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Cellular biomarker responses of bagrid catfish, *Chrysichthys nigrodigitatus* in a contaminated coastal ecosystem

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An assessment of the pollution status of Agboyi creek, a water body associated with various anthropogenic activities was carried out in order to determine responses induced in Catfishes, *Chrysichthys nigrodigitatus* inhabiting it. Cellular biomarkers of stress including the antioxidative stress enzyme, catalase (CAT), lipid peroxidation measured as thiobarbituric acid reactive substance (TBARS), as well as serum enzymes alanine aminotransferase (ALT) and Aspartate aminotransferase (AST) were evaluated in *C. nigrodigitatus* from Agboyi creek and compared to a control (non-polluted) water body, Epe Lagoon. The results of physicochemical assessments of both water bodies showed significant differences (P<0.05) with Agboyi creek having high levels of total suspended solids (TSS), phosphate as well as total dissolved solids (TDS) and heavy metal concentrations which exceeded National Environmental Regulations (NESREA) safe limits. The mean concentration (Mean ± SD) of TBARS in the liver of *C. nigrodigitatus* at Agboyi Creek (2455.43 ± 1440.0 nmol/mg protein) was about twice the levels at Epe Lagoon (1398.31 ± 1446.50 nmol/mg protein). Inhibition of CAT activity was observed in liver samples of catfishes at Agboyi Creek (48.17 ± 60.23 µmol/min/mg protein) compared to Epe Lagoon (87.97 ± 13.00 µmol/min/mg protein). The mean activities of ALT and AST were significantly higher (P<0.05) at Agboyi Creek (12.67 ± 15.04 and 151.67 ± 76.76 U/L) compared to Epe Lagoon (2.33 ± 0.52 and 6.00 ± 3.46 U/L). The present study shows altered biochemical conditions in fishes sampled in the water body impacted by anthropogenic contaminants and suggest that those parameters could be used as reliable biomarkers of contaminant exposure to fish.

Key words: Biomonitoring, water pollution, oxidative stress, fish health.

INTRODUCTION

The increase of population in coastal areas and the rise of our standard of living is driving the efforts to produce more food, thereby increasing domestic, agricultural and industrial activities. These activities generate solid wastes,

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sewage and energy which are released into the coastal ecosystem resulting in the disturbance of their delicate balance, threatening the health and existence of living organisms including humans (Chukwu and Ogunmodede, 2005). Despite the fact that the sea has an enormous capacity to buffer the various impacts from human activities degrading it, streams, creeks, rivers, estuaries and swamps have only a little capacity to do so due to their relative small sizes (Odiete, 1999). The aquatic environment provides a sink for many environmental contaminants some of which have the potential to cause oxidative stress in aquatic organisms (Amaeze, 2014). In Nigeria, the lagoons and estuaries have continued to be under intensifying pressure from pollution (Ajao, 1996; Oyewo, 1998; Otitoloju, 2000). Primary concerns are the effects of domestic and industrial effluents on the general health of aquatic life, the maintenance of hitherto viable artisanal commercial fisheries and the safety of humans occupationally exposed to the pollution (Ajao and Fagade, 1990). Apart from mortality, some of the more common and equally serious effects of environmental stressors on aquatic organisms are changes in behavior, growth, and reproduction (Walker et al., 2001).

Fish are considered to be the bioindicators of freshwater/marine pollution because of their ability to respond to pollutants (Adams et al., 1989). They are obligate aquatic animals and require movement of water across their gills and mouth for respiration and feeding, respectively. Their physiological responses to their environment have been employed by investigators to monitor aquatic pollution (Odiete, 1998). Such specific responses described as biomarkers are employed in monitoring changes in status resulting from exposure of living organisms to contamination (Depledge and Hopkin, 1995). Biomarkers effect consist of biochemical and/or physiological changes in organisms exposed to toxicants or varying abiotic conditions and thus represent initial responses to environmental perturbations and contamination (Bengtson and Henshel, 1996; Roy et al., 1996). They are generally regarded as more sensitive than bioindicators, which are employed at higher levels of the biological hierarchy (Stegeman et al., 1992). This is because subtle changes at the individual level is more rapid than at population or community levels and presents an early warning signal for monitoring changes in status of the environment (Doherty, 2014).

The use of biochemical biomarkers in monitoring organism health status is now a regular procedure given their ease of measurement and relationship with concentrations of pollutants to which organisms are exposed to (Otitoloju and Olagoke, 2011). They are often used in monitoring oxidative stress impacts from pollutants by comparing relative cellular enzyme activity with exposure levels. Typically, the activities of antioxidant stress enzymes are increasingly gaining relevance in aquatic ecosystem monitoring. Oxidative stress may result from an increase in reactive oxygen species (ROS), an impairment of antioxidant defense systems or an insufficient capacity to repair oxidative damage. It may ensue when the ability to buffer against ROS is exceeded either by excessive production of ROS or by depletion of antioxidants. This can alter cellular redox-potential and initiate a variety of responses via intracellular pathways (Timbrell, 2000). ROS are produced by the cellular metabolism of aerobic organisms either enzymatic or non-enzymatic reaction which produces oxyradicals. The ROS are formed due to incomplete reduction of oxygen, which may generate the superoