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Pitout JDD, Church DL, Gregson DB, Chow BL, McCracken M, Mulvey M, Laupland KB (2007). Molecular epidemiology of CTXM-producing Escherichia coli in the Calgary Health Region: emergence of CTX-M-15-producing isolates. Antimicrob. Agents Chemother. 51: 1281-1286.

Pelczar JR, Harley JP, Klein DA (1993). Microbiology: Concepts and Applications. McGraw-Hill Inc., New York, pp. 591-603.

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Full Length Research Paper

Fish distribution in relation to environmental characteristics in the Aby-Tendo-Ehy lagoon system (Southeastern Côte d'Ivoire)

Barthélemy K. Koffi*, Benié R. D. Aboua, Tidiani Koné and Mamadou Bamba

Laboratoire d'Hydrobiologie, UFR-Biosciences, Université Félix Houphouët-Boigny, 22 BP 582 Abidjan 22, Côte d'Ivoire.

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Although West African lagoons are known to provide significant fishery resources to populations, few studies have been done on processes responsible for their fish composition, abundance and spatial distribution. The aim of this study was to assess fish species distribution along the Aby-Tendo-Ehy lagoon system in Côte d'Ivoire. Sampling sites were distributed in the lagoon and grouped into three zones from a freshwater zone with high contributions of freshwater (zone 1) to a mixo-eurihaline water zone (zone 3), with a transition site (zone 2) located between the first two zones. Environmental characteristics showed gradual decrease of mean pH from zone 1 to 3, whereas mean conductivity, total dissolved solids and transparency measurements increased from zone 1 to 3. Salinity data were 0 all along the sampling period in zones 1 and 2 and increased up to 3 ppt in zone 3. A total of 67 species belonging to 29 families were caught. Overall fish diversity decreased from zone 1 (n=58) to 3 (n=40), with 45 species caught in zone 2. The number of species in different fish trophic categories (invertivorous, herbivorous, piscivorous and omnivorous species) decreased from the zone 1 to 3. Fish compositions in zones 1 and 2 were dominated by freshwater species, while in the zone 3 it was dominated by estuarine dependent species. The canonical correspondence analysis performed showed a clear-cut influence of some environmental variables on fish ecological categories distribution: the zone under continental freshwater discharges had higher pH and temperature measurements and housed more freshwater, estuarine resident, marine migrant and estuarine dependent freshwater species, while the site with marine influences had higher conductivity, salinity, transparency and dissolved oxygen data and was mainly associated with estuarine dependent marine species.

Key words: Ichthyofauna, species distribution, environmental variables, Aby lagoon, Côte d'Ivoire.

INTRODUCTION

Estuaries are transition zones between freshwater and marine environments with an extreme spatial and temporal variability of physical, chemical and biological characteristics. In these environments, the diversity of

*Corresponding author. E-mail: kofbarth@yahoo.fr. Tel: (225)40001771.

fish community is an outcome of ecosystem processes reflecting changes in productivity, energy pathways and material flow, disturbance regimes, abiotic stress and biological interaction (Lowe-McConnell, 1987). Research on fish assemblages in estuaries has shown that salinity plays a major role in shaping assemblage structure (Marshall and Elliott, 1998; Barletta et al., 2005; Selleslagh and Amara, 2008), although only a few studies encompass the full salinity gradient, that is, from ocean to tidal freshwater. Its influence on fish is often due to the tolerance and preference of species for this variable (Elliott et al., 1990).

Other environmental variables such as temperature, depth, transparency, dissolved oxygen, pH, conductivity and total dissolved solids can also play important roles in determining fish assemblages (Pombo and Rebelo, 2002; Aboua et al., 2010). Fish are known to play a fundamental role in the functioning of shallow waters through a series of physico-chemical (e.g. nutrient release, sediment turbation) and biological mechanisms (for example, competition, predation) (Gelós et al., 2010). Fish may affect the spatial distribution of their prey through the behavioural cascades processes (Schmitz et al., 2004; Súarez et al., 2004; Gelós et al., 2010).

Many human uses of estuaries (transportation, wastewater, pollution, overfishing, etc.) are potentially in conflict with the aquatic resources (Vinagre et al., 2004; Baeta et al., 2005). They not only have an impact on fish communities, but in the same way also rebound in human communities associated with the exploitation of these resources (Costa and Elliott, 1991). Thus, fish community diversity is a basic ecological indicator of health, knowledge of which is necessary for the correct exploitation, regulation and management of fishing resources since it can provide a first approach to the health level of the estuarine system and allows for the identification of response patterns to possible environment impacts.

Although, the importance of fish in these ecosystems is well recognized, few studies have attempted to characterize the fish communities and to elucidate the processes responsible for their composition and abundance in West Africa. The objectives of this paper were to establish fish species composition and abundance in different zones of the Aby-Tendo-Ehy lagoon system and to assess the impact of environmental factors on fish assemblages.

MATERIALS AND METHODS

Sample collection

The Aby-Tendo-Ehy lagoon system (5°05'-5°22'N; 2°51'-3°21'W), located in southeast of Côte d'Ivoire encompasses an area of 424 km^2 and is 24 km long north-south direction and extends 54 km wide east-west direction (Figure 1). The Aby lagoon is the most extended on the studied lagoon system and covers 305 km^2. It has a total shoreline of 24.5 km long, and is 15.5 km wide. The Tendo lagoon, which is the median part of the studied system, is more stretched, with a length of 22 km and a width varying between 1.5 and 3.5 km. Its surface is 74 km^2. The Ehy lagoon is located in the eastern side of the lagoon system and has a surface area of 45 km^2 (Chantraine, 1980). The overall Aby-Tendo-Ehy lagoon complex is lined with mangroves, and communicates with the sea by the Assini channel. It is supplied with freshwater inputs by the rivers Bia in the northwest and Tanoe in the east.

A total of 6 sampling sites were selected, distributed along the lagoon in three areas (two sites per zone) according to different environmental characteristics related to horizontal salinity range (Figure 1). Seu-Anoï et al. (2011) describes the salinity gradients found in the lagoon. Sampling zone 1, in the most inland part of the system (Ehy lagoon) had no marine water influences, but was under a considerable contribution of freshwater from the Tanoe Ehy Swamp Forest and the Tanoe River. Zone 2 (Tendo lagoon) sampling sites were in transition positions within the study area, while zone 3 (in Aby lagoon) were greatly influenced by marine waters and corresponded to the closest zone to the ocean. Monthly fish samplings were carried out between March 2012 and February 2013 using two sets of 12 weighted monofilalement gill nets (bar mesh sizes 6, 8, 10, 12, 15, 20, 25, 30, 35, 40, 45 and 50 mm), each measuring 30 m long by 1.5 m deep. Nets were set overnight (17-7 h). Fish collected were identified to species level following Paugy et al. (2003a, b) and Decru et al. (2012), counted and measured to the nearest 1 mm body length. The depth (cm) was recorded at each sampling station. Water temperature (°C), dissolved oxygen (mg/l), pH, conductivity (µS/cm), and total dissolved solids (mg/l) were recorded between 7 and 9 h using a Sper Scientific multiparameter while salinity (ppt) and transparency (cm) were recorded with a Hydrobios refractometer and a Secchi disc, respectively. The study area is characterized by two rainy seasons (April-June and October-December) and two dry seasons (July-September and January-March) (Konan et al., 2014).

Data analysis

To categorize the fish composition within the coastal lagoon, fish species were grouped into ecological categories following Albaret (1994, 1999) and Chabanne (2007), and classified as estuarine resident fish (ER) (those that inhabit estuarine waters throughout their life cycle), estuarine dependent marine fish (EDM) (marine species which are predominantly found in lagoons at some stages of their life cycle), estuarine dependant freshwater fish (EDF) (freshwater species which are predominantly found in lagoons at some stages of their life cycle), estuarine nondependent marine fish (EN) (species commonly found in both estuarine and coastal inshore areas and do not depend to estuarine environment to complete their life cycles), accessory marine visitor fish (AV) (marine species which are regularly caught in lagoon but not abundant in the catch), occasional marine visitor fish (OV), and freshwater fish (FW).

Fish classification into herbivorous, invertivorous, omnivorous, piscivorous, and planktivorous categories were made following Trewavas (1983), King (1994), Diomandé et al. (2009), Yao et al. (2010), Kouamélan et al. (2012), and FishBase (2013). Species richness (which is the number of species sampled at each sampling zone) was used to determine the structure and ecological dynamics of the community. Jaccard's coefficient (J) was used to measure similarity between the sampling zones. Mann-Whitney U tests, based on ecological categories occurrence, were used for univariate comparisons.

Environmental influences on the ecological categories of each sampling zone were assessed with a canonical correspondence analysis (CCA) performed on log-transformed [log10(x+1)] data (ter Braak, 1986).

The CCA was done using CANOCO software for windows (version 4.5). This analysis was based on fish ecological categories occurrence data and physico-chemical data as well.

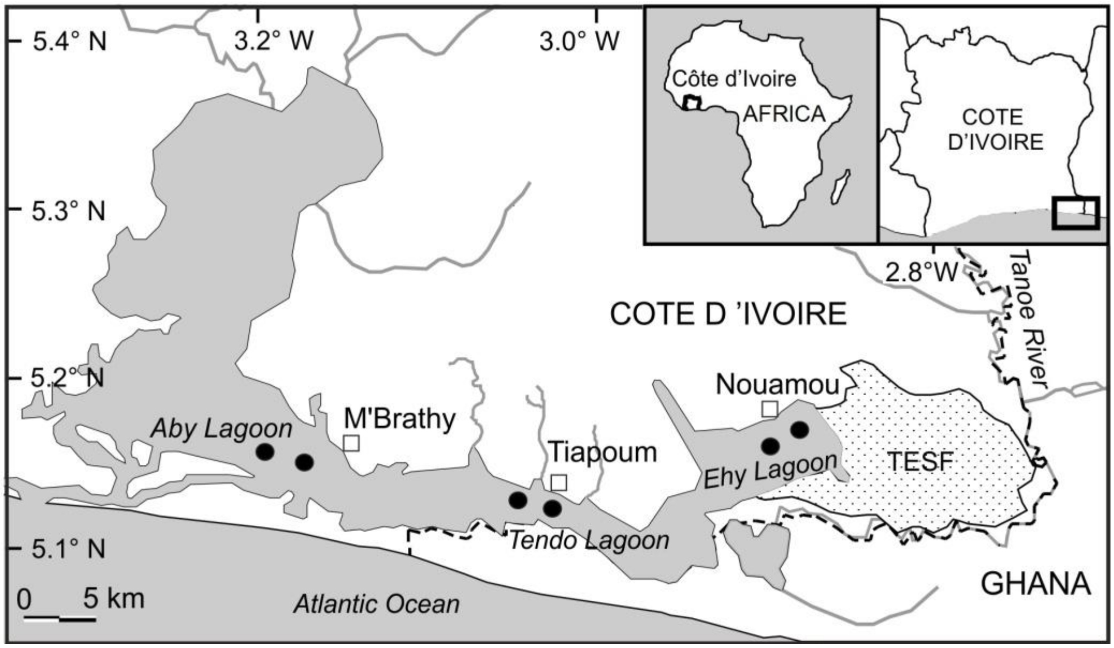

Figure 1. Sampling sites (●) in the Aby-Tendo-Ehy lagoon system (Côte d'Ivoire). TESF = Tanoe Ehy Swamp Forest.

Table 1. Environmental parameters [minimum (min), maximum (max), mean and standard deviation (SD)] in the different sampling zones of the Aby-Tendo-Ehy lagoon system (Côte d'Ivoire) between March 2012 and February 2013. T°C = temperature, DO = dissolved oxygen, Salt = salinity, Cond = conductivity, TDS = total dissolved solids, and Transp = transparency.

Sampling zone		Environmental characteristic							
		T°C	DO (mg/l)	pH	Salt (ppt)	Cond (µS/cm)	TDS (mg/l)	Transp (cm)	Depth (cm)
	Min	25.5	1.18	5.3	0	48.2	25.1	20	64
Zone 1	Max	35.8	7.35	9.15	0	123.1	65.5	120	298
(Ehy Lagoon)	Mean	30.13	5.17	7.27	0	65.47	34.98	43.86	147.87
	SD	3.41	1.51	0.84	0	16.05	8.88	16.37	64.15
	Min	25.3	2.03	5.31	0	60	30	24	68
Zone 2	Max	31.8	6.91	8.55	0	497	249	82	510
(Tendo lagoon)	Mean	28.22	4.74	7.02	0	156.76	84.91	42.69	289.75
	SD	1.87	1.07	0.8	0	119.82	64.74	14.41	153.37
	Min	25.6	3.18	4.29	0.5	70.7	36.8	37	46
Zone 3	Max	30.9	7.72	8.78	3	1546	804	101	264
Aby Lagoon	Mean	28.5	5.45	6.65	1.73	594.27	349.08	63.43	179.6
	SD	1.36	0.98	0.92	0.87	416.22	227.75	17.39	63.1

RESULTS

Environmental characteristics

Overall environmental parameters showed spatial trends in Aby-Tendo-Ehy lagoon system (Table 1). Mean pH decreased slightly from zone 1 (pH=7.27) to 3 (pH=6.65). Zones 1 and 2 had freshwater all along the sampling period (salinity=0 ppt) versus brackish water in zone 3 (with a salinity varying between 0 and 3 ppt). Furthermore, means of conductivity (65.47, 209.69 and 594.27, respectively for zones 1, 2 and 3) and total

Table 2. Ecological categories, trophic groups, occurrence percentage (%F), mean abundance (mean ab.±SD) of species collected in different sampling zones of the Aby-Tendo-Ehy lagoon system (Côte d'Ivoire) between March 2012 and February 2013.

Taxa	Zone 1: Ehy lagoon			Zone 2: Tendo lagoon			Zone 3: Aby lagoon		
	F (%)	Mean ab.	SD	F (%)	Mean ab.	SD	F (%)	Mean ab.	SD
Estuarine resident (ER)									
Monodactylus sebae (I)	18.18	0.25	0.71	40.00	2.08	5.85	72.73	5.75	0.55
Sarotherodon melanotheron (Pt)	100.00	15.42	5.29	100.00	9.58	8.13	100.00	5.92	5.18
Tilapia guineensis (I)	72.73	9.25	2.76	90.00	4.17	5.32	72.73	5.67	8.65
Tylochromis jentinki (I)	100.00	14.67	11.63	80.00	2.08	2.90	100.00	5.33	5.60
Awaous lateristriga (U)	18.18	0.25	0.71	0.00	0.00	0.00	63.64	0.92	0.98
Porogobius schlegelii (I)	45.45	1.58	0.96	80.00	4.83	1.81	63.64	1.58	2.36
Eleotris vittata (U)	36.36	0.33	0.49	50.00	0.58	0.89	81.82	3.25	3.61
Eleotris senegalensis (U)	0.00	0.00	0.00	0.00	0.00	0.00	9.09	-	-
Estuarine dependent freshwater fish (EDF)									
Pellonula leonensis (I)	81.82	3.17	4.84	90.00	20.75	1.33	100.00	30.17	11.71
Chrysichthys maurus (I)	72.73	1.42	2.10	60.00	4.25	7.20	36.36	1.08	1.71
Chrysichthys nigrodigitatus (I)	100.00	32.17	3.70	100.00	6.67	5.64	90.91	8.58	8.14
Chrysichthys teugelsi (I)	9.09	-	-	0.00	0.00	0.00	0.00	0.00	0.00
Hemichromis fasciatus (P)	100.00	6.50	6.12	100.00	3.08	1.88	100.00	5.33	1.67
Tilapia mariae (Pt)	72.73	1.42	1.81	80.00	2.00	2.20	9.09	-	-
Estuarine dependent marine fish (EDM)									
Ethmalosa fimbriata (Pt)	9.09	-	-	0.00	-	-	63.64	1.33	2.36
Hemiramphus balao (Pt)	0.00	0.00	0.00	0.00	0.00	0.00	9.09	-	-
Trachinotus teraia (I)	27.27	0.25	0.00	0.00	0.00	0.00	18.18	0.25	0.71
Plectorhincus macrolepis (U)	9.09	-	-	0.00	0.00	0.00	9.09	-	-
Pomadasys jubelini (I)	18.18	0.17	0.00	70.00	1.50	0.41	45.45	1.08	1.34
Liza falcipinnis (Pt)	90.91	12.25	1.62	60.00	1.67	2.25	72.73	3.25	3.36
Citharichthys stampflii (I)	18.18	0.33	1.41	10.00	-	-	100.00	11.50	9.26
Estuarine nondependent marine fish (EN)									
Elops lacerta (P)	63.64	0.75	0.76	50.00	2.00	5.22	54.55	1.75	2.43
Caranx hippos (I)	63.64	0.67	0.38	20.00	1.25	7.78	54.55	3.00	4.47
Eucinostomus melanopterus (I)	27.27	0.50	1.73	30.00	0.33	0.58	90.91	5.25	6.04
Mugil cephalus (Pt)	9.09	-	-	0.00	0.00	0.00	9.09	-	-
Occasional marine visitor fish (OV)									
Hemicaranx bicolor (U)	9.09	-	-	0.00	0.00	0.00	9.09	-	-
Accessory marine visitor fish (AV)									
Hyporamphus picarti (Pt)	0.00	0.00	0.00	0.00	0.00	0.00	9.09	-	-
Lutjanus goreensis (I)	0.00	0.00	0.00	0.00	0.00	0.00	9.09	-	-
Synaptura lusitanica (U)	0.00	0.00	0.00	10.00	-	-	0.00	0.00	0.00

* = introduced species, ** = hybrids, H = herbivorous, I = invertivorous, O = omnivorous, P = piscivorous, Pt = planktivorous, U = unknown.

dissolved solids (34.98, 150.92 and 349.08, respectively for zones 1, 2 and 3) increased importantly from zone 1 to 3. Mean transparency varied relatively slightly from zones 1 and 2 (43.86 and 42.69 cm, respectively) to zone 3 (63.43 cm).

Fish composition and ecological categories

Overall 5175 individuals belonging to 67 species and 29 families were collected during the study period. Regarding the ecological categories, 8 permanent residents, 6 estuarine dependents freshwater, 7 estuarine dependents marine, 4 estuarine non-dependents marine, 1 occasional, 3 accessory visitors and 38 freshwater species occurred in the studied lagoon (Table 2). Among these, two introduced species in Côte d'Ivoire (*Heterotis niloticus* and *Oreochromis niloticus*) and one hybrid (*Tilapia zillii* × *Tilapia guineensis*) were recorded. The

Table 2. Contd.

Species	Zone 1: Ehy lagoon			Zone 2: Tendo lagoon			Zone 3: Aby lagoon		
	F (%)	Mean ab.	SD	F (%)	Mean ab.	SD	F (%)	Mean ab.	SD
Freshwater fish (FW)									
*Heterotis niloticus** (I)	81.82	0.92	0.44	10.00	-	-	9.09	-	-
Papyrocranus afer (I)	90.91	2.00	2.88	20.00	0.25	0.71	0.00	0.00	0.00
Mormyrus rume (I)	27.27	0.33	0.58	0.00	0.00	0.00	0.00	0.00	0.00
Marcusenius furcidens (I)	9.09	-	-	0.00	0.00	0.00	0.00	0.00	0.00
Marcusenius senegalensis (I)	63.64	3.33	0.00	30.00	0.58	2.31	0.00	0.00	0.00
Marcusenius ussheri (I)	27.27	0.50	1.73	10.00	-	-	0.00	0.00	0.00
Mormyrops anguilloides (P)	18.18	0.33	1.41	10.00	-	-	0.00	0.00	0.00
Petrocephalus bovei (I)	0.00	0.00	0.00	10.00	-	-	0.00	0.00	0.00
Hepsetus akawo (P)	90.91	2.67	3.08	60.00	2.33	3.44	27.27	0.83	2.31
Brycinus longipinnis (I)	63.64	1.42	2.30	30.00	0.42	1.15	9.09	-	-
Brycinus nurse (I)	36.36	0.17	0.00	10.00	-	-	0.00	0.00	0.00
Brycinus imberi (I)	18.18	0.75	1.50	10.00	-	-	0.00	0.00	0.00
Brycinus macrolepidotus (H)	18.18	0.33	1.41	0.00	0.00	0.00	0.00	0.00	0.00
Distichodus rostratus (H)	0.00	0.00	0.00	40.00	0.50	0.58	0.00	0.00	0.00
Barbus wurtzi (U)	0.00	0.00	0.00	10.00	-	-	9.09	-	-
Barbus snoeksi (U)	9.09	-	-	30.00	0.25	0.00	0.00	0.00	0.00
Labeo coubie (Pt)	90.91	4.25	1.64	70.00	6.75	4.27	18.18	0.25	0.71
Labeo parvus (Pt)	9.09	-	-	40.00	0.33	0.00	9.09	-	-
Parailia pellucida (I)	9.09	-	-	60.00	26.92	2.36	27.27	5.50	6.36
Schilbe intermedius (P)	9.09	-	-	30.00	0.92	3.06	0.00	0.00	0.00
Schilbe mandibularis (I)	100.00	10.50	10.76	100.00	14.33	14.69	81.82	5.08	4.60
Heterobranchus isopterus (O)	45.45	0.42	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Heterobranchus longifilis (O)	18.18	-	-	0.00	0.00	0.00	0.00	0.00	0.00
Clarias anguillaris (O)	81.82	0.83	0.33	0.00	0.00	0.00	0.00	0.00	0.00
Clarias buettikoferi (O)	63.64	1.75	0.84	10.00	-	-	0.00	0.00	0.00
Malapterurus electricus (P)	18.18	0.25	0.71	0.00	0.00	0.00	0.00	0.00	0.00
Synodontis bastiani (O)	0.50	-	-	30.00	0.42	0.58	0.00	0.00	0.00
Synodontis koensis (H)	9.09	-	-	0.00	0.00	0.00	0.00	0.00	0.00
Synodontis punctifer (H)	0.00	0.00	0.00	10.00	-	-	0.00	0.00	0.00
Synodontys schall (O)	0.00	-	-	10.00	-	-	0.00	0.00	0.00
Parachanna obscura (P)	0.70	1.50	1.23	20.00	0.25	0.71	9.09	-	-
Thysochromis ansorgii (U)	9.09	-	-	0.00	0.00	0.00	0.00	0.00	0.00
Chromidotilapia guntheri (I)	2.92	7.50	0.45	70.00	2.17	2.93	36.36	5.83	17.99
*Oreochromis niloticus** (Pt)	27.27	0.42	0.58	0.00	0.00	0.00	18.18	0.33	1.41
Tilapia zillii (H)	90.91	6.42	2.14	100.00	12.17	4.22	100.00	13.58	13.46
*Tilapia hybride*** (U)	9.09	-	-	0.00	0.00	0.00	0.00	0.00	0.00
Ctenopoma petherici (I)	72.73	1.00	0.93	10.00	-	-	0.00	0.00	0.00
Mastacembelus nigromarginatus (U)	36.36	0.42	0.50	0.00	0.00	0.00	9.09	-	-

highest monthly average of total fish abundance was obtained in zone 1 with 172.54 ± 137.35 individuals while the lowest was recorded in zone 3 with 147.54 ± 86.54 individuals.

Fifty-eight of the 67 species collected occurred in zone 1 (Table 1). *Chrysichthys nigrodigitatus*, *Hemichromis fasciatus*, *Sarotherodon melanotheron*, *Schilbe mandibularis* and *Tylochromis jentinki* were the most frequent (100%), followed by *Clarias anguillaris*, *Heterotis niloticus, Pellonula leonensis*, (81.81%), *Chromidotilapia guntheri*, *Chrysichthys maurus*, *Ctenopoma petherici, Tilapia guineensis* and *Tilapia mariae* (72.72%). Species with the highest monthly mean abundance data were *C. nigrodigitatus* (32.17±3.70), *S. melanotheron* (15.42±5.29), *T. jentinki* (14.67±11.63), *Liza falcipinnis* (12.25±1.62), *S. mandibularis* (10.50±10.76), and *T. guineensis*(9.25±2.76).

Forty-five of the 67 species collected occurred in zone 2. *C. nigrodigitatus*, *H. fasciatus*, *S. melanotheron,* and *S. mandibularis* were recorded in all the samples (100%). They were followed by *Tilapia zillii* (83.33%), *P. leonensis, T. guineensis* (75%), *Porogobius schlegelii*, *T. mariae* and *T. jentinki* (66.67%). The most abundant species were *Parailia pellucida* (26.92±2.36), *P. leonensis* (20.75±1.33), *S. mandibularis* (14.33±14.69), *T. zillii* (12.17±4.22), and *S. melanotheron* (9.58±8.13).

The lowest number of species was recorded in zone 3 (40 out of 67). The most frequent species in this area were *Citharichthys stampflii, C. nigrodigitatus*, *Hemichromis fasciatus*, *Pellonula leonensis, Sarotherodon melanotheron*, *Schilbe mandibularis, T. zillii,* and *T. jentinki* (100%). The species that were most abundant were *P. leonensis* (30.17±11.71), *T. zillii* (13.58±13.46), *C. stampflii* (11.50±9.26) and *C. nigrodigitatus* (8.58±8.14).

The Jaccard's coefficient of similarity (J) indicated that zones 1 and 2 were more similar in their species composition [$J_1(z_1,z_2)$ = 0.63] than the comparisons between zones 1 and 3 [$J_2(z_1,z_3)$ = 0.53], and between zones 2 and 3 [$J_3(z_2,z_3)$ = 0.51].

Based on feeding habit data recorded in the literature the numbers of species in different trophic categories were higher (except for planktivorous species) in zone 1 than zone 2 and zone 3 with 26 invertivorous (versus 23 and 18 respectively), 7 piscivorous (versus 6 and 4), 5 omnivorous (versus 3 and 0), and 3 herbivorous (versus 3 and 1) (Table 2).

In terms of ecological categories, fish composition was dominated by freshwater species in zones 1 and 2 (respectively 34 and 26 out of 67 species) and by estuarine dependent fishes (including ER, EDF, and EDM) (20 out of 67) in zone 3. These estuarine dependent species were almost equally present in the three zones with 19 and 15 species, respectively in zones 1 and 2. The non-dependent marine fish species diversities were almost comparable, with 4 species in both zones 1, 3 and 3 species in zone 2 out of 4 species collected. For occasional marine visitor fishes, out of 4 species collected, 1 was recorded in zones 1 and 2, against 3 in zone 3.

Furthermore, univariate Mann-Whitney U tests on the occurrences of the ecological categories was performed to compare dry and wet season's samples between sampling zones. The results showed significant difference ($p<0.05$) only for estuarine nondependent fishes (EN) between zones 1 and 3 in dry season ($p=0.006$) and estuarine dependent marine fish (EDM) between zones 2 and 3 in wet season ($p=0.02$). Indeed, EN was represented in zone 1 by 66 specimens, versus 10 in zone 3. In this group, *Caranx hyppos* and *Eucinostomus melanopterus* exhibited a higher occurrence data differences with, respectively, 25 specimens in zone 1, against 5 in zone 3, and 35 specimens in zone 1, versus 1 in zone 3. The EDM was represented in zone 2 by 10 specimens, against 128 in zone 3. Specifically for this group, there were: 0 *C. stampflii* in zone 2, versus 87 in zone 3; 5 *L. falcipinnis* in zone 2, versus 16 in zone 3; and 0 *Ethmalosa fimbriata* in zone 2, versus 9 in zone 3.

Influence of environmental variables

Results of CCA showed that first and second axes accounted respectively for 86.1 and 13.9% of the total variance for the environmental-species ecological categories relationship. Based on first axis which expressed maximum percentage variance, there is a clear-cut separation of species ecological categories and environmental characteristics between Ehy (zone 1) and Aby (zone 3) lagoons (Figure 2): The first zone, with higher pH and water temperature measurements is associated with freshwater, estuarine resident (ER), marine migrant (MM) and estuarine dependent freshwater (EDF) species. Aby lagoon had higher values of conductivity, salinity, transparency, and dissolved oxygen and was associated with EDM species. The Tendo lagoon, which had an intermediate position, could be distinguished from other sampling sites mainly by its higher water depth based on axis 2 of the CCA.

DISCUSSION

Physical and chemical data showed spatial trends in Aby-Tendo-Ehy lagoon system, based on sampling sites chosen in this study. The fact that there was no variation in the salinity of zones 1 and 2 further showed that these parts of the lagoon are freshwater environments, as compared to the zone 3 where the salinity varied between 0 and 3 ppt. The spatial variation in the salinity level corresponded to results of N'Goran (1998) and Seu-Anoï et al. (2011) for the Aby-Tendo-Ehy lagoon system. According to Chantraine (1980) salinity level in coastal
Coastal lagoon depends on freshwater supply: lagoon salinity is relatively lower when freshwater inputs are higher. Hauhouot (2004) indicated that the Tanoe River, which is connected to Ehy lagoon (zone 1), contributes to 63% of the Aby-Tendo-Ehy lagoon system. This data could explain why the overall salinity measurements along the Aby-Tendo-Ehy complex increased from sampling zone 1 to 3.

Species richness recorded for the Aby-Tendo-Ehy lagoon system is 67 in this study. It was lower than 83 species reported by Charles-Dominique (1993), but higher than 60 species noted by Daget and Iltis (1965), and 33 species mentioned by N'Goran (1998). Species recorded by Daget and Iltis (1965) and Charles-Dominique (1993) but not caught in the present study in the Aby-Tendo-Ehy lagoon included *Arius latiscutatus, Epinephelus aeneus, Sphyrena afra, Polydactylus*

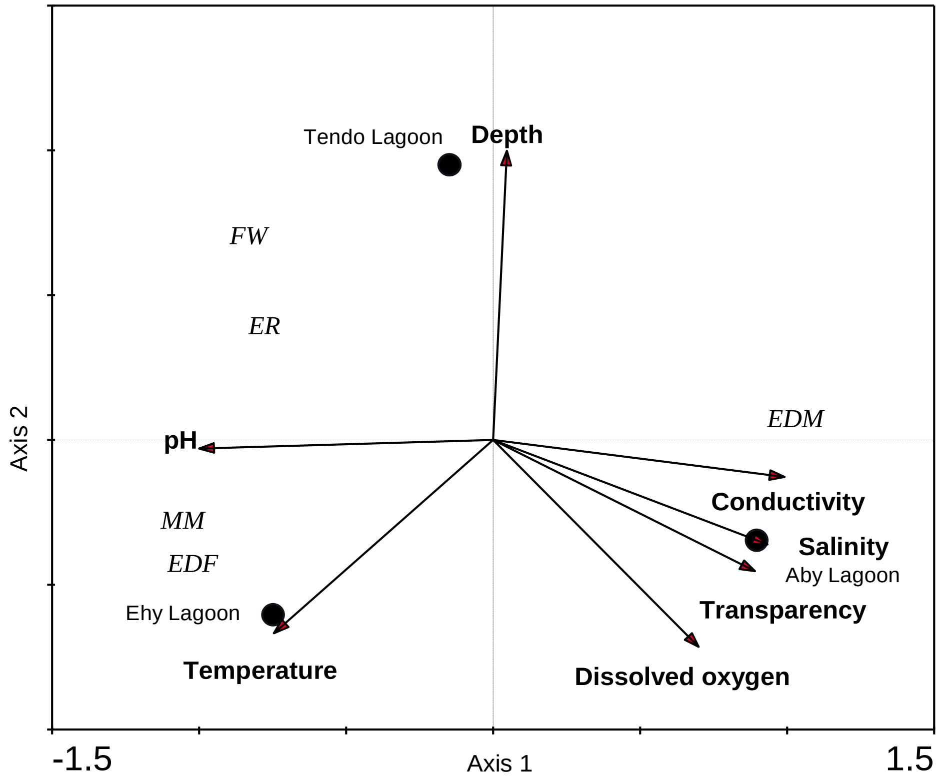

Figure 2. Canonical correspondence analysis applied to the environmental variables and to the fish ecological categories in the Aby-Tendo-Ehy lagoon system (Côte d'Ivoire). EDM = estuarine dependent marine fish, EDF= estuarine dependent freshwater fish, MM = marine migrant, ER = estuarine resident and FW = freshwater fish species.

quadrifilis, Pseudotholitus elongatus, Eleotris senegalensis, Scomberomorus tritor, Liza grandisquamis, Drepane africana, Strongylura senegalensis, Galeoides decadactylus, Cynoglossus senegalensis, Lutjanus dentatus, Caranx rhonchus, Dasyatis margarita, Trachinotus ovatus, Sardinella maderensis, Bathygobius soporator, Caranx senegallus, Ilisha africana, Lichia amia, Mugil curma, Pegusa triophtalma, Sardinella aurita, Megalops atlantica, Gymnothorax afer, Dalophis cepholopeltis, Myrophis plumbeus, Neolebias unifasciatus, Aplocheilicthys splilauchen, Epiplatys chaperi, Nimbapanchax petersii, Enneacampus kaupi, Gerres nigri, Pomadasys perotaei, Oblada melanura, Scarus hoefleri, Gobionelus occidentalis, Periophtalmus barbarus, Acanthurus monroviae and *Sphoeroides spengleri*. Many reasons such as the differences in sampling gear [experimental gillnets for the present study, against commercial fishing captures considered by Charles-Dominique (1993) and N'Goran (1998)] (Koné et al., 2003), the variation in fishing pressure due to human population increase (Albaret and Laë, 2003), and the environmental characteristic modifications (Charles-Dominique, 1993) could explain these species diversity differences.

In zone 3 which was much more investigated by previous studies, N'Goran (1998) and Charles-Dominique (1993), based on artisanal fisheries, indicated that the most abundant species was clupeid *E. fimbriata* (60 to 80% of total catch), versus *P. leonensis* for the present study. N'Goran (1998) and Charles-Dominique (1993) noticed a gradual decline in the capture of *E. fimbriata* in the Aby lagoon and attributed this to the increasing fishing intensity. In addition to these reasons, fishing gears characteristics in the present study could also have caused some differences: *P. leonensis* is a small sized species that was caught only by gillnet with small mesh size (06 and 08 mm), which is prohibited for commercial fisheries in the Aby-Tendo-Ehy lagoon. This result raised the question of some small-sized species that can be abundant but not exploited due to regulations on fishing gear.

Several studies suggested that tropical fish communities do not exhibit a clear organizational pattern (Goulding et al., 1988; Saint-Paul et al., 2000; Súarez et al., 2004). However, this study does not support the concept of unpredictability in the richness of fish community along Ehy-Tendo-Aby lagoon system: the number of species was found to decrease from zone 1 under freshwater influence to zone 3 with marine water influence. Furthermore canonical correlation analysis showed that sampling zone characteristics explain the variation in species richness: lowest values of salinity, transparency, dissolved oxygen and conductivity were associated with zones 1, whereas the highest values occurred in zones 3. This study also showed a variation in the number of different trophic categories. Piscivorous, herbivorous and omnivorous species number was higher in zone 1 with a reduced conductivity, salinity and transparency and a higher pH and temperature data. Planktivorous species were almost equally (species number) found in zones 1 and 3. Fish may affect diversity and water transparency by indirect trophic cascading effects: by consuming zooplankton and plant-attached macroinvertebrate grazers, fish may indirectly enhance phytoplankton and periphyton biomass (Jones and Sayer, 2003; Gelós et al., 2010), thus increasing water turbidity. But in the case of Ehy lagoon (zone 1) low transparency could also be the consequence of the turbulence phenomenon that occurred in this part of the lagoon due to high nutrient loads from both continental drainage and flooding tides (Neves et al., 2011; Konan et al., 2014).

Indeed, it is recognized that during the rainy season, runoff brings to aquatic environments a significant amount of organic material (which may include plant materials and/or insects) and nutrients from land that enrich these environments (Castillo-Rivera, 2013). The Tanoe River which is directly connected to zone 1 and the surrounding swampy forest of this zone act as important nutrient input sources. Insects and other terrestrial organisms, fruit and plant debris would also likely fall in the water under the effect of wind and rain (Konan et al., 2014). This possible importance and heterogeneity of food resources in this area could explain, partly, the high diversity both in species and trophic category diversities observed in zone 1.

In conclusion, this study recorded 67 species in the Aby-Tendo-Ehy lagoon system. Overall, fish diversity was higher in the most continental part of the studied lagoon than in the zone that was closer to the ocean. Species distribution along the Aby-Tendo-Ehy lagoon system was influenced by some environmental characteristics: the zone under the influence of freshwater discharges had higher pH and water temperature data and was mainly associated with freshwater, estuarine resident, marine migrant, and estuarine dependent freshwater species; the zone under marine water influences presented higher conductivity, salinity, transparency and dissolved oxygen data and had higher proportion of estuarine dependent marine species.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Levels of heavy metals in fish obtained from two fishing sites in Akwa Ibom State, Nigeria

Edet Okon Akpanyung*, Udoudo Moses Ekanemesang, Ekam Ime Akpakpan and Ngozi Obiageli Anadoze

Department of Biochemistry, Faculty of Basic Medical Science, University of Uyo. P. M.B. 1017, Uyo, Akwa Ibom State, Nigeria.

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Akwa Ibom State is located in the Niger Delta region of Nigeria and a substantial amount of the fishes consumed in the area are bought at Ifiayong and Ibaka beaches. This study was carried out to analyze heavy metals (Zn, Cu, Cd, Pb, Cr and As) in kidney, heart, gills and liver of silver catfish (*Chrysichthys nigrodigitatus)* from these locations. Analysis was performed using Atomic Absorption Spectrophotometry (AAS). The results show that the levels of Zn and Cu were significantly higher than maximum recommended levels (p<0.05) at both locations and were significantly higher in Ifiayong than Ibaka in all the organs (p<0.05). Concentrations of Pb, As, Cr and Cd were significantly higher (P <0.05) in Ibaka than Ifiayong in all the organs of fish analyzed. The order of accumulation of metals in the organs were as follows; Ibaka: heart/gills: Zn > Cu > Cr > Pb > As > Cd; kidney: Zn > Cu > Cr > Pb > Cd > As; liver: Zn> Cu > Cr > As >Pb > Cd. Ifiayong: gills/heart: Zn> Cu > Cr > Pb > Cd > As; kidney: Zn > Cu > Cr > As > Cd = Pb and Liver: Zn > Cu > Cr > Pb > Cd = As. In general, these results show that the levels of Zn, Cu, Pb, Cr and As in the fish bought at Ibaka were above recommended levels while those bought at Ifiayong (with the exception of Zn and Cu) were significantly lower (p<0.05) than standards set by WHO/FAO/UNEP. This study, therefore, suggests the need for regular monitoring and assessment of fishing sites in this region for heavy metal contamination to protect the health of consumers.

Key words: *Chrysichthys nigrodigitatus*, heavy metals, Ibaka, Ifiayong, Niger Delta region, silver catfish.

INTRODUCTION

Heavy metal contamination of aquatic ecosystem constitutes a major public health problem (Ashraf et al., 2006). Consequently, researchers and regulatory agencies carry out periodic assessment of the aquatic ecosystem to ascertain the quality of fish consumed by the populace. Heavy metals such as iron, copper, chromium, and zinc are essential for metabolic activities, but become toxic at higher concentrations, whereas lead and cadmium have no beneficial roles in living organisms but are toxic (Malik and Zeb, 2009). Nutritionally, fish consumption is widely encouraged due to its high content of omega-3 polyunsaturated fatty acids: eicosapentanoic

*Corresponding author. E-mail: edetakpanyung@gmail.com.

acid (EPA), docosahexanoic acid (DHA) and protein (Clarkson, 2002). However, the presence of toxic heavy metals can counteract the positive effects of omega-3 fatty acids present in fish. There is evidence that metals accumulate in tissues of fish; therefore, levels of heavy metals measured in tissues of fish can reflect previous exposure to these pollutants (Ashraf, 2005). Heavy metals cause damage by enhancing the production of free radicals in several organs (brain, liver, kidney, heart) and interfering with cellular mechanisms against oxidation, leading to oxidative stress which has been implicated in the aetiology of several diseases (Castro-Gonzalez and Mendez-Armenta, 2008). Exposure to crude oil and its derivatives can act as a mediator in free radical generation and can induce a variety of toxic symptoms in experimental animals (Achuba and Osakwe, 2003). Heavy metal toxicity, persistence and tendency to accumulate in water and sediment, render them severe poisons for all living organisms in high concentrations (Has-Schon et al., 2006).

Many authors have reported increased concentrations of toxic metals in fish caught in Nigerian waters. For example, Farombi et al. (2007) reported high concentration of metals (Zn, Cu, Cd, Pb, As) above WHO/FAO standards in Ogun river. Alinnor (2005) reported that Aba River is polluted due to the discharge of waste from six (6) industries located close to it. High concentrations of heavy metals have also been reported in Olifant River, South Africa (Avenant-Oldewage and Marx, 2000). The present study assessed the quality of silver cat fish (*Chrysichthys nigrodigitatus*) obtained from Ibaka and Ifiayong beaches, Nigeria, by determining heavy metal concentrations in various organs (liver, heart, kidney and gills).

MATERIALS AND METHODS

Study area

The sampling areas for this study are indicated in Figure 1. Ibaka beach is located on the banks of Mbo river which is one of the major rivers in Akwa Ibom State, Nigeria. Mbo River lies within latitude 4° 39' North and longitude 8° 19' East on the southeastern Nigerian coastline. It empties into the Cross River Estuary at Ibaka in the Bight of Bonny and plays a major role in the fisheries resources of Akwa Ibom State (Essien-Ibok et al., 2010). Presently, the river is receiving serious developmental attention by both the state government (the proposed establishment of an international seaport at its banks) and the Mobil oil company that has discovered new oil deposits within the rivers catchment area (Essien Ibok et al., 2010). Conversely, Ifiayong beach is located at latitude 5° 03' North and longitude 8° 01' in Ifiayong, Uruan, Akwa Ibom State. To the best of our knowledge, Ifiayong river is devoid of oil exploration activities but may be susceptible to fertilizer run-offs from fertilizers applied to soils as well as waste discharges.

Collection of fish samples

Samples of *C. nigrodigitatus* were bought directly from fishermen at Ibaka and Ifiayong beaches. They were transported to the labora-Tory in ice-cold containers (0 - 4°C). The samples were authenticated by Dr J. P. Udoh, Department of Fisheries and Aquaculture, University of Uyo, Uyo. The live fishes (10 from each location) weighing between 200 and 650 g were dissected and the liver, heart, gills and kidney were removed and weighed. The organs were frozen and stored at -20°C (in a deep freezer) until required for analysis.

Heavy metal analysis

All fresh organs from the fish were dried in an oven at 105°C for 24 h to constant weight and milled with a mortar and pestle. The samples were transferred into dry labeled plastic containers and stored in a desiccator until required for digestion. A procedure similar to that described by Poldoski (1980) was used to digest the samples. This involved digesting 1 g portion of the ground samples with 10 ml HNO_3/2 ml $HClO_4$ and heating on a hot plate for one hour. After complete digestion, the residue was dissolved and diluted with 0.2 % v/v HNO_3 to 20 ml. The concentrations of metals (Zn, Cu, Cd, Pb, Cr and As) were determined in an Atomic Absorption Spectrophotometer (Bulk Scientific 205)

Statistical analysis

Data were expressed as mean ± standard deviation (SD) and analyzed with the SPSS 18.0 software. Independent T-test was used for the evaluation of data between Ibaka and Ifiayong beaches. P values <0.05 were regarded as statistically significant.

RESULTS AND DISCUSSION

Four different organs (gills, liver, kidney and heart) were analyzed for six metals (Cd, Pb, As, Cr, Zn and Cu) and the results obtained are presented in Table 1. The concentrations (ppm) of Zn and Cu were significantly higher ($P< 0.05$) in all the organs of fish obtained from Ifiayong than Ibaka with the exception of Zn concentrations in the gills which showed no significant difference at the two locations. The characteristic similarity in metal accumulation in liver, gills, kidney and heart in both locations were in the order Zn > Cu > Cr. There was slight variation in the pattern of bioaccumulation of the other metals (As, Cd and Pb) in the organs. This may be attributed to difference in the affinity of metals to fish tissue (Jezierska and Witeska, 2006), metabolic disposition of the organ (Karadede and Unlu, 2000), route of absorption (Ney and Vanhassel, 1983) and age of the fish (Khan et al., 2012).

The accumulation of Zn and Cu in the liver has been attributed to the role of this organ in the storage, metabolism and detoxification of heavy metals (Langston et al., 1998). Also metallothionine which is abundant in fish liver (Atli and Canli, 2007) has affinity for Cu and Zn and therefore may concentrate these metals (Sakulsak, 2012). Jezierska and Witeska (2001) reported that the levels of heavy metals in fish liver can be used to monitor the extent to which water is polluted by these elements. This is due to the fact that the concentration of metals in fish liver is proportional to those in the aquatic environ-

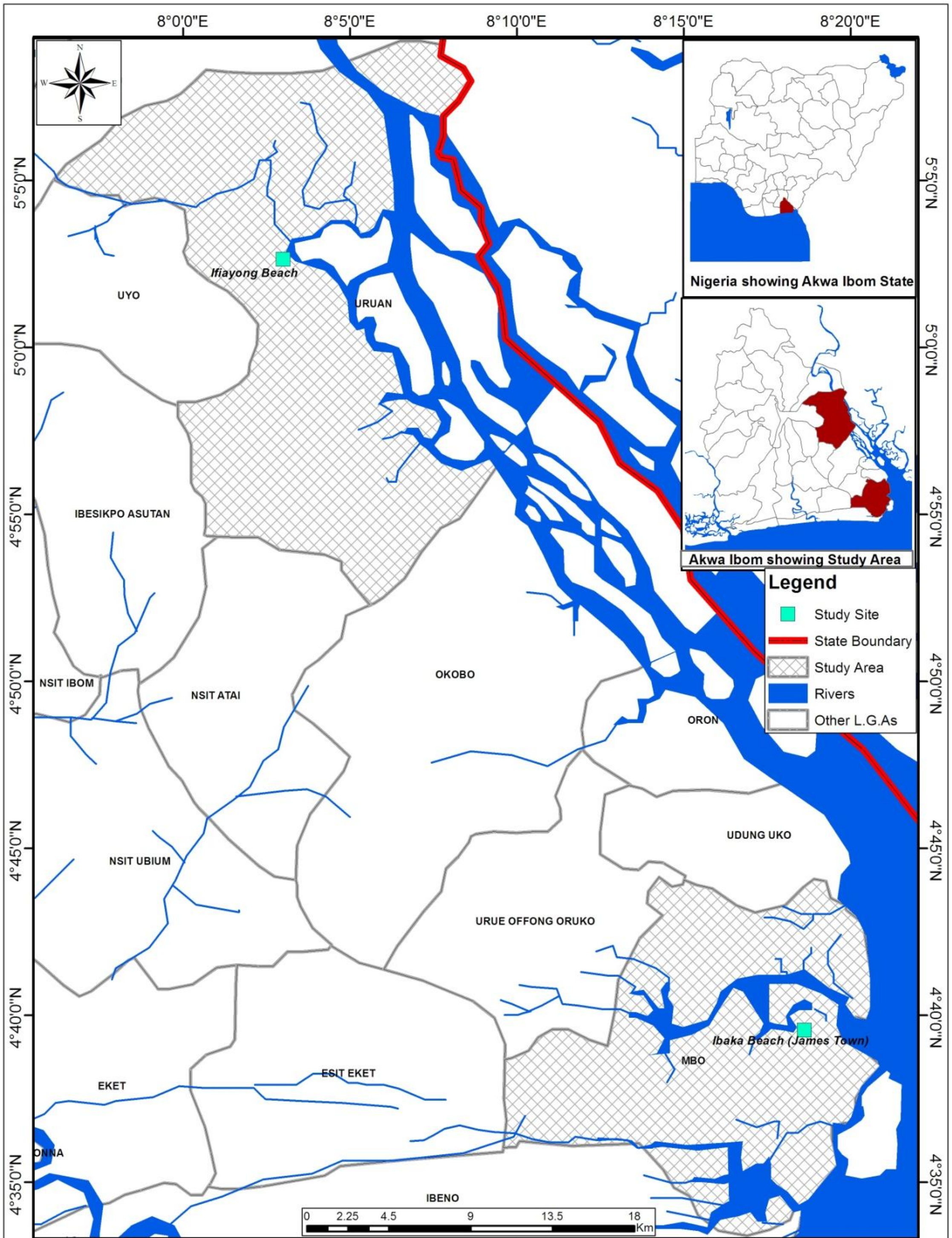

Figure 1. Study Area showing Ibaka beach and Ifiayong beach with inserted maps of Nigeria and Akwa Ibom State.

ment. The high mean concentration of Cu and Zn obtained in this study correlates with the report of other authors (Farombi et al*.,* 2007; Etesin and Benson, 2007; Avenant-Oldewage and Marx, 2000). Zn is neurotoxic at high concentrations and causes neuronal cell death in a dose dependent manner (Chen-Jung and Su-Lan, 2003).

Table 1. Comparison of levels of heavy metals (Zn, Cu, Cd, Pb, As and Cr) (ppm) in organs of *Chrysichthys nigrodigitatus* from Ibaka and Ifiayong Rivers in Akwa Ibom State, Nigeria.

Location	Organ	Cd	Cr	Pb	As	Zn	Cu
Ibaka	Gills	0.0178±0.0055*	0.1109 ± 0.0222*	0.0193 ± 0.0017*a	0.0180± 0.0098	151.1853 ± 0.4161*	56.664± 8.4159 *b
Ifiayong		0.0129 ± 0.0016	0.0018 ± 0.0006	0.0020 ± 0.0005	0.0016 ± 0.0007	151.3052 ± 0.6325 *ab	77.5724 ± 2.7408*
Ibaka	Heart	0.0103 ± 0.0057 a	0.1360 ± 0.0143*	0.0170 a± 0.0034	0.0108± 0.0048	152.3543± 9.1324*	81.3210± 3.0650a
Ifiayong		0.0138 ±0.0005	0.0013 ± 0.0005	0.0013 ± 0.0005	0.0013 ±0.0005	170.4480 ±4.3357*a	88.8493 ±3.5911
Ibaka	Kidney	0.0229± 0.0089*	0.1334± 0.0180*	0.0311± 0.005*	0.0174 ± 0.0082	145.5368± 10.8170*	64.6692± 9.6776*
Ifiayong		0.01156 ± 0.0025	0.0021 ± 0.0019	0.0021 ± 0.0030	0.0021±0.0110*	208.6261 ± 13.8601*	80.4076 ±10.8079*
Ibaka	Liver	0.0109 ± 0.0044	0.0436± 0.0510	0.0129± 0.0032	0.0165± 0.0215	223.0013± 23.4667	81.3645 ± 5.0634
Ifiayong		0.0178 ± 0.0129	0.0010 ± 0.0000	0.0058 ± 0.0066	0.0010 ±0.0000	250.6429 ±16.7823	93.3513 ±6.7834

Values are expressed as mean ± S.D of 10 fishes. *Significantly different from liver at P< 0.05; a = significantly different from kidney at P<0.05; b = significantly different from heart at P<0.05.

The harmful toxicity of Copper is largely attributed to its cupric (Cu^{2+}) form which is commonly found in the species (Olaifa et al., 2004). The permissible limits of Zn and Cu in fish are 5.0 and 0.5 ppm respectively (UNEP, 1986).

The gills also accumulate high concentrations of Zn and Cu. Metal ions are first absorbed through the gills because they are directly in contact with the contaminated medium and also have thinnest epithelium when compared to other organs (Bebianno et al., 2004) Also, the kidney showed high concentration of Zn which according to Jaffer and Pervaiz (1989) could be based on specific metabolic process and co-enzyme catalyzed reactions involving Zn in the kidneys.

Zn and Cu concentrations were found to be higher than the WHO/UNEP/FAO permissible limits of 5.0 and 0.5 ppm respectively, (UNEP, 1986) in fish obtained from Ibaka and Ifiayong

In the present study, the level of Cr was found to be significantly higher (P<0.05) in fish obtained from Ibaka than Ifiayong in all the tissues except liver. This observation might be due to activities such as oil exploration. The health hazards associated with exposure to chromium are dependent on its oxidation state. The metal form (chromium) is of low toxicity. The hexavalent form is toxic and is known to be carcinogenic and teratogenic. Adverse effects of the hexavalent form on the skin may include ulcerations, dermatitis, and allergic skin reactions (Velma et al., 2009). Low doses of Cr produce marked inhibition of glucose reabsorption as a result of damage to convoluted proximal tubules (Stine and Brown, 2006). The mean concentration of Cr in fish from Ibaka was within the range reported by Nyirenda et al. (2011) (0.13 ± 0.01 ppm-liver and 0.11 ± 0.03 ppm-kidney) in catfish caught at Modila Dam, South Africa. The mean concentration of Cr at Ibaka was above limits specified by US EPA (0.1ppm) (US EPA, 1995) while that of Ifiayong were below the limits.

Natural as well as anthropogenic sources of Cd which includes industrial effluents as well as fertilizer and sewage sludge to farmland could increase environmental levels of Cd (Agency for Toxic Substance and Disease Registry (ATSDR), 2012). Our results show that Cd concentration was significantly higher in all the organs in fish from Ibaka than Ifiayong. This could be related to industrial activity of Mobil Oil Producing Company along Ibaka River. The relative order of bioaccumulation in the organs were as follows: Ibaka; kidney > gills > liver > heart while Ifiayong: liver > kidney > gills > heart. Generally, the mean concentration of Cd at the two locations was lower than the permissible limits of 0.05 ppm by International Program on Chemical Safety (WHO, 1992). The mean concentrations of Cd in the organs of fish at Ifiayong and Ibaka were similar to the values reported by Nyirenda et al. (2011). The Cd concentrations in Ibaka and Ifiayong were lower than that reported in the work of Farombi et al. (2007), Cogun et al. (2006) and Ashraf (2005). The results further showed that the mean concentration of As and Pb in fishes bought at Ibaka was significantly higher (p< 0.05) than that of Ifiayong in all the organs. The mean concentration of Pb and As in the gills and kidney samples of fish in both locations ranged between 0.0174-0.0311 ppm. The two organs contained the highest concentration of these metals compared to other organs. The results showed that kidney possesses the ability to concentrate heavy metals; this may be due to the presence of metal binding proteins (Kargin and Cogun, 1999). Also the high concentrations of metals in the gills may be due to its direct contact with the contaminated medium (Bebianno et al., 2004). Has-Schon et al. (2006) also reported concentrations of As to be within the range (0.001-0.019 ppm) in fish obtained from river Neretva (Croatia). In contrast to the present study, high concentrations of As had been reported by some authors (Nyirenda et al., 2011; Farombi et al., 2007; Usero et al., 2003). Our findings on mean concentration of Pb was in line with the results of Falco et al. (2006) who reported lead concentrations in various edible marine species which varied from 0.002-0.21 µ/g fw. The mean concentration of As and Pb in both locations were below the permissible limits of 0.01 and 0.29 ppm respectively (FAO/WHO, 2005; WHO, 1995). However, ATSDR (2007) states that there is no safe concentration of lead. Lead causes toxicity by replacing zinc in heme synthesis and inhibiting the function of heme-synthesizing enzymes (Goyer and Clarkson, 2001). National Academy of Science/National Research Council (1993) reported that substitution of calcium by lead resulted in toxicity of several vital enzyme systems in the central nervous system. This toxicity impaired the development and function of enzymes involved in the production and transport of neurotransmitters. Victims of Pb intoxication have been reported to manifest various forms of neurological syndrome such as lead palsy and encephalopathy, especially in children (Klaassen, 1995). Some of the clinical manifestations include muscular weakness and fatigue which are more pronounced in the fingers, wrist, toes and forearm; clumsiness, ataxia, headache, insomnia and irritability. Arsenic causes coagulation of proteins, forms complexes with coenzymes and inhibits the production of adenosine triphosphate (ATP) during respiration (Institute of Environmental Conservation and Research, 2000). It is possibly carcinogenic and high-level exposure can cause death (Ogwuegbu and Ijioma, 2003; USDOL, 2004).

Conclusion

This study shows that *C. nigrodigitatus* obtained from Ibaka and Ifiayong beaches were at various levels of contamination by heavy metals. The concentrations of these metals in the fish could endanger public health since this species of fish is most preferred by consumers in this environment. Metals with concentrations below the permissible limits may cause harm due to their synergistic effects. Therefore, regular monitoring of these rivers is desirable. Also, effective methods of waste disposal should be adopted to prevent agricultural runoff into these rivers, preserve healthy aquatic environment and ultimately protect the health of the humans who consume the fish.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Heavy metal concentration in selected fish species from Eleyele reservoir Ibadan Oyo State South-western Nigeria

Ayeloja, A. A.[1]*, George, F. O. A.[2], Shorinmade, A. Y.[3], Jimoh, W. A.[1], Afolabi, Q. O.[3] and Olawepo, K. D.[1]

[1]Department of Fisheries Technology, Federal College of Animal Health and Production Technology Moor Plantation, PMB 5029 Ibadan, Oyo State, Nigeria.
[2]Department of Aquaculture and Fisheries Management, Federal University of Agriculture, Abeokuta (FUNAAB) PO Box 2240 Abeokuta, Ogun State, Nigeria.
[3]Department of Science Laboratory Technology, Federal College of Animal Health and Production Technology Moor Plantation, PMB 5029 Ibadan, Oyo State, Nigeria.

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Heavy metal concentrations (lead, cadmium, zinc, copper, chromium and manganese) in selected fish species from Eleyele reservoir Ibadan Oyo State South-Western Nigeria were investigated. A sample each of catfish (*Clarias gariepinus*), Africa pike *(Hepsetus odoe*) and tilapia fish (*Oreochromis niloticus*) from Eleyele lake Ibadan Oyo state were collected from fish farmers at the landing site early in the morning using standard procedure and transported to the laboratory within 30 minutes for laboratory analysis. Heavy metal concentration in the flesh of the fish species and water sample were analysed using atomic absorption spectrophotometer. There existed significant difference ($p<0.05$) in the concentration of heavy metals in fish flesh of various fish species with that of herbivorous fish (Tilapia fish) being the highest followed by omnivorous fish (catfish), followed by piscivorous fish (*H. odoe*), while that of the water body was the lowest. It was concluded that fish could be considered bio-indicator of environmental contamination within the aquatic ecosystem; it also indicates that fish could be useful in estimating bioavailability of metal to freshwater biota.

Key words: Heavy and trace metal, *Clarias gariepinus*, *Hepsetus odoe, Oreochromis niloticus,* Eleyele reservoir.

INTRODUCTION

Heavy metal comprises a number of elements which are manganese, chromium lead, cadmium, etc. (Mazvila, 2001), but these metals are also the most important source of necessary for living organisms: that is, iron, zinc, copper, pollution (Chovanec et al., 2003; Popek et al., 2008). The subject of heavy metal is receiving increasing popularity in food industry due to high incidence of contamination in agricultural and seafood

*Corresponding author. E-mail: ayeloja2@gmail.com, aye_ayo@yahoo.com. Tel: +2348032111426.

products (Mohammad et al., 2011). Heavy metal affects freshwater organisms and induces certain harmful modifications at histological and morphological levels, also decreases the growth and developmental rates resulting in increase of death rate and the decrease of birth rate (Authman, 2008). Their potential toxic effects are given by the presence in water solution at concentrations exceeding certain threshold levels and their long persistence in the aquatic ecosystems and their bioaccumulation and biomagnification in the food webs (Naeem et al., 2011). Metal accumulation in fish tissues poses a direct threat for human being (Papagiannis et al., 2004). The distribution of metals varies between fish species, depending on age, development status and other physiological factors (Kagie and Schaffer, 1998). The ingestion of food is an obvious means of exposure to metals, not only because many metals are natural components of food stuffs, but also environmental contamination and contamination during processing (Voegborlo et al., 1999). Heavy metals having penetrated into human being through food chains might cause various disturbances or serious diseases (Idzelis et al*.,* 2007). Once heavy metals are ingested, numerous health problems will take place. Lead may cause learning disabilities, impaired protein and hemoglobin synthesis and shorten the lifespan of red blood cells which leads to severe anemia (hypochromic microcytic anemia) in children (Sultana et al., 1998). The most common toxic effects of cadmium in human is renal failure, accumulation in the bone resulting in calcium loss and malfunctioning of peripheral and central nervous system (Schroeder et al., 1965; Castro et al., 2008). Nickel has different undesirable effects on human health such as impairing the biological activity of cells, lung and nasal cancer in long-term exposure; respiratory, nervous and digestive disorders and also psychological problems will be increased (Sultana and Rao, 1998). Zinc causes slow growth in children, reduced fertility, dry mouth, headache and nausea (Castro et al., 2008). Although fish can be effective in preventing cardiovascular disease (CVD), the fish found in waters with heavy metals may increase the incidence of some illnesses such as cancer (Capar and Yess, 1996). Therefore investigation of the heavy metals in fishes becomes important to estimate freshwater pollution and the risk potential of human consumption (Dural et al., 2007). This study therefore evaluates the presence of heavy metals in three commercial fishes from selected water bodies in Ibadan metropolis.

MATERIALS AND METHOD

The study area

Eleyele reservoir

The study location Eleyele Reservoir is located in north-eastern part of Ibadan, Southwestern Nigeria within longitude N07025'00" and N07027'00" and Latitude E03050'00" and E03053'00" (Figure 1). The study site is surrounded by Eleyele neighborhood in the south, Apete in the east and Awotan in the north. Eleyele wetland is a modified natural riverine wetland type with area of about 100 km2 including the catchment area. The elevation is relatively low ranging between 100- 150 m above sea level and surrounded by quartz-ridge hills toward the downstream section where the Eleyele dam barrage is located. A number of stream channels serve as feeding / recharge streams to the Eleyele wetland basin. In 1942, the quest to create a modern water supply system to meet the challenge of water scarcity for the emerging Ibadan metropolis led to the construction of Eleyele Dam on the main River Ona with a reservoir storage capacity of 29.5 million litres (Tijani et al., 2001).

Sample collection

A sample each of catfish (*C. gariepinus*), African pike *(Hepsetus odoe*) and tilapia fish (*O. niloticus*) (Figure 2) from Eleyele lake Ibadan Oyo state were bought from fish farmers at the landing site by 8.00 am, the fish were collected inside an ice box and transported to SMO laboratory Joyce B road Ibadan, Oyo State, Nigeria within 30 min for laboratory analysis. Sample of the water body in which these fish were sourced was also collected in water sampling bottle using a standard procedures described by Welz and Sperling (1999): the sampling bottles were conditioned by washing with detergent solution that is metal free and non-ionic and finally rinsing several times with distilled water. The sampling bottles were rinsed with the dam water first before the sample were finally collected. The heavy metal concentration of the fish species and the water sample were analyzed in triplicate using the following analytical procedure:

Digestion of fish samples

1 g of sample was weighed into a 50 ml digestion tube, 20 ml of acid mixture H_2SO_4, HNO_3, $HClO_4$ (2:1:1) were added to the sample and set in the appropriate hole of the digestion block to digest to a clear colourless solution. The digest was cooled down and carefully washed with deionized water into a 50 ml volumetric flask and made up to mark. The element digest was used to read for the level of the trace metals on the Atomic Absorption Spectrophotometer at a wavelength and allow cathode lamp related to each trace metal.

RESULTS AND DISCUSSION

Table 1 shows heavy metal concentration (mg/l) in fish species sampled from Eleyele Lake, Ibadan, Oyo State, Nigeria. The result of this study indicates that there was significant difference ($P<0.05$) in the concentration of lead (Pb) present in the different fish species and the water body; the lead concentration in the water body was the lowest with mean value of 0.2730 ± 0.05% while that of African pike was the highest with mean value 0.663 ±0.02%. The levels of lead in these fish samples were less than those recommended by European commission (EC) 2001 guideline and FAO, as reported by Sivaperumal et al. (2007) that the allowable level of lead in fish, is 0.4 and 0.5 mg/kg respectively. Furthermore, there was significant difference ($p<0.05$) in the concentration of cadmium (Cd) present in different fish species with the cadmium concentration in tilapia body being the lowest with the mean value of 0.073 ±0.02%

Figure 1. Map of the study area. Source: Tijani et al. (2001).

Table 1. Heavy metal concentration (mg/l) in fish species sampled from Eleyele lake, Ibadan, Oyo State, Nigeria.

Fish	Pb	Cd	Zn	Cu	Cr	Mn
Tilapia	0.393 ± 0. 04[c]	0.073 ± 0.02[b]	0.442 ± 0.83[b]	0.236 ± 0.11[a]	0.273 ± 0.05[c]	0.008 ± 0.13[d]
Catfish	0.463 ± 0.12[b]	0.123 ± 0.04[a]	0.464 ± 0.03[a]	0.108 ± 0.32[b]	0.173 ± 0.02[d]	0.012 ± 0.02[c]
African pike	0.663 ± 0.02[a]	0.093 ± 0.12[b]	0.235 ± 0.13[c]	0.042 ± 0.22[d]	0.325 ± 0.22[b]	0.162 ± 0.24[a]
Water	0.273 ± 0.05[d]	0.833 ± 0.02[b]	0.093 ± 0.12[d]	0.097 ± 0.02[c]	0.113 ± 0.03[a]	0.074 ± 0.33[b]

Column means with different superscripts are significantly different (P<0.05) from one another.

while that of water is the highest with the mean value of 0.833 ± 0.02%. The values obtained for cadmium present in fish samples in this study is far less than those reported in Egypt and Saudi Arabia as reported by Voegborlo et al. (1999) when they determined the amount of cadmium in the tuna fish; the amount of cadmium in tuna was 0.32 and 0.35 μg g^{-1} in each sample respectively.

However, prevention of cadmium in Eleyele water body should be encouraged so as to prevent its bioaccumulation because when cadmium accumulates in the human body, it may induce kidney dysfunction, skeletal damage and reproductive deficiencies (Mohammad et al., 2011). There was also significant difference (P<0.05) in the concentration of zinc (Zn) present in different fish species with the zinc concentration in water being the lowest with the main value of 0.09317±0.12%. There was significant difference (P<0.5) in the copper (Cu) concentration with that of *H. odoe* been the lowest with the mean value of 0.042±0.22% while the copper concentration in tilapia fish is the highest with the mean value of 0.236±0.11. This agrees with the opinion of Bordajandi et al. (2003) that diet has a remarkable role in the bioconcentration process for some metals, mainly for the Cu and Zn. Protasowicki et al. (1983) also reported that feeding strategy influenced the content of Cu and Zn in fish.

The result also indicates that there was significant different (P<0.5) in the chromium (Cr) concentration present in different fish species with the chromium concentration in water been the lowest (0.11273±0.03) while that of African pike was the highest (0.3253±0.22). Also, there exists significant difference (P<0.05) in the

Catfish (*Clarias gariepinus*)

African pike (*Hepsetus odoe*)

Tilapia fish (*Oreochromis niloticus*)

Figure 2. Fish samples used for the study.

manganese (Mn) concentration present in different fish species with the manganese concentration in tilapia fish been the lowest (0.008±0.13) while that of African pike was the highest (0.162±0.24). Similar manganese range of 0.14 - 3.36 mg/kg for muscle of fish was reported by Turkmen and Ciminli (2007). This study indicate that heavy metals concentration in different fish species differs; this in line with the opinion of Atuanya et al. (2011) that concentration of heavy metals varies with variation in fish species. This study also indicate that mineral content of herbivorous fish (Tillapia fish) is highest followed by ominiovorous fish (catfish) followed by piscivorous African pike (*H. odoe*), while that of the water body was lowest. This agrees with the report of Farkas et al. (2000) that the concentrations of element in fish body could be related primarily to their feeding habits.

Burger et al. (2002) also reported that fishes are good indicators for heavy metal contamination in aquatic systems because they occupy different trophic levels with different sizes and ages. Figure 3 shows heavy metal concentration in fish species sampled from Eleyele lake, Ibadan Oyo State Nigeria.

Transfer factor (TF)

The transfer factor in fish tissues from the aquatic ecosystem was calculated according to Kalfakakour and Akrida-Demertzi (2000), Rasheed (2001) and Anim-Gyampo et al. (2013):

$$\mathrm{TF} = \frac{\text{Metal concentration in tissue}}{\text{Metal concentration in water}}$$

Table 2 shows heavy metal concentration (mg/l) in the water of Eleyele reservoir. The result of this study indicates that the mean heavy metal concentrations in raw water from Eleyele reservoir follow an increasing order of Mn< Zn<Cu<Cr < Pb < Cd. This result trend was similar to what was reported in the work of Anim-Gyampo et al. (2013).

The heavy metal concentrations obtained from the raw water with the exception of Zn and Cu exceeded the various raw water quality guidelines (WHO, 2003; USEPA, 1986). The concentrations of Pb, Cd and Cr (0.273, 0.833 and 0.113 mg/l) exceeded all the raw water guideline values, while Mn (0.074 mg/l) exceeded the guideline value of USEPA (1986).

The transfer factor is as presented in Table 3 which indicates that the concentration of heavy metals in the tissue was more than the concentration of the heavy metals in the water body with exceptions of Cd and in all the fish samples; Cu in African pike and Mn in tilapia and catfish. This result is in consonance with the report of Anim-Gyampo et al. (2013) that the mean heavy metal concentrations in tissues of the fish were higher than

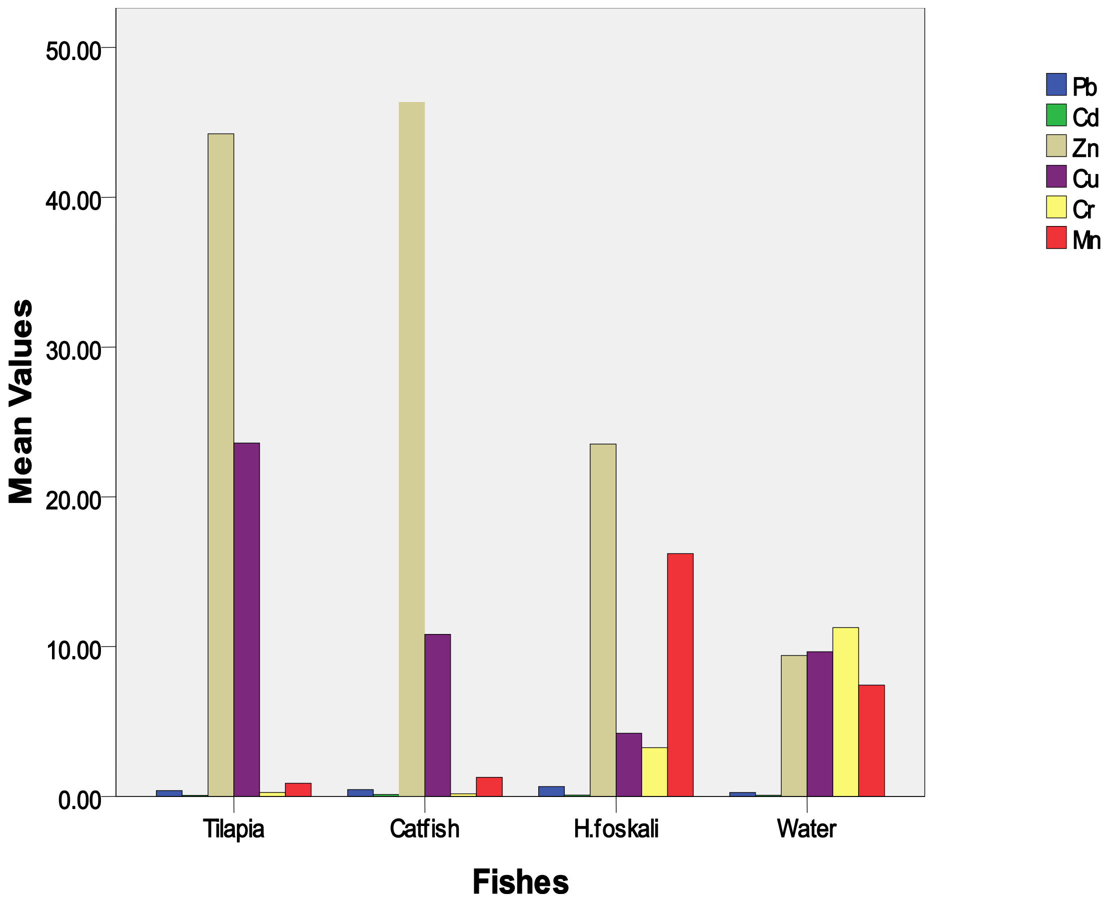

Figure 3. Chart showing heavy metal concentration in fish species sampled from Eleyele Lake, Ibadan Oyo State Nigeria.

Table 2. Mean heavy metal concentration (mg/l) in the Water of Eleyele reservoir.

Guideline	Pb	Cd	Zn	Cu	Cr	Mn	Reference
WHO	0.01	0.010	0.50	2.25	0.05	0.50	WHO,2003
USEPA	0.11	0.010	0.50	2.25	0.10	0.02	USEPA,1986
Water	0.273	0.833	0.093	0.097	0.113	0.074	This study

Table 3. Transfer factor (water/muscle) in different fish species.

Fish species	Pb	Cd	Zn	Cu	Cr	Mn
Tilapia	1.44	0.09	4.75	2.43	2.42	0.11
Catfish	1.70	0.15	4.99	1.11	1.53	0.16
African pike	2.43	0.12	2.53	0.43	2.96	2.19
WHO	0.005	0.003	5.0	2.00	0.15	0.50

metal concentration in raw water. Similarly, Chale (2002) also reported that heavy metal concentration in fish tissue is higher than that of water.

Conclusion

The result of this study supplied valuable information on the heavy metal level of some fish species in Eleyele lake Ibadan Oyo State Nigeria. The values obtain for heavy and trace metals in this study were below the limits in muscle tissue for fish proposed by EU commission Regulation (2001). The study indicates that fish could be considered bio-indicator of environmental contamination within the aquatic ecosystem. It also indicates that fish could be useful in estimating bioavailability of metal to freshwater biota. It is therefore recommended that heavy metal pollution of the rivers and lakes by Industries in Ibadan should be checked by relevant authorities so as to guarantee food safety and minimize environmental pollution.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Assessment of heavy metals in vegetables irrigated with Awash River in selected farms around Adama town, Ethiopia

Girmaye Benti

Department of Biology, Dilla University College of Natural and Computational Science, P. O. Box.419 Dilla, Ethiopia.

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A study was conducted at Melka Hida and Wonji Gefersa farms where Awash River was used for cultivation of vegetable crops to assess heavy metal contamination of vegetables. To what extent these vegetables are contaminated is not known. Three leafy vegetable samples, namely, cabbage (*Brassica oleracea Linn*.), lettuce (*Lactuca sativa*) and spinach (*Spinacea oleracea*) from Melka Hida and Wonji Gefersa farms were examined for heavy metal (Cd, Cr and Pb) contamination using atomic absorption spectroscopy. The results indicate that the heavy metals in vegetables of Melka Hida farm were higher than those of the vegetables in Wonji Gefersa farm. In all the samples analyzed, the concentration of Pb and Cd was more than the maximum limit and their levels varied from 0.31 to 0.65 and 0.21 to 0.40 mg/kg, respectively. However, the level of chromium was generally within the normal range in cabbage (0.85 and 0.29 mg/kg) and spinach (1.30 and 1.06 mg/kg) from Melka Hida and Wonji Gefersa farms, respectively, except in lettuce from Melka Hida farm, 2.4 mg/kg. The high levels of these heavy metals place the consumers of these vegetables grown within the study area at health risk with time unless an urgent step is taken by relevant agencies to address this issue.

Key words: Awash River, contamination, trace elements, vegetables.

INTRODUCTION

Vegetables constitute an important part of the human diet since they contain carbohydrates, proteins, as well as vitamins, minerals and trace elements (Abdola and Chmtelnicka, 1990). In recent years, their consumption is increasing gradually, particularly among the urban community. This is due to increased awareness on the food value of vegetables, as a result of exposure to other cultures and acquiring proper education (Thompson and Kelly, 2003). However, they contain both essential and toxic elements over a wide range of concentrations.

Rapid and unorganized industrialization and urbanization have contributed to the elevated levels of heavy

*E-mail: gurmuukoo@gmail.com or girme2008@yahoo.com.

metals in the urban environment in developing countries (Wong et al., 2003). As urban populations in developing countries increase, and residents seek better living standards, larger amounts of freshwater are diverted to domestic, commercial and industrial sectors, which generate greater volumes of wastewater (Asano et al., 2007; Qadir et al., 2007a). There is, however, a lack of investment capacity worldwide for construction and operation of adequate treatment facilities which threatens the quality of surface waters, soils and groundwater to which wastewater is discharged.

In addition to this, excessive application of nitrogen and other inorganic fertilizers and organic manures to these vegetables can accumulate high levels of nitrate and other anions as well as heavy metals. Heavy metals, such as cadmium, copper, lead, chromium and mercury, are important environmental pollutants, particularly in areas under irrigated with wastewater. Several studies have revealed that contamination of vegetables with heavy metals and pesticides poses a threat on consumers (D'Mello, 2003; Sharma et al., 2006; Zandstra and De Kryger, 2007).

International Water Management Institute (IWMI) (2006) suggests that at least 3.5 million ha of land is irrigated globally with untreated, partly treated, diluted, or treated wastewater. Wastewater often contains a variety of pollutants: salts, metals, metalloids, pathogens, residual drugs, organic compounds, endocrine disruptor compounds and active residues of personal care products. Moreover, the excessive accumulation of heavy metals in agricultural soils through wastewater irrigation may not only result in soil contamination but also may lead to elevated heavy metal uptake by vegetables, and thus affect food quality and safety (Muchuweti et al., 2006).

According to Bahemuka and Mubofu (1999) and Ikeda et al. (2000), humans are exposed to the risks through the consumption of vegetables contaminated with heavy metals. Most consumers are not aware of the source of the produce and the use of polluted irrigation water.

Adama and Wonji Gefersa towns are found in Adama *Woreda* of East Showa Zone, Oromia Region, with a population of 260,600 and 23,510, respectively (CSAE, 2005). Awash River is the only important river in Adama *Woreda* used for irrigating around 1132 ha of land. Among the major rivers of Ethiopia, Awash River, which flows from central highlands through Ethiopia's major industrial and agro-industrial belt, taking in a whole burden of all types of raw effluent stands as one of Ethiopia's river streams in urban areas of developed rivers (Tesfamariam, 1989). Most of the existing industries and major towns with in the upper watershed have no treatment plants for discharge of their wastes and are seriously polluting the water course (MWEE, 2010).

In addition, the Modjo River, which is highly polluted by discharging effluent from Modjo tannery industry and waste disposed from the town, is the main tributary of Awash River. Besides this, the expansion of new industries and disposal of industrial wastes to the Awash River is of great concern to the nation (Girma, 2001). Furthermore, food and beverage factories tend to discharge heavy organic pollutants and dyes from textile factories are also released into the same river. The level of toxic heavy metals in vegetables grown on irrigated Awash River is not known in the study area. Therefore, the study was designed to assess the levels of some toxic heavy metals contaminants on selected vegetables irrigated with Awash River in Melka Hida and Wonji Gefersa farms around Adama town.

MATERIALS AND METHODS

Description of the study area

This study was conducted at two wastewater irrigated vegetable growing farms, that is, Melka Hida and Wonji Gefersa that are found in Adama *Woreda*. Melka Hida is found in Adama Town Administrative Zone, Oromia Region, which is 99 km away from Addis Ababa and is located at latitude of 8° 33′ 0″ north and longitude 39° 16′ 12″ east. It has an elevation of 1620 m above sea level.

Wonji Gefersa is a town that is found in Adama *Woreda* of East Showa Zone, Oromia Region, nearby Adama Town, which is 107 km away from Addis Ababa and located at a latitude of 8° 26' 59'' north and longitude of 39° 16' 48'' east. It has an elevation of 1588 m above sea level and its temperature and annual rain fall is 23°C and 500-800 mm, respectively (Environmental Protection Authority, 2005). Awash River is the only important river in Adama *Woreda* used for irrigating around 1132 ha of land, which originates from the highlands of Dandi *Woreda* located west of Addis Ababa, Ethiopia, and flows along the rift valley into the Afar region, where it eventually terminates in a salty lake, Lake Abbe, found on the border with Djibout.

Study design

A cross sectional survey was conducted to assess the level of heavy metal contamination on the main leafy vegetables [lettuce (*Lactuca sativa*), cabbage (*Brassica oleracea Linn*.), and spinach (*Spinacea oleracea*)] that were grown in Melka Hida and Wonji Gefersa vegetable farms irrigated with Awash River. The samples were regularly collected in three week intervals during January 2013 - March 2013. The vegetable samples were analyzed for heavy metals, cadmium (Cd), lead (Pb), and chromium (Cr) concentrations using atomic absorption spectroscopy (AAS).

Sample collection

A total of 72 samples comprising three types of fresh vegetables (cabbage, lettuce, spinach,) were collected from Melka Hida and Wonji Gefersa vegetable farms using a random sampling technique method. Recently, matured leaves of lettuce, cabbage, and spinach were sampled at early maturity according to methods used by Fisseha (1998). All samples were collected aseptically in a sterilized

Table 1. Mean concentration of three purposively selected heavy metals in vegetables cultivated at Melka Hida and Wonji Gefersa farms in terms of mg/kg dry weight (Mean±SE).

Parameter	No. of examined sample	Site	Vegetable type				
			Cabbage	Lettuce	Spinach	Mean	Maximum limit
	12	MH	$0.31±0.3^{b}$	$0.65±0.3^{a}$	$0.33±0.3^{b}$	$0.43±0.2^{a}$	
Pb	12	WG	$0.30±.03^{b}$	$0.40±0.3^{a}$	$0.31±0.3^{b}$	$0.34±0.2^{b}$	0.3*
		Mean	$0.31±0.2^{b}$	$0.53±0.2^{a}$	$0.32±0.2^{b}$		
	12	MH	$0.85±0.4^{b}$	$2.4±0.4^{a}$	$2.1±0.4^{a}$	$1.78±0.2^{a}$	
Cr	12	WG	$0.29±0.4^{b}$	$1.33±0.4^{a}$	$1.06±0.4^{a}$	$0.89±0.2^{b}$	2.3**
		Mean	$0.57±0.3^{b}$	$1.86±0.3^{a}$	$1.58±0.3^{a}$		
	12	MH	$0.23±0.3^{b}$	$0.40±0.3^{a}$	$0.3±0.3^{b}$	0.31±0.2	
Cd	12	WG	$0.20±0.3^{b}$	$0.32±0.3^{a}$	$0.22±0.3^{b}$	0.25±0.2	0.2*
		Mean	$0.22±0.2^{b}$	$0.36±0.2^{a}$	$0.26±0.2^{b}$		

$^{a-b}$ Means with different superscript letters along the row for the same parameter in the same site do significantly differ (P<0.05). Pb = Lead, Cr = Chromium, Cd = Cadmium. **Source: Weigert (1991) *Source: FAO/WHO (2001).

universal container and plastic bags and transported to Dilla University for laboratory processing.

Determination of heavy metals in leafy vegetables

Vegetable samples were washed with distilled water to eliminate suspended particles. The leafy stalks were removed from all samples and these were sliced and dried on a sheet of paper to eliminate excess moisture; and then carefully dried in oven at 70°C for 24 h. 2 g of the plant material were weighed and ground in a pestle and mortar followed by wet digestion with HNO_3 and H_2O_2 in Tappi (1989) test method, as cited in Subhashini (2013) in the ratio of 3:1. The samples were digested on a hot plate at a temperature of 93°C for 4 h. Heating was done such that it did not boil and until it dried up completely to give a whitish brown dry mass. It was then cooled and the precipitate/digest mixture was extracted in acid water mixture (HCl: distilled water, ratio 3:1) and filtered through Whatman filter paper No. 42. Following this, the volume of the filtrate was made up to 50 ml. Finally, the filtrate was analysed for heavy metal content using atomic absorption spectroscopy (GBC 932AA).

Data analysis

In this study, all statistical analyses were computed using SAS software version 9.1 for heavy metal analysis. The recorded data were subjected to analysis of variance (ANOVA) to assess the effect of vegetable type and site of production on the concentrations of heavy metal contaminant in the vegetables tested. As the level of heavy metal contamination might vary with sample collection site and vegetable type, ANOVA was used to test the existence of significant difference between means. In all statistical analyses, confidence level was held at 95% and P<0.05 was considered as significant.

RESULTS AND DISCUSSION

Heavy metal contamination of vegetables

The concentrations of heavy metals in leafy vegetables (lettuce, spinach and cabbage) from both study sites are shown below in Table 1. Average concentration of Pb in lettuce was 0.65 and 0.4 mg/kg; spinach 0.33 and 0.31 mg/kg; cabbage 0.31 and 0.30 mg/kg dry weight each at Melka Hida and Wonji Gefersa, respectively. Lettuce showed a highly significant difference (p<0.01) in Pb concentration among the other vegetables and between the sites. However, all the Pb concentrations on the samples analyzed exceeded the permissible limit of 0.3 mg /kg dry weight (FAO/WHO, 2001), except cabbage at Wonji Gefersa farm. Meanwhile the cadmium (Cd) concentration in the leafy vegetables (spinach, lettuce and cabbage) analyzed mean were 0.3, 0.4, 0.23 and 0.22, 0.32, 0.20 mg/kg dry weight at Melka Hida and Wonji Gefersa sites, respectively. The concentrations of Cd in leaf vegetables had highly significant difference (P <0.01) between vegetable types, and there was significant difference (p<0.05) between sites. This might be because the plantation of industries there directly discharges their effluents into Awash River where the water is used in Melka Hida farm.

However, the concentrations of Cd in almost all samples exceed the tolerable limit of 0.2 mg/kg dry weight (FAO/WHO, 2001), except cabbage at Wonji Gefersa site. However, chromium accumulation in the analyzed leafy vegetables was within normal range of the permissible levels, except lettuce at Melka Hida farm, which is 2.40 mg/kg dry weight. There were highly significant differences (P <0.01) between vegetable types and between sites.

Lead

Elevated lead levels are toxic to plants and humans.

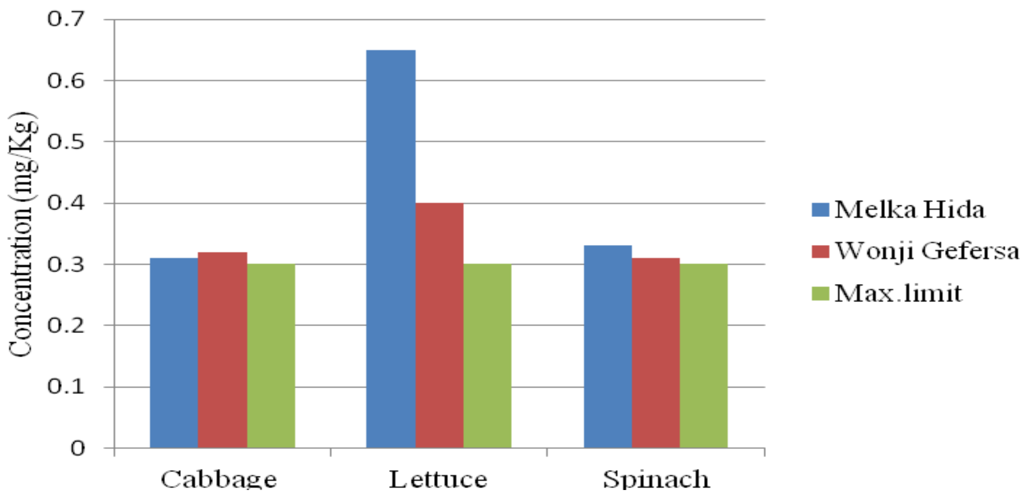

Figure 1. Lead concentration levels in vegetables of Melka Hida and Wonji Gefersa farms.

