites was presented in Table 5 while the mean metal accumulation in aquatic ecosystem as well as in the sediment were reported in Table 6.

Table 6

Metal concentration in water and sediment media of the Lekki Lagoon.

Medium	Cu	Cr	Ni	Pb	Fe
Water	0.809	10.864	1.052	0.069	9.235
	0.287	1.721	0.061	0.015	1.475
Sediment	0.911	10.597	0.071	0.765	1.219
	0.147	0.933	0.024	2.209	2.983
FEPA limit	Less than 1	20	Less than 1	Less than 1	NA

FEPA: Federal Environmental Protection Agency; NA: Not available.

3.5. Bioaccumulation factor of fish and parasite in Lekki Lagoon

Using the calculation according to Kalfakakour and Akrida-Demertzi[32] and Rashed[33], the bioaccumulation factor of fish and parasite were calculated and reported in Table 7.

Table 7

Bioaccumulation Factor of fish and parasite in Lekki Lagoon.

Metals		Cu	Cr	Ni	Pb	Fe
Infected	*P. obscura*	0.01	0.02	4.28	0.26	2.46
	C. gariepinus	0.10	0.01	0.71	0.45	3.10
Non-infected	*P. obscura*	0.06	0.02	0.50	0.41	3.10
	C. gariepinus	0.40	0.03	0.07	0.64	4.72
Parasite	*Wenyonia* sp.	0.06	0.01	2.01	0.32	3.12
	Procamallanus spp.	3.57	0.40	14.20	1.24	3.87

4. Discussion

A total of 100 specimens of *P. obscura* (50) and *C. gariepinus* (50) were inspected for parasitic infections. They were examined for heavy metals and parasitic infections. Garg *et al.*[34] reported that several organisms have been examined to authenticate their ability as pollution indicators in the aquatic environment. Dzika and Wyżlic[35] emphasized the fact that parasites of fish have been proved to be affected both by biotic and abiotic changes in the environment. The significantly higher concentration of Pb, Cd, Fe, Cu and Zn recorded for the infected intestinal tissue of the fish hosts compared to the resident *Procamallanus* sp. is a confirmation of the poor quality of water in the study area[36]. Kumar[36] is of the opinion that being linked with human welfare should be a great concern for mankind. Khaled[37] in his report confirmed that pelagic fishes with high life span have the ability to bioaccumulate contaminants and therefore are used as heavy metals indicators in aquatic environment. The low condition factor obtained in the fish hosts is a confirmation of stress as a result of heavy metals accumulation which has affected their metabolic activities. Khaled[37] stressed the fact that contaminants accumulate in metabolically active organs in the affected organisms. This is an environmental concern as a result of dumping of industrial wastes to the aquatic ecosystems by anthropogenic activities. In this study, Cu, Cr, Ni, Pb, and Fe were examined in the two fish hosts and that of the parasites. A pollutant free homeostatic environment must be present for the survival of all aquatic flora and fauna. Vinodhini and Narayanan[38] observed high concentrations of erythrocytes, hyperglycaemia, and elevated cholesterol level in common carp exposed to heavy metals. Huspeni and Lafferty[39] and Ogut and Palm[40] concurred with the results of this study which confirmed parasites as good indicators of quality of the environment. High level of Cr was observed in water and sediment which does not agree with Ugoji and Aboaba[41] who reported lower level of Cr from textile industries effluent in Lagos metropolis. Oboh and Edema[42] reported that the occurrence of heavy metal in fish always differed from that of the water. This concurs with the report of Madanire-Moyo *et al*.[43] who stated that fish hosts living in polluted environment tend to have higher intake of contaminants which may later increased in the immediate environment of the resident parasites. Eneji *et al.*[44]reported the pattern of metal concentration in tilapia different from that of the River Benue water. The order were deduced to be as a result of some internal factors and variation in feeding structure. The result of heavy metals accumulation in Table 4 in this study is a confirmation that the water and sediments have been polluted with high quantities of the contaminant. The parasites were also found to have accumulated high level of these toxic substances as reported in Table 4. Bioaccumulation factors of heavy metal in infected hosts' tissues were higher than in the resident nematodes confirmed the report of Perez-I-Garcia *et al.*[45] that different genera of fish parasites show variable sensitivity and response to aquatic contaminants. The high concentration of metals in the intestinal wall could be expected due to reabsorption of these metals in the *C. gariepinus*. The low concentration of these trace metals in intestinal nematode of *P. obscura* and *C. gariepinus* may be traced to its low efficiency in accumulation of metals which makes more metal to be reabsorbed into the intestinal wall and therefore increase the concentration of these contaminants in the host intestine. The physiochemical parameters of the Epe Lagoon at the time of collection were found below Federal Environmental Protection Agency limits which confirm that those resident fishes may still be consumed by man. The formation of insoluble complex compound removes metal ions from the aquatic ecosystem. The various magnitudes of metals in the water medium and sediment were found below Federal Environmental Protection Agency limits. But, greater concentrations were found in the fish and the parasites as shown in this study. Idodo-Umeh[46] in a confirmation to this study reported that bigger fishes tend to accumulate contaminants than smaller fishes. Since anthropogenic activities which continues to dump toxic metals from industries and domestic activities into the water bodies may not cease, sustained measurements may therefore be necessary to assess the set limitation standards and to quantify the magnitude of the contaminants in the aquatic environments as reported by Kaki *et al.*[47]. This study showed that there are variations in the direction of metals accumulation in organisms and this is dependent on species, sex, age, diseases, nutritional and genetic factors which is in agreement with Farombi *et al.*[48]. The parasitic organisms recovered from the fish hosts could cause lesions and mechanical damage as a result of burrowing and blockages which may cause necrosis, goblet cells hyperplasia, deformity and death especially when no treatment or control measures are applied. Aydoğdu *et al*.[49] reported that the nutritive values of fishes may be degraded through the activities of these parasites which can result in deficiency and devaluation in protein content of the fish. The intensity of infection of the parasites recovered in this study was higher in the largest size classes than in the small fishes. The result of the present study was in agreement with the findings of Tekin-Őzan *et al.* and Adikwu and Ibrahim[50,51].

This study confirmed that fish tissues and their relative nematode parasites like other helminth parasites accumulate heavy metals and that the concentration of metals in fish tissues can be influenced by their relative resident parasite metal accumulation. This study also confirmed that intestinal nematode may be used as a potential sink of metal pollution in any aquatic environment. The results of this study has confirmed and consolidated the fact that fish parasites can act as an indicator of pollution of contaminants as well as bioaccumulation ability of these toxic substances in the aquatic ecosystem. The consumption of fishes of Lekki Lagoon at present may not induce metal hazard in man. In this study, it is known that *P. obscura* and *C. gariepinus* obtained these toxic metals from water, sediment, and their daily diet which eventually resulted in accumulation as reported by Goodwin *et al.*, Labonne *et al*. and Osman *et al*.[52-54].

Conflict of interest statement

We declare that we have no conflict of interest.

Acknowledgments

The authors wish to thank Lekki Lagoon fishermen for the availability of fishes for this study.

References

[1] Ezemonye L, Enuneku A. Evaluation of acute toxicity of cadmium and lead to amphibian tadpoles (toad: *Bufo maculates* and frog: *Ptychadena bibroni*). *J Aquat Sci* 2005; **20**(1): 33-8.

[2] Lima D, Santos MM, Ferreira AM, Micaelo C, Reis-Henriques MA. The use of the shanny *Lipophrys pholis* for pollution monitoring: a new sentinel species for the northwestern European marine ecosystems. *Environ Int* 2008; **34**(1): 94-101.

[3] Matoka CM, Omolo SO, Odalo JO. Heavy metal bioaccumulation as indicators of environmental pollution and health risks. *IOSR J Environ Sci Toxicol Food Technol* 2014; **8**(2): 24-31.

[4] Baby J, Raj JS, Biby ET, Sankarganesh P, Jeevitha MV, Ajisha SU, et al. Toxic effect of heavy metals on aquatic environment. *Int J Biol Chem Sci* 2010; **4**(4): 939-52.

[5] Ashraf W. Accumulation of heavy metals in kidney and heart tissues of *Epinephelus microdon* fish from the Arabian Gulf. *Environ Monit Assess* 2005; **101**(1-3): 311-6.

[6] Akinsanya B, Otubanjo OA. Helminth parasites of *Clarias gariepinus* (Clariidae) in Lekki Lagoon, Lagos, Nigeria. *Rev Biol Trop* 2006; **54**: 93-9.

[7] Akinsanya B, Otubanjo OA, Hassan AA. Helminth parasites of *Malapterurus electricus* (Malapteruridae) from Lekki Lagoon, Lagos, Nigeria. *J Am Sci* 2007; **3**(3): 1-6.

[8] Ejere VC, Aguzie OI, Ivoke N, Ekeh FN, Ezenwaji NE, Onoja US, et al. Parasitofauna of five freshwater fishes in a Nigerian freshwater ecosystem. *Croat J Fish* 2014; **72**: 17-24.

[9] Sures B. The use of fish parasites as bioindicators of heavy metals in aquatic ecosystems: a review. *Aquat Ecol* 2001; **35**(2): 245-55.

[10] Adefemi SO, Awokunmi EE. Determination of physico-chemical parameters and heavy metals in water samples from Itaogbolu area of Ondo-State, Nigeria. *Afr J Environ Sci Technol* 2010; **4**(3): 145-8.

[11] Irenosen OG, Festus AA, Coolborn AF. Water quality assessment of the Owena multi-purpose dam, Ondo State, Southwestern Nigeria. *J Environ Prot* 2012; **3**: 14-25.

[12] Marcogliese DJ, Gendron AD, Plante C, Fournier M, Cyr D. Parasites of spottail shiners (*Notropis hudsonius*) in the St. Lawrence River: effects of municipal effluents and habitat. *Can J Zool* 2006; **84**(10): 1461-82.

[13] Sures B. Environmental parasitology: relevancy of parasites in monitoring environmental pollution. *Trends Parasitol* 2004; **20**(4): 170-7.

[14] Sures B, Siddall R. Pomphorhynchus laevis (Palaeacanthocephala) in the intestine of chub (*Leuciscus cephalus*) as an indicator of metal pollution. *Int J Parasitol* 2003; **33**(1): 65-70.

[15] Thielen F, Zimmermann S, Baska F, Taraschewski H, Sures B. The intestinal parasite *Pomphorhynchus laevis* (Acanthocephala) from barbel as a bioindicator for metal pollution in the Danube River near Budapest, Hungary. *Environ Pollut* 2004; **129**(3): 421-9.

[16] Lafferty KD. Ecosystem consequences of fish parasites. *J Fish Biol* 2008; **73**(9): 2083-93.

[17] Taylor RS, Muller WJ, Cook MT, Kube PD, Elliott NG. Gill observations in Atlantic salmon (*Salmo salar*, L.) during repeated amoebic gill disease (AGD) field exposure and survival challenge. *Aquaculture* 2009; **290**: 1-8.

[18] Svobodová Z, Čelechovská O, Kolářová J, Randák T, Žlábek V. Assessment of metal contamination in the upper reaches of the Tichá Orlice River. *Czech J Anim Sci* 2004; **49**: 458-641.

[19] Adams MB, Nowak BF. Experimental amoebic gill disease of Atlantic salmon, *Salmo salar* L.: further evidence for the primary pathogenic role of *Neoparamoeba* sp. (Page, 1987). *J Fish Dis* 2004; **27**(2): 105-13.