Even though many plants accumulate large amounts of lead without visible changes in their appearance or yield, this may cause a series of metabolic changes in plant such as slow growth, delayed flowering and reduction in quality. In addition, this can bring Pb into the human food chain, thereby becoming a major concern for health (Concon, 1988). Like most heavy metals, Pb can bioaccumulate overtime and exist in the body for long periods.

Thus, it is necessary to detect such metals even at very low concentrations. Heavy metal contamination of vegetables may occur due to irrigation with contaminated water (Sinha et al., 2006) and emissions of heavy metals from the industries and vehicles may be deposited on the vegetable surfaces during production, transport and marketing (Maleki and Zarasvand, 2008; Sharma et al., 2008a and 2008b) the addition of fertilizers and metal based pesticides on vegetable farm. A similar study that is conducted by Singh and Kumar (2006) and Kumar et al. (2009), reported that lead concentrations of lettuce ranged from 2.3-5.30 mg /kg sample by which super passed the maximum permissible level of Pb set by (FAO/WHO, 2001).

In respective of these results, Farooq et al. (2008) stated that Pb concentration was above toxicity level in leafy vegetables grown in vicinity of an industrial area of Faisalabad, Pakistan. In this study, the concentration of Pb levels in cabbage is least among the other vegetables (Figure 1).

This finding is similar to that of Fisseha (1998) who commented that cabbage was generally the least accumulator of heavy metals as compared to other vegetables. In the current study, the high level of Pb in all vegetables suggests that the water used for irrigation was not good for irrigation of crops in general and leafy vegetables in particular.

Chromium

Exposure to chromium may occur through breathing air, drinking water, or eating food containing chromium or even through skin contact. Exposure to elevated levels chromium leads to skin irritation, ulceration, damage to circulatory and nerve tissue which lead to health problems (Bubb and Lester, 1994). In this study, the chromium content of samples analyzed ranged from 0.29 to 2.40 mg/kg of dry weight. This shows that chromium metal levels are generally within normal range in all vegetable samples from both farms, except lettuce in Melka Hida farm. The chromium contents of lettuce at Melka Hida farm exceed maximum limit of metal concentration set by Weigert (1991) among all vegetables studied as shown in Figure 2.

In line with these results, Fisseha (1998) reported that lettuce had generally the highest concentrations of Cr, Cd, Co, Fe and Mn at Peacock (Addis Ababa) vegetable farm. Similarly, Farooq et al. (2008) reported that Pb and Cd were above toxicity level in leafy vegetables grown in vicinity of an industrial area of Faisalabad, Pakistan whereas other heavy metal (Cr) were within the permitted limits.

Cadmium

Cadmium is a non-essential element in foods and natural waters. It accumulates principally in the kidneys and liver (Divrikli et al., 2006). Various sources of environmental contamination have been implicated for their presence in

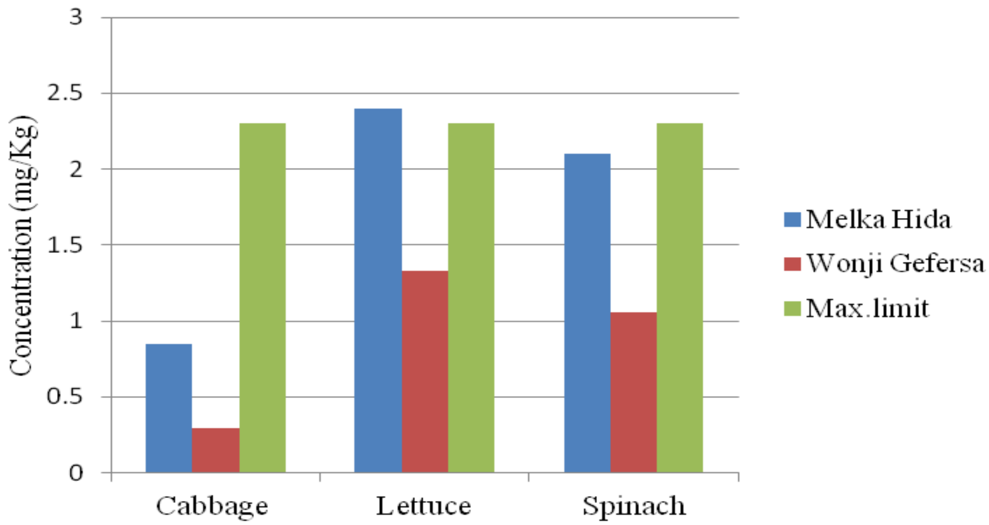

Figure 2. Chromium concentration levels of vegetables in Melka Hida and Wonji Gefersa farms.

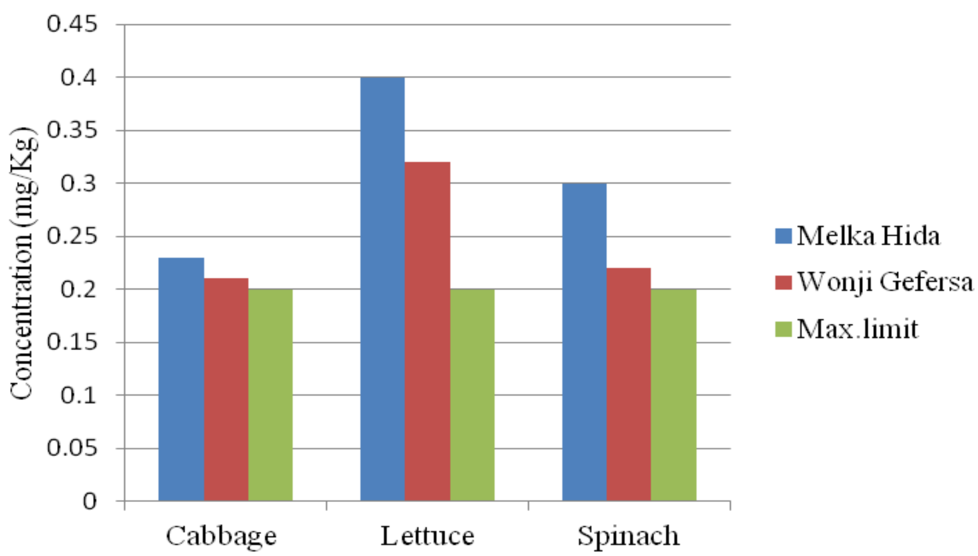

Figure 3. Cadmium concentration levels of vegetables in Melka Hida and Wonji Gefersa farms.

foods. Cadmium is the most toxic heavy metal because its bioaccumulates has a long half-life of about 30 years and may cause health disorders even at low doses (Lenntech, 2006). Toxic effects of Cd on plants include chlorosis, growth inhibition, reduction in water and nutrient uptake and crop protein synthesis (Dass et al., 1997). Cadmium is easily absorbed and translocated to shoots of food crops and may lead to chronic Cd toxicity in human (Mumba et al., 2008). However, it can also cause damage to the skeletal system and kidneys and induce cancer in humans (He et al., 2005). The level of cadmium in this study ranges from 0.20 to 0.40 **(**Figure 3**)** which exceeded the recommended limit set by FAO/WHO (2001), 0.20 mg /kg dry weight. In strong connection with this finding, an earlier study by Rahlenbeck et al. (1999) reported that metal contents of vegetables from Addis Ababa market showed that lettuce contained the highest Cd accumulation and cabbage contained the least.

Similarly, Bhatia and Choudhri (1991) reported the concentrations of Cd in edible vegetables ranged from 0.05 to 0.9 mg/kg dry weight and leafy plants such as lettuce, spinach and cabbage contains relatively higher Cd than grain or fruit plant such as apple, due to their higher transpiration. In addition, investigation done by Awashthi (2000) showed that the concentrations of Cd in spinach (4 mg/kg) and radish (2.5 mg/kg) were above the recommended level. In the present study, the accumulation of elevated concentration of Cd in lettuce and spinach might be attributed to the use of contaminated water and industrial effluents for their cultivation. The other possible reason for accumulation is that Cd is relatively easily taken by food crops and especially by leafy vegetables.

Comparing the two contaminated sites, lettuce and spinach accumulated more Pb and Cd at both sites (Melka Hida and Wonji Gefersa); while the cabbage and lettuce accumulated (Pb and Cr) more at Melka Hida farm, respectively. This shows that Melka Hida farm is, hence, more contaminated than Wonji Gefersa farm. This might be due to the fact that more industrial effluents from various industrial sources enter Awash River near the point where water is used for irrigation.

Conclusions

The study reveals that there was heavy metals contamination of fresh leafy vegetables grown in Melka Hida and Wonji Gefersa vegetable farms. In this study, lettuce exhibits higher Cr, Pb and Cd concentrations than other vegetables, whereas elevated Cd level was also exhibited by spinach. However, cabbage was found to be the least accumulator of heavy metals. Generally, the results of the present study revealed heavy metal contamination of vegetables in varying magnitude among vegetables in the study area. Hence, it poses an important public health risk. So monitoring heavy metals in plant tissues is essential in order to prevent excessive build-up of these metals in the human food chain.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Bacteriological physicochemical quality of recreational water bodies: Case studies from Addis Ababa and Oromiya region Ethiopia

Thewodros Bekele* and Seyoum Leta

Centre for Environmental Science, College of natural Science, Addis Ababa University, P. O. Box 1176 Addis Ababa, Ethiopia.

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Waterborne diseases are common and major problem in developing countries. Considering the great importance of the safety of recreational waters, a cross-sectional study at Addis Ababa and Oromiya regional state was carried out over a three month period of time from May-July, 2008. A total of 72 water samples from two natural bathing lakes and six outdoor swimming pools were collected and analyzed for total and fecal coliforms, fecal streptococci, hetrotrophic bacteria, *Staphylococcus aureus*, pH, temperature, free chlorine and turbidity. The study demonstrated that from all the samples analyzed for microbiological water qaulity 52(96.3%) were found to be positive for *S. aureus*, 44 (81.5%) for total coliforms, 43 (79.6%) for total bacteria count, and 38 (70.4%) for fecal coliforms. All of the samples from the swimming pools do not have the required level of chlorination (1.0 mg l^{-1} (100%)). Moreover, 75.9% of the pool samples passed the required turbidity level and 33.3% of samples were alkaline in pH. All of the microbial analyses of the two natural bathing lakes were within guideline limit of bathing water regulations of United Kingdom. From these results it can be concluded that, except that of the natural bathing lakes, most of the bacteriological and physicochemical parameters measured from outdoor swimming pools were not in compliance with the reference values set out by WHO guideline. This is mainly due to lack of awareness, absence of monitoring, proper disinfection and/or lack of information or control over related parameters to efficient disinfection processes. The study findings suggest that the observed problems can be minimized by promoting good hygiene education and practices for swimmers, applying a better and strict supervision, providing training and education for operators, monitoring the biological and chemical conditions through guideline development of the pool at regular intervals.

Key words: Swimming pools, microbiological indicators, microbial water quality, recreational water quality.

INTRODUCTION

Recreational waters contain a mixture of pathogenic and non-pathogenic microorganisms, which may be derived from sewage effluents, the recreational population using the water, livestock, industrial processes, farming activities, domestic animals and wildlife (WHO, 2003). Now-adays, large numbers of people are taking up recreational

*Corresponding author. E-mail: nigusutheddy@gmail.com. Tel: +251911370536.

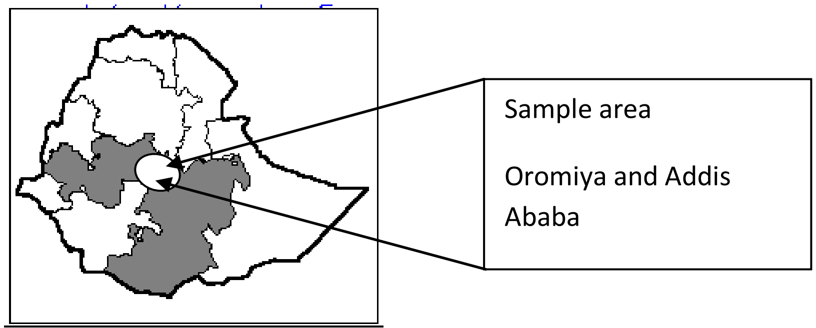

Figure 1. Sampling area.

activities in and around water, and these are becoming part of leisure and tourism around the world (WHO, 2006). Water based recreation (swimming), how-ever, can expose people to a variety of health risks. The hazards that are encountered in recreational water environ-ments vary from site to site, as do to the nature and extent of exposure, the type of water, geographical location and local conditions. Perhaps, the hazards are linked to physical, microbial and chemical agents, most available information relates to health outcomes arising from exposure through swimming and ingestion of water (WHO, 2003).

Recreational water illnesses (RWIs) are illnesses that are spread by swallowing, breathing, or having contact with contaminated water from swimming pools, spas, lakes, rivers, or the ocean. RWIs symptoms include intestinal, skin, ear, eye, respiratory and neurologic infec-tions. Currently, poor pool maintenance, the emergence of chlorine-resistant germs, and pool staff and swimmers that are illformed about RWIs is a challenge for the public health community and increases the complexity of any plan to prevent the spread of RWIs (CDC, 2008). Consequently, recreational water use is attracting the public, concerned professionals, regulatory agencies, and the tourist industry (WHO, 2006).

Although there are recreational water bodies which are regularly visited by people in Ethiopia, there is little, (if any) or no information available about their bacterio-logical quality, and there are no guidelines (standards) towards the safe use and quality control of recreational water. Under this circumstances, it is neither possible to know the gravity of the problem, nor simple to manage the possible health related risks that are associated with the use of recreational water bodies. It is therefore imperative to collect information about the microbial quality in recreational water bodies to assess the quality in relation between microbial contamination and health related problems. The obtained information would help to create awareness, develop guidelines in order to control or manage the possible health related problem.

The present work therefore, aims at evaluating the level of specific bacteriological indicator species (TC, FC, FS, *S. aureus* and HPC) as well as analyzing bacteriological related physiochemical quality parameter such as temperature, pH, turbidity and free chlorine residual from selected recreational water, 3) compare bacteriological quality of the selected recreational waters bodies in Addis Ababa and Oromiya Region in Ethiopia. The findings will serve as a baseline data for stakeholders and the public authorities to work in terms of better management of the recreational areas in the country.

MATERIALS AND METHODS

Description of the study area

The cross sectional study was conducted between May - July, 2008 from two natural lakes and six different outdoor swimming pools that are located at Addis Ababa and Oromiya regional state. Site one is located in Addis Ababa geographically located between 9° 0'19.4436"N and 38°45'48.9996''E with an elevation of 2356 a.s.l. Site two is geographyically located between 8°59'N37°51'E and 8°.983'N37.850°E with an elevation of 2101 at West Shewa zone of Oromiya region. Site three of the swimming pool is located at Bishoftu (Debre Zeyit) geographically located between 8°45'0N and 38°58'60E having an elevation of 1999 m a.s.l. The main swimming pool and teaching pools were constructed separately side by side and have different water system except that of site 2. Lake Hora and Babogaya are used as recreational water and the local inhabitants used it for washing and cooking. Both lakes are found at Debre Zeyit (Bishoftu) about 1 to 2 km apart from each other with an altitude 1860 m a.s.l and 8°50'N 39°E, respectively (Figure 1).

Sampling and sample collection

Recreational water bodies, which are frequently visited by most and those which are easily accessible for public and sample transport are randomly selected. Triplicate water samples were collected from each recreational sample site following on APHA (1998) and WHO (2006) guidelines. All samples were collected during the peak of bathing periods (weekends) by using a sterile glass bottles with capacity of 1 L containing sodium thio sulphate for complete neutralization of residual chlorine (1 ml of 10% $Na_2S_2O_3$). Free and total chlorine, pH and water temperature were determined on the spot at the time of sample collection. The samples were collected from a depth of 20 to 40 cm, at a point about 50 cm away from the pool edge and 1 m away of lake shore. Each sample site has three separate sampling points or location. A total of nine samples were systematically collected from each sample site at two weeks interval during the maximum bathing time and day (2:00 to 9:30 PM, Friday to Sunday), respectively, within the month of May to July 2008.

A total of 54 water samples, 18 samples from each site (sites1 to 3) were collected and transferred to Applied Microbiology laboratory, Addis Ababa, Ethiopia by keeping the samples at 4°C in ice box. Samples were processed immediately after arrival within 1 to 6 h from sample collection time to avoid the death and growth of organisms.

Microbiological analyses

Microbial indicators, total coliforms (TC), fecal coliforms (FC), fecal streptococcus (FS) were analyzed by membrane filtration (100 ml) technique by using 0.47 mm diameter, 0.45 µm pore size filters and absorbents (Gelman Sciences). For TC and FC membrane, lauryl sulfate (mLS) medium (PARK) was used and incubated at 35 and 44.5°C for 24 h, respectively; and all yellow colonies were counted as TC and FC. FS was detected using M Entrococcus agar which was prepared following APHA (1998); and all plates were incubated at 44°C for 24 to 48 h. All black colonies were counted as FS. Spread plate technique was used for *S. aureus* and heterotrophic plate count (HPC). From the original sample, 0.1 ml aliquots were spread- plated in duplicates on pre dried surface of manitol salt agar (MSA) (PARK) and incubated at 37°C for 24 to 72 h; golden yellow colonies were counted as *S. aureus*. Similarly for heterotrophic plate count (HPC), plate count agar (PCA), (FLUKA) was used and incubated at 37°C for 24 to 48 h for all colony counting (WHO, 2006; APHA, 1998). All microbial analysis was done by following strict aseptic techniques of microbiology procedures.

Physicochemical analyses

Chlorine was determined by using the diethyl-p-phenylene diamine (DPD_1 and DPD_3) palin test, Wagtech international (0.1 to 1.0 mg/l) comparator disc-Wag-WE10210, Wag-WE10212 chlorine. Temperature and pH were also measured at the pool side by portable 370 pH meter JENWAY, EU. Turbidity was measured colorometrically using a spectrophotometer (DR/2010 HACH, Loveland, USA) at the laboratory following HACH instructions.

Statistical analysis

Statistical analysis of the data gotten was done by using SPSS version13 for windows and the data were compared with World Health Organization (WHO, 2006) guideline levels for outdoor swimming pools and British bathing water regulations of natural water bodies.

RESULTS AND DISCUSSIONS

Microbiological parameters

The highest mean TC (112.1±45.2) obtained from site 1A; not significantly different from site 1B) and the lowest mean TC (14.4±3.1) was obtained from site 3A). On other hand, the maximum mean FC (149.2 ± 72.8) was observed from site 2B and the lowest (7.9±3.4) from site 2A (Table 1). In addition to these, HPC was highest at site 3B while the least was from site 1B but, it is not significantly different from sites 1A, 3A and 2A (Table 1).

The high presence of total coliforms (TC) and fecal coliforms (FC) obtained might be as a result due to possible fecal accidental or deliberate contamination of the pools from the bathers and animals. Both are highly available in excreta of warm blooded animal. The presence of these organisms in the water sample indicates that recent fecal contamination of the pool water and the presence of inefficient treatment system (Al-Khatib and Salah, 2003). Weak controlling system observed on the related parameters (pH and turbidity) of swimming pools might be additional factor for the obtained results. For instance, weak disinfection process in the pool during sampling time, or the presence of turbidity by debris that serve as attachment sites reduce the efficiency of disinfection process and may serve as source of nutrients for the growth of such microbes within the water system (Le Chevallier et al., 1981).

In addition, among the total 54 samples tested for indicator microbes, 81.5, 70.4, 79.6 and 96.3% were positive for total coliforms, fecal coliforms, heterotrophic plate count, and for *Staphylococcus aureus*, respectively (Table 2).

Samples from site 2 A main swimming pool and site 1B had relatively greater FC; this is might be due to high temperature from its source (thermal water) that favor the growth of FC since they can resist 44.4°C and the temperature is also comfortable for bathers (stay longer periods, may shade or discharge large amount of FC). Comparing the level of contaminants with the size of the pools, the teaching pools and the natural spa were relatively polluted than the main swimming pools. This might be associated with the size of teaching pool (smaller) and the large number of people (bather load) that hold at a time or per day than the main swimming pools plus the low awareness about hygiene in swimming. During sampling period, it was observed that all of the teaching pools and natural spa were relatively busy than that of the main. The pools were mostly occupied by people (trainees especially teenagers) with low level of swimming ability and experience. There is a consistent correlation between bather density and heterotrophic bacteria (Mood, 1977) and this can be related as, there is a possibility to drink and spit the water from the pool during their exercise of swimming; this will contribute a lot to discharge microbes from the body (body discharges like mucus from the nose, saliva, sweat, fecal matter and dead skin).

Furthermore, HPC also includes those microbes which are found in water as natural inhabitants, street and work place soil, dust, animal droppings, insects and others may contribute to the proliferation of heterotrophic microbes with in water body by serving as source of food and shelter. Overall high level of HPC>200 cfu/ml indicate that, the absence of proper pool monitoring and/or the result may also indicate failure of the

Table 1. Mean levels of TC, FC, FS, *S. aureus* and HPC counts of outdoor swimming pools ,2008 (n= 9 for each).

Parameter	Outdoor swimming pools					
	Site 1 (Addis Ababa)		Site 2 (Ambo)		Site 3 (Debre ziet)	
	Main A	Teach. B	Main A	Spa B	Main A	Teach. B
TC cfu /100 ml <10 cfu*	112.1±45.2[a] HP	97.7± 34.2[a] HP	43.8± 6.8[b] P	46.2± 8.5[b] P	14.4± 3.1[c] LP	30.4± 16.1[b] P
FC cfu /100 ml <1 cfu*	11.2± 4.2[c] HP	13.1± 5.7[c] HP	36.0± 8.1[b] HP	149.9± 2.2[a] VHP	7.9± 3.4[c] HP	8.4± 3.0[c] HP
FS cfu /100 ml <40 cfu*	3.22± 0.9[c] S	4.1± 1.3[c] S	9.1± 2.3[a] S	11.7± 2.2[a] S	6.6± 1.4[b] S	4.0± 10[c] S
S. aureus cfu /ml <1 cfu*	111.1±47.5[b] VHP	231.1± 81.2[a] VHP	62.2± 19.1[b] VHP	226.7± 7.6[a] VHP	26.8± 7.9[c] P	24.6± 0.4[c] P
HPC cfu/ml <200 cfu*	891.1±312.6[c] P	497.7± 167.3 [c] P	943.3± 260.5[c] P	1421.1± 352.6[b] P	750± 215[c] P	2261.1± 343.6[a] HP
Total	16	16	14	16	12	14

*Standards of WHO; TC, total coliforms; FC, fecal coliforms; FS, fecal S*treptococcus*; HPC, hetrotrophic plate count; VHP, very highly polluted, value greater than 100x with the standard; HP, highly polluted, value greater than 10x and less than 100x from the standard; P, polluted, value greater than 3x but less than 10x from the standard; LP, least polluted, value between 1x-2x times greater form the standard; S, safe values relatively closer to the standard or less. Letters a, b, ab, c and d indicates their relative significance of the recorded values to the standard. Letter 'a' is highly significant than 'c'. Points are given for easy calculation VHP=5; HP=4; P=3; LP=2; S=0.

Table 2. Range values and frequencies of TC, FC, and FS, *S. aureus*, HPC of all swimming pools, 2008 (n=9 for each).

Bacteriological parameter	*Standard (WHO, 2006)								Total
	0*	>0	<10 cfu*	>10 cfu	<40 cfu*	>40 cfu	<200 cfu*	>200 cfu	54
FC/100 ml	16	38 (70.4%)							54
S. aureus/ml	2	52 (96.3%)							54
TC/100 ml			10	44 (81.5%)					54
FS/100 ml					54 (100%)				54
HPC/ml							11	43 (79.6%)	

*WHO, 2006 standards; TC, total coliforms; FC, fecal coliforms; FS, fecal *Streptococcus*; HPC, hetrotrophic plate count.

treatment process at the time of sampling (QGQH, 2004). This can be demonstrated by the 74.9% of the samples which were beyond the required level (HPC) and tell the poor hygienic condition of the environment. Low level of hygienic condition coupled with weak disinfection process was observed during sample collection. HPC measurements in water bodies are used to indicate the effectiveness of water treatment process, to measure number of regrowth organisms and to investigate aesthetic quality. Hence high level of HPC resulted due to the availability of nutrients, presence of optimum conditions like temperature and lack of sufficient level of free residual disinfectant and possible over growth of microbes (Table 3). Similar study in South America reveals that among the 60 swimming pools examined, 70.4% were positive for THC and it was observed positive relation among the levels of microorganisms, the bather load and the water temperature (Martin et al., 1992, 1995).

Analysis shows that for Fecal *Streptococcus* and *Enterococci, a*ll of the samples were containing less than 40 cfu/100 ml. High risk of infection might be resulted when the presence of FS in 100ml exceeds 40cfu (WHO, 2003; WHO, 2006).

In all the samples analyzed 96.3% of samples were found to be positive for *Staphylococcus aureus*

Table 3. Mean levels of physicochemical parameters of outdoor swimming pools and natural water bodies 2008 (n= 9 for each).

Physicochemical parameter	Outdoor swimming pools					
	Site 1 (Addis Ababa)		Site 2 (Ambo)		Site 3 (Debre Zeit)	
	Main A	Teach. B	Main A	Spa B	Main A	Teach. B
T°C	21.98±0.15[d]	22.89± 0.5[d]	30.4± 0.06[b]	35.2±1.1[a]	23.1± 0.6[d]	24.6±0.4[c]
pH	7.64± 0.22[c]	7.75±0.4[c]	6.8± 0.04[d]	6.5±0.08[c]	8.8± 0.03[a]	8.2±0.08[b]
Turbidity NTU	6.22± 1.5[b]	7.8± 2.12[ab]	9.9± 0.8[ab]	8.8±1.2[ab]	11± 0.8[a]	9.4±0.8[ab]
Free Cl_2 Mg/L	0.1± 0.0[c]	0.1±0.0[c]	0.1± 0.0[c]	0.1±0.0[c]	0.18± 0.02[a]	0.13± .02[b]

Letters a, b, ab, c, d indicates their relative significance of the recorded values to the WHO standard. Letter 'a' is highly significant than letter'd'.

(Table 2). In this study, *S. aureus* count was relatively higher than fecal coliforms and fecal streptococci in all of the outdoor swimming pools. The result is supported from findings by Tosti and Volterra (1988). This shows that the presence of *S. aureus* and fecal indicators (FC and TC) in water shows that swimming pools examined contain both fecal and non-fecal contaminants. The higher percen-tage of isolation of *S. aureus* compared to fecal coliforms can be explained by the ecology of these bacteria as a normal inhabitant of the skin, nose, mouth and throat and its higher resistance to chlorine and environmental conditions (Croone and Tee, 1974; Alico and Dragonjiac, 1986; QGQH, 2004). Bathers can transport significant amounts of *S. aureus* to the water column, so this may indicate that bathers may not take proper shower (pre showering) before swimming to reduce the amount of bacteria that is shed per bather at a particular period of time (attributed to lack of hygiene of bathers before entering the water). The result shows the presence of incorrect management in swimming pools. Similar results have been reported by Esterman et al. (1984) in South Australia, Leoni et al. (1999) in Bologna, Italy; Marins et al. (1995), Hajjartabar (2004) in Iran and Rigas et al. (1998) in Greece.

The relative presence (amount) of *S. aureus,* in all of the tested outdoor pools shows that, site 1B is more polluted then followed by site 2b and site 1A. High FC count was obtained in the order from sites 2B, 2A and 1A, respectively. The least count was observed with low count in all except high HPC count in site 3B next site 2A and B. Specifically among the six pools, site 1A was highly polluted by TC. Among all tested microbial parameters, site 3A was least polluted, next to sites 3B and 2A. This might be due to the fact sites 3A and B pools uses filtration technique besides the disinfection processes hence this disinfection system might account for the low level of pollution (contamination) by microbes (Table 1).

Physicochemical parameters

Turbidity level in outdoor swimming pool samples was 75.9% which exceeds WHO guideline values (>5NTU) for turbidity. The sources of the observed turbidity may include presence of organic or/and inorganic suspended materials from street or working place soil, dust, pollen, microorganisms like algae etc. Since the pools are outdoor (exposed to every type of contaminants), particulate matters from the environment may easily fall or enter to the pools. Moreover the observed relatively high turbidity levels in the pool water might be the position of the pools which are near to the main road and the surrounding trees. The nature of source of water (ground water) may also contribute for higher value of turbidity besides the number of bathers. High level of turbidity levels might contribute for the shielding effect of microbes for proper disinfection (Table 3).

Analysis for the presence of free chlorine level for disinfection revealed that all samples contained free chlorine which is much less than the required level. Chorine is used as disinfectant in all of the swimming pools and must be present continually and in sufficient concentrations in order to protect against survival of newly introduced pathogens, but the reasons might be using less amount and concentration of chlorine which may be incomparable to the volume of water, presence of high level of organic matter, microbial load, higher temperature (chlorine easily evaporate) and remains unavailable. Generally, physicochemical parameters of the water have strong influence on the efficiency of disinfection process. Factors like pH, turbidity of the water, concentration of chlorine and contact time, influence the efficiency of disinfection with chlorine (Al-Khatib and Salah, 2003; Galal-Gorchev, 1996). The observed pH in the pools occurred possibly from nature of water source surface or ground water. Variation in pH was due to the type of water they used for example; thermal hot spring water (site 1 and 2), municipal water (site 2) and non thermal ground water (site 3).

Moreover, since all of the swimming pools uses Chlo-rine for disinfection, to increase the efficiency of chlorine, WHO (2006) recommends the pH of pool water between 7.2 and 7.8. The bacterial loads of the two lakes are within the recommended level of bacteriological load and both can be considered as safe for the time being (Table 4). However both lakes are under increasing threat from habitat deterioration because of accelerated human impact

Table 4. Comparison of physicochemical microbiological levels of Two natural bathing Lakes at DZ, 2008 (n=9 for each) with limit values.

Site	Physicochemical parameter							
	TC	FC	FS	HPC	*S. aureus*	Temperature (°C)	pH	Turbidity NTU
Lake Babogaya	73.2±7.6	37.7±5.7	103.3±32.7	2618.8±377.6	53.6±17.1	24.2±0.07	8.9±0.1	17.4±2.63
Lake Hora	117.8±24.3	44.3±9.55	66.8±8.0	1793.3±378.5	51.4±16.8	24.0±0.31	8.83±0.022	21.2±4.02
Limit Value* cfu/100m/	≤500	≤100	≤100	NA	NA	NA	NA	NA
Status	S	S	S					

NA, Not available; TC, total coliforms; FC, fecal coliforms; FS, fecal *Streptococcus*; HPC, hetrotrophic plate count; Temp, temperature; NTU, nephelometric turbidity unit. * The Bathing Waters (Classification) Regulations 1991. Statutory Instrument 1991. No. 1597. London: HMSO, 1991.

in and around the area. Hotels and resorts have already been built around the rims with more to be constructed in the future. These lakes are used by local inhabitants other than recreation; sustainable waste management is highly required to safeguard the possible health hazard that may come as a result of recreation. Lake Babogaya is facing the possible danger of environmental degradation.

Conclusion

The bacteriological results of the outdoor swimming pools showed that most of the bacteriological parameters measured were not in harmony with the reference values set out by WHO (2006). Among the sample site, water samples from site 2B were very highly polluted. Moreover, the physicochemical parameters measured, free Chlorine, turbidity of the swimming pools were not in accordance with WHO limit values. The problem might result from the synergetic effect of absence of strict regulations, monitoring (supervision) and control system. This situation could result in health related hazards for the swimmers and the surrounding communities due to the spread of pathogenic microorganisms, including opportunistic pathogens.

The findings from this study indicates that since swimming pools and spas are expanding in the country, water use for recreational purpose should have to be enforced with quality control guidelines, standards and limit values. Moreover, users need to be properly trained and as well as provided with basic sanitation and hygienic protocols during swimming which will reduce the potential hazards that may mabe encountered during swimming.

In other to minimize the health risks, not only swimming water samples must constantly be checked for water but also further studies using advanced techniques are required on other recreational water bodies in the country.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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An appraisal of the handler awareness of electrical and electronic equipment toxicity in Nigeria

Onyenekenwa Cyprian Eneh

Institute for Development Studies, Enugu Campus, University of Nigeria, Nsukka, Enugu, Nigeria.

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Some developing countries in Africa are waking up to the broadband race by providing public access to information communications technologies (ICTs) to instigate social and economic development and to narrow the digital divide. One of such countries is Nigeria, which ranked 60th in 2006 in e-readiness report by the Economist Intelligence Unit. Consequently, the market, marketers and repairers of electrical electronic equipment (EEE) are growing geometrically in Nigeria. Incorporated in EEE are about 46 separate chemical substances or elements, some of which are hazardous. Their emission from EEE translates to toxicity through inhalation of the polluted air, especially by marketers and repairers. Becoming aware of this danger is key to exercising the necessary caution in handling EEE. This study assessed the awareness of marketers and repairers of EEE toxicity and adoption of safety measures against the same. Questionnaires were administered on 80 purposively selected marketers in Alaba International Market, Lagos and on 20 repairers in C-to-C Plaza, Enugu. Data were analysed using average mean score technique. Results show that all participants were completely ignorant of the toxicity associated with EEE and did not associate it with various symptoms of ill-health.The study recommends education programmes for marketers and repairers of EEE and developing policies on how to handle EEE.

Key words: Hazardous chemical components, electrical electronic equipment, toxicity awareness, handlers, safety measures.

INTRODUCTION

Some developing countries in Africa are adopting the information communications technologies (ICTs) for the needed leverage in their development trajectory in the belief that it will contribute to social and economic development and in narrowing the digital divide. Little wonder, the 2006 global e-readiness rankings positioned South Africa 35th, Egypt 55th, Nigeria 60th and Algeria 63rd. This is an indication that Africa is waking up to the broadband race (Gomez et al., 2009; Mutula, 2005; Nkamnebe, 2010).