[20] Farkas A, Salánki J, Varanka I. Heavy metal concentrations in fish of Lake Balaton. *Lakes Reservoirs Res Manag* 2000; **5**(4): 271-9.

[21] Ravera O, Cenci R, Beone GM, Dantas M, Lodigiani P. Trace element concentrations in freshwater mussels and macrophytes as related to those in their environment. *J Limnol* 2003; **62**(1): 61-70.

[22] Sures B. Environmental parasitology. Interactions between parasites and pollutants in the aquatic environment. *Parasite* 2008; **15**(3): 434-8.

[23] Sures B, Riemann N. Analysis of trace metals in the Antarctic host-parasite system *Notothenia coriiceps* and *Aspersentis megarhynchus* (Acanthocephala) caught at King George Island, South Shetland Islands. *Polar Biol* 2003; **26**(10): 680-6.

[24] Vidal-Martínez VM, Pech D, Sures B, Purucker ST, Poulin R. Can parasites really reveal environmental impact? *Trends Parasitol* 2010; **26**: 44-51.

[25] Sures B. How parasitism and pollution affect the physiological homeostasis of aquatic hosts. *J Helminthol* 2006; **80**(2): 151-7.

[26] Sures B. Accumulation of heavy metals by intestinal helminths in fish: an overview and perspective. *Parasitology* 2003; **126**(Supp 1): S53-60.

[27] Sures B. Host-parasite interactions from an ecotoxicological perspective. *Parassitologia* 2007; **49**(3): 173-6.

[28] Verrengia Guerrero NR, Taylor MG, Davies NA, Lawrence MA, Edwards PA, Simkiss K, et al. Evidence of differences in the biotransformation of organic contaminants in three species of freshwater invertebrates. *Environ Pollut* 2002; **117**(3): 523-30.

[29] Obodo GA. The bioaccumulation of heavy metals in fish from Anambra River. *J Chem Soc Niger* 2004; **29**: 60-3.

[30] Kusemiju K. The Hydrobiology and fishes of the Lekki Lagoon, Nigeria. *Niger J Nat Sci* 1981; **3**: 135-46.

[31] Sures B, Siddall R, Taraschewski H. Parasites as accumulation indicators of heavy metal pollution. *Parasitol Today* 1999; **15**(1): 16 -21.

[32] Kalfakakour V, Akrida-Demertzi K. Transfer factors of heavy metals in aquatic organisms of different trophic levels. 2000; **1**: 768-86. [Online] Available from: http://biopolitics.gr/biowp/wp-content/uploads/2013/04/kalfakakou.pdf [Accessed on 25th March, 2016]

[33] Rashed MN. Monitoring of environmental heavy metals in fish from Nasser Lake. *Environ Int* 2001; **27**(1): 27-33.

[34] Garg S, Gupta RK, Jain KL. Sublethal effects of heavy metals on biochemical composition and their recovery in Indian major carps. *J Hazard Mater* 2009; **163**(2-3): 1369-84.

[35] Dzika E, Wyżlic I. Fish parasites as quality indicators of aquatic environment. *Zool Pol* 2009; **54-55**(1-4): 59-65.

[36] Kumar A. *Water pollution*. New Delhi: APH publishing corporation; 2004, p. 199.

[37] Khaled A. Trace metals in fish of economic interest from the west of Alexandria, Egypt. *Chem Ecol* 2009; **25**(4): 229-46.

[38] Vinodhini R, Narayanan M. The impact of toxic heavy metals on the hematological parameters in common CARP (*Cyprinus carpio* L.). *Iran J Environ Health Sci Eng* 2009; **6**(1): 23-8.

[39] Huspeni TC, Lafferty KD. Using larval trematodes that parasitize snails to evaluate a saltmarsh restoration project. *Ecol Appl* 2004; **14**(3): 795-804.