Also, a World Bank publication reports that “the digital divide” between the rich and poor nations is narrowing fast; telecommunications services to poor countries were growing at an explosive rate and the digital divide was rapidly closing. “People in the developing world were getting more access, especially to cell phone communi-

E-mail: onyenekenwa.eneh@unn.edu.ng. Tel: +234-803-338-7472.

cations, far faster than they got access to new technologies in the past” (Mutula, 2005).

In the information age, EEE drive development and have consequently become ubiquitous even in developing countries. Therefore, their markets, marketers and repairers are growing geometrically. Researches have shown that about forty-six (46) separate chemical substances or elements are incorporated in EEE. Some are toxic by inhalation of the air polluted by gaseous emissions of these chemical components from EEE (Slade, 2006; Murali, 2009). For instance, the emission of lead from EEE constitutes health hazards.

An earlier study revealed a perfect positive correlation between the log dose of crude lead-extract from waste-EEE materials and % mortality of the rats to which the crude lead-extract from waste-EEE had been exposed by oral administration. The degree of confidence that crude lead-extract had lethal effect on rats was high, as well as the reliability. The lethal dose for rat was higher than the reported lowest lethal dose for man and the lowest lethal dose for guinea pig and dog.

Since the EEE marketers and repairers spend greater part of their time in the presence of EEE, the lethal concentrations of the various chemical components of EEE are easily attained (by inhalation). Osibanjo and Ogundiran (2010), submit that risk is the sum of hazard and exposure. In this case, emissions of various chemical components of EEE constitute the toxicity. The exposure or regular inhalation is high beacuse the EEE marketers and repairers keep close with the equipment most day. Thus, the risk is high. This is a serious cause for worry over the toxicity of EEE. More so, as indoor air pollution and urban air quality, of which emission is a factor, are listed as two of the world's worst pollution problems in 2008 World's Worst Polluted Places report (Blacksmith Institute, 2008).

Awareness of this danger is key to being informed, enlightened, knowledgeable, mindful of and alert or alive to the need for exercising the necessary caution in handing EEE. The present study was aimed at minimising the environmental health effects of the chemical components of EEE on marketers and repairers in Nigeria. The specific objectives of the study were to (i) assess the awareness of EEE toxicity by marketers and repairers, (ii) assess the adoption of safety measures in handling EEE by marketers and repairers, and (iii) recommend measures to ameliorate the environmental health effects of EEE on marketers and repairers. The study assumed that EEE makrters and repairers (i) were not aware of the toxicity of EEE, and (ii) were not adopting safety measures for handling EEE.

The study will greatly benefit EEE marketers and repairers, as it offers them a thought regarding EEE toxicity and adopting safety measures for handling the equipment. The findings will guide government and non-governmental organisations on the need to create awareness on safety practices among EEE marketers and repairers. Policy makers will find the results of the study useful in formulating policies for ameliorating the environmental health effects of EEE on marketers and repairers.

METHODOLOGY

Key informant technique was used to elicit information from purposively selected fifty (50) EEE marketers in Alaba International Market, which is famous for EEE trading business, and twenty (20) repairers in C-To-C Business Plaza, Nkpokiti Street, Enugu, Nigeria, where significant EEE repairing activities take place at commercial scale. All trader respondents had lasted 20 years upwards in the business, while repairers had lasted ten (10) years upwards on the job, to qualify for participation. Questionnaire copies were administered to the key informants to elicit information from them.

Part A of the questionnaire elicited demographic information on participants, while the Part B elicited information on the awareness of the participants of the toxicity of EEE and their adoption of safety measures for handling them. Answer options to each question were rated on a five-point lycert scale: strongly agree (5), agree (4), not sure (3), disagree (2) and strongly disagree (1).

The Average Mean Score test technique was used to analyse the data using the formula (Osuala, 2007):

$$\text{Calculated value (CV)} = \frac{\sum Fx}{\sum F}$$

Where, F is frequency and x is scale point. The CV was compared with the decision value (DV) of 3 (neutrality value). If CV was greater than DV, then the answer was regarded as being in the affirmative, otherwise it was in the negative. Similarly, null hypothesis was rejected if CV was greater than DV, and accepted if otherwise.

RESULTS AND DISCUSSION

Table 1 contains demographic information on participants. No woman owned EEE marketing shop or repairs workshop; but, their spouses did. All 100 participants were male. Therefore, the businesses were not gender-balanced, but that of males.

All participants were literate, having obtained the first School Leaving Certificate (FSLC) (7%), attained secondary education (21%), obtained the Ordinary/Higher National Diploma (OND/HND) (45%), bagged a degree (25%) and/or obtained a higher degree (2%). Therefore, the businesses were for the literate class of the society.

The mode age bracket of participants was 18 to 25 (28%), followed by 26 to 35 (24%), 36 to 45 (23%), 46 to 55 (15%), 56 to 65 (8%) and above 65 years (3%). Thus, the businesses were for the youth (18^+ years) and productive age (25 to 45 years) in the society. Although, 37% of the participants were single, 56% were married, and 7% either separated or divorced, showing that most of the participants were married. This implies that victims of EEE toxicity were mostly married people and the brunt of its ugly effects was borne by families. These ugly effects include loss of breadwinners, ophaning children,

Table 1. Personal data of participants.

Subject		% Score
Sex	Female	0
	Male	100
Highest educational level	FSLC	7
	Secondary education	21
	OND/HND	45
	Degree	25
	Above degree	2
Age bracket	18-25	28
	26-35	24
	36-45	23
	46-55	15
	56-65	8
	Above 65	3
Marital status?	Single	37
	Married	56
	Separated/divorced	7
No.of years on the business involving EEE	11 - 20	68
	21 - 30	21
	31 - 40	7
	41-50	4
	50 upwards	-

Source: Field work, 2012.

child labour, street children, widowing women, widowhood practices, among others (Eneh and Nkamnebe, 2011).

Sixty-eight per cent of participants had been in the businesses for between 11 and 20 years, 21% for between 21 and 30 years, 7% for between 31 and 40 years, 4% for between 41 and 50 years, and none of them for above 50 years. Thus, people drop from the businesses as years go by, and hardly continued till old age. Those of them who drop into joblessness and idleness may get into addictions, thereby creating some problems in the society.

Table 2 shows the data on the awareness of the marketers and repairers of the toxicity of EEE and their adopton of safety measures. Forty-nine (49) or 49% of participants strongly disagreed that EEE emit hazardous gases that they inhale, 29 disagreed, and 21 were not sure. None of them (0%) agreed and none (0%) strongly agreed. The CV (1.70) was less than DV (3.0), showing that the answer was in the negative. That is, all participants were completely ignorant of the fact that EEE emit toxic gases. And, this ignorance is suicidal.

Forty-eight (48) or 48% of participants strongly disagreed that inhaling the emissions from EEE caused them some health problems, 33 disagreed, and 19 were not sure. None of them (0%) agreed and none (0%) strongly agreed. The CV (1.71) was less than DV (3.0), showing that the answer was in the negative. Therefore, all participants were completely ignorant of the fact that their inhalation of hazardous gases emitted from EEE caused them some health problems. In their ignorance, more havock would likely result because they would not care to take precaution.

Thirty-eight (38) or 38% of participants strongly disagreed that inhaling emissions from EEE had anything to do with some symptoms of ill-health, 31 disagreed, 28 were not sure, 3 agreed, and none (0%) strongly agreed. The CV (1.76) was less than DV (3.0), showing that the answer was in the negative. That is, most (97%) of the participants did not associate any symptoms of ill-health with inhalation of emissions from EEE. This ignorance would only occasion more harm.

Fifty-nine (59) or 59% of participants strongly disagreed that some EEE marketers and repairers have had to quit the trade because of EEE toxicity and its effects on them, 39 disagreed, and 2 were not sure. None (0%) agreed and none strongly agreed. The CV (1.43) was less than DV (3.0), showing that the answer was in the negative.

Table 2. Awareness of health effects and compliance with manufacturer's guides.

Parameter	Lycert scale (x)					∑F	∑Fx	CV	Remark	Decision
EEE gas emission	**1**	**2**	**3**	**4**	**5**	100	170	1.70	CV < DV.	Accept null
Frequency (F)	49	29	21	0	0				Answer is neg.	hypothesis (i)
Fx	49	58	63	0	0					
EEE toxicity						100	171	1.71	CV < DV.	Accept null
Frequency									Answer is neg.	hypothesis (i)
Fx	48	33	19	0	0					
	48	66	57	0	0					
Symptoms knowledge						100	176	1.76	CV < DV.	Accept null
Frequency									Answer is neg.	hypothesis (i)
Fx	38	31	28	3	0					
	38	62	64	12	0					
People quiting trade						100	143	1.43	CV < DV.	Not apllicable
Frequency	59	39	2	0	0				Answer is neg.	
Fx	59	78	6	0	0					
Need to quit trade						100	144	1.44	DV > CV.	Not applicable
Frequency	61	34	5	0	0				Answer is	
Fx	61	68	15	0	0				affirmative	
Quiting trade before old age						100	168	1.68	CV < DV.	Not applicable
Freuency	48	38	12	2	0				Answer is neg.	
Fx	48	76	36	8	0					
Need for precaution						100	155	1.53	CV < DV.	Accept null
Frequency	63	26	5	4	2				Answer is neg.	hypothesis (ii)
Fx	63	52	15	16	10					
Knowledge of caution						100	156	1.56	CV < DV.	Accept null
Frequency	60	31	4	3	2				Answer is neg.	hypothesis (ii)
Fx	60	62	12	12	10					

Source: Field work, 2012.

That is, although all participants were aware of some of their colleagues quiting the trade, they were certain that none of such cases had to do with EEE toxic effects on them. But, this ignorance would not stop the harm.

Sixty-one (61) or 61% of participants strongly disagreed that they could be required to quit the EEE trade on account of EEE toxic effects on them, 34 agreed, and 5 were not sure. None (0%) agreed and none strongly agreed. The CV (1.44) was less than DV (3.0), showing that the answer was in the negative. That is, most (95%) participants were certain it would not come to their being required to quit the trade on account of EEE toxic effects on them. This ignorance would not help matters.

Forty-eight (48) or 48% of participants strongly disagreed with the speculation that they would not last on EEE business till old age of retirement because of EEE toxic effects on them, 38 disagreed, 12 were not sure, and 2 agreed. None (0%) strongly agreed. The CV (1.68) was less than DV (3.0), showing that the answer was in the negative. That is, most (86%) participants were certain it would not come to their being required to quit the trade before their retirement age because of EEE toxic effects on them. This ignorance is as dangerous as the harm precursor.

Sixty-three (63) or 63% of participants strongly disagreed that they needed to adopt some safety measures for handling EEE, 26 disagreed, 5 were not sure, 4 agreed, and 2 strongly agreed. The CV (1.53) was less than DV (3.0), showing that the answer was in the negative. That is, most (91%) participants were certain that there was no need for adopting some safety measures for handling EEE in order to minimise toxic effects. Again, this ignorance is as dangerous as the harm precursor.

Sixty (60) or 60% of participants strongly disagreed with the safety measures for handling EEE, 31 disagreed, 4 were not sure, 3 agreed, and 2 strongly agreed. The CV (1.56) was less than DV (3.0), showing that the answer was in the negative. That is, most (95%) participants disregarded the safety measures for handling EEE and did not apply them. This attitude was not helpful, but suicidal.

Tests of hypotheses

Questions B1-3 probed the awareness of participants of the toxicity of EEE. Their respective CVs were 1.70, 1.71 and 1.76, each being lower than the DV of 3.0. Therefore, null hypothesis (i) was accepted for each of the cases. That is, marketers and repairers were not aware of EEE toxicity.

Questions B7 and B8 probed the adoption of common safety measures for handling EEE. Their respective CVs were 1.53 and 1.56, each being lower than the DV of 3.0. Therefore, null hypothesis (ii) was accepted for each case. That is, marketers and repairers were not adopting safety measures for handling EEE.

Woolf et al. (2007), shows that lead is a very strong poison. When lead dust is inhaled, some of the poison can stay in the body and cause serious health problems. Worse still, it is more common for lead poisoning to build up slowly over time from repeated exposure to small amounts of lead. In this case, there will be no obvious symptoms. In adults, lead can increase blood pressure and can cause digestive problems, kidney damage, nerve disorders, sleep problems, muscle and joint pain, and mood changes.

Classification of the consequences of lead poisoning by toxicity levels has shown decreased learning, decreased verbal ability, early signs of attention-deficit/hyperactivity disorder (ADHD) and low intelligence quotient (IQ), as general effects. Mild toxicity produces abdominal discomfort, lethargy, mild fatigue, myalgia, and paresthesia. Moderate toxicity produces constipation, irritability, difficulty concentrating, diffuse abdominal pain, mild fatigue, headache, muscular exhaustibility, tremor, vomiting, and weight loss. Severe toxicity produces colic, encephalopathy (seizures, coma, death), lead line on gingival tissue, and paresis or paralysis.

Reports by Karri et al. (2008), Timbrell (2008) and Marshall and Bangert (2008) show that the symptoms and signs of lead poisoning vary according to the individual and the duration of lead exposure. They may be subtle, and someone with elevated lead levels may have no symptoms. Symptoms usually develop over weeks to months as lead builds up in the body during a chronic exposure, but acute symptoms from brief, intense exposures also occur.

The main symptoms in adults are headache, abdominal pain, memory loss, kidney failure, male reproductive problems and weakness, pain, or tingling in the extremities. The classic signs and symptoms in children are loss of appetite, abdominal pain, vomiting, weight loss, constipation, anaemia, kidney failure, irritability, lethargy, learning disabilities, and behavior problems.

In acute poisoning, typical neurological signs are pain, muscle weakness, paraesthesia, and, rarely, symptoms associated with encephalitis. Abdominal pain, nausea, vomiting, diarrhoea, and constipation are other symptoms of acute lead poisoning. Lead's effects on the mouth include astringency and a metallic taste. Gastrointestinal problems, such as constipation, diarrhoea, poor appetite, or weight loss, are common in acute poisoning. Absorption of large amounts of lead over a short time can cause shock (insufficient fluid in the circulatory system) due to loss of water from the gastrointestinal tract. Haemolysis (the rupture of red blood cells) due to acute poisoning can cause anaemia and haemoglobin in the urine. Damage to kidneys can cause changes in urination, such as decreased urine output. People, who survive acute poisoning, often go on to display symptoms of chronic poisoning.

Chronic poisoning usually presents with symptoms affecting multiple systems, but is associated with three main types of symptoms: gastrointestinal, neuromuscular, and neurological. Central nervous system and neuromuscular symptoms usually result from intense exposure, while gastrointestinal symptoms usually result from exposure over longer periods.

Signs of chronic exposure include loss of short-term memory or concentration, depression, nausea, abdominal pain, loss of coordination, and numbness and tingling in the extremities. Fatigue, problems with sleep, headaches, stupor, slurred speech, and anemia are also found in chronic lead poisoning. A "lead hue" of the skin with pallor is another feature. A blue line along the gum, with bluish black edging to the teeth is another indication of chronic lead poisoning. Children with chronic poisoning may refuse to play or may have hyperkinetic or aggressive behaviour disorders.

According to the reports by Hu et al. (2007), about 35-40% of inhaled lead dust is deposited in the lungs, and about 95% of that goes into the bloodstream of adults. Guidotti and Ragain (2007), report that the complications arising from lead poisoning show that lead affects every one of the body's organ systems, especially the nervous system, but also the bones and teeth, the kidneys, and the cardiovascular, immune, and reproductive systems. Hearing loss, tooth decay and cataracts have been linked to lead exposure.

Findings, Conclusions and Recommendations

Summary of results showed that:

1) All participants were completely ignorant of the fact that EEE emit hazardous gases.

2) All participants were completely ignorant of the fact that their inhalation of the hazardous emissions from EEE caused them some health problems.
3) Most (97%) of the participants did not associate any of the common symptoms of ill-health with inhalation of emissions from EEE.
4) Although all participants were aware of some of their colleagues quiting the trade, they were certain that none of such cases had to do with EEE toxic effects on them.
5) Most (95%) participants were certain it would not come to their being required to quit the trade on account of EEE toxic effects on them.
6) Most (86%) participants were certain it would not come to their being required to quit the trade before their retirement age because of EEE toxic effects on them.
7) Most (91%) participants were certain that there was no need for adopting some safety measures for handling EEE in order to minimise toxic effects.
8) Most (95%) participants disregarded the safety measures for handling EEE and did not apply them.

Toxic substances are ubiquitous; no one can run away from them. Their uses are getting increasingly important; people need to use them for personal and society development at various levels. EEE workers are exposed to toxic components of EEE through several pathways (gases emission, dust, water, food contami-nation, and so on). Therefore, exercise of caution is what is required from EEE marketers and repairers. They need to know that their stock contains chemical components that emit hazardous gases and that their inhalation of these emissions leads to adverse health effects that manifest in various symptoms of ill-health. If, through awareness campaign, they are made to know about the hazardousness of WEEE and the need to adopt recommended safety measures, they would exercise caution as they continue with the trade in less risky manners.
It is recommended, therefore, that:

1) EEE shops/workshops be well ventilated;
2) EEE marketers and repairers should take breaks from their shops/workshops;
3) EEE marketers and repairers should take vacations from their jobs;
4) EEE marketers and repairers should wear nose masks and gloves in workplace;
5) The government and non-governmental organisations should conduct awareness creation fora to enlighten the EEE marketers and repairers on proper professional practice to minimise the toxic effects of EEE on them;
6) Policies should be made to control the careless handling of EEE by marketers and repairers, in order to curb health diseases, life tolls and socio-economic loses attendant upon growing EEE sales and services businesses in the era of idiosyncratic adoption of ICTs.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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