[40] Ogut H, Palm HW. Seasonal dynamics of *Trichodina* spp. on whiting (*Merlangius merlangus*) in relation to organic pollution on the eastern Black Sea coast of Turkey. *Parasitol Res* 2005; **96**(3): 149-53.

[41] Ugoji EO, Aboaba OO. Biological treatments of textile industrial effluents in Lagos metropolis, Nigeria. *J Environ Biol* 2004; **25**(4): 497-502.

[42] Oboh IP, Edema CU. Levels of heavy metals in water and fishes from the River Niger. *J Chem Soc Niger* 2007; **32**(2): 29-34.

[43] Madanire-Moyo GN, Luus-Powell WJ, Olivier PA. Diversity of metazoan parasites of the Mozambique tilapia, *Oreochromis mossambicus* (Peters, 1852), as indicators of pollution in the Limpopo and Olifants River systems. *Onderstepoort J Vet Res* 2012; **79**(1): E1-9.

[44] Eneji IS, Sha'Ato R, Annune PA. Bioaccumulation of heavy metals in fish (*Tilapia zilli* and *Clarias gariepinus*) organs from River Benue, North-Central Nigeria. *Pak J Anal Environ Chem* 2011; **12**(1&2): 25-31.

[45] Pérez-i-García D, Constenla M, Padrós F, Soler-Membrives A, Solé M, Carrassón M. Parasite communities of the deep-sea fish *Alepocephalus rostratus* Risso, 1820 in the Balearic Sea (NW Mediterranean) along the slope and relationships with enzymatic biomarkers and health indicators. *Deep Sea Res Part I Oceanogr Res Pap* 2015; **99**: 65-74.

[46] Idodo-Umeh G. Pollution assessment of Olomoro water bodies using physical, chemical, and biological indices [dissertation]. Benin: University of Benin; 2002, p. 485.

[47] Christophe K, Patient G, Nelly K, Patrick EA, Rodrigue A. Evaluation of heavy metals pollution of Nokoue Lake. *Afr J Environ Sci Technol* 2011; **5**(3): 255-61.

[48] Farombi EO, Adelowo OA, Ajimoko YR. Biomarkers of oxidative stress and heavy metal levels as indicators of environmental pollution in African cat fish (*Clarias gariepinus*) from Nigeria Ogun River. *Int J Environ Res Public Health* 2007; **4**(2): 158-65.

[49] Aydoğdu A, Kostadinova A, Fernandez M. Variations in the distribution of parasites in the common carp, *Cyprinus carpio*, from Lake Iznik, Turkey: population dynamics related to season and host size. *Helminthologia* 2003; **40**(1): 33-40.

[50] Tekin-Őzan S, Kir I, Barlas M. Helminth parasites of common carp (*Cyprinus carpio* L., 1758) in Beyşehir Lake and population dynamics related to month and host size. *Turkish J Fish Aquat Sci* 2008; **8**: 201-5.

[51] Adikwu A, Ibrahim BA. Studies on the endoparasites in the gastro-intestinal tract of *Clarias garienpinus* (Tugels) in Wase Dam, Kano State, Nigeria. *Afr J Appl Zool Environ Biol* 2004; **6**: 36-40.

[52] Goodwin TH, Young AR, Holmes MG, Old GH, Hewitt N, Leeks GJ, et al. The temporal and spatial variability of sediment transport and yields within the Bradford Beck catchment, West Yorkshire. *Sci Total Environ* 2003; **314-316**: 475-94.

[53] Labonne M, Othman DB, Luck JM. Pb isotopes in mussels as tracers of metal sources and water movements in a lagoon (Thau Basin, S. France). *Chem Geol* 2001; **181**(1-4): 181-91.

[54] Osman AG, Wuertz S, Mekkawy IA, Exner HJ, Kirschbaum F. Lead induced malformations in embryos of the African catfish *Clarias gariepinus* (Burchell, 1822). *Environ Toxicol* 2007; **22**(4): 375-89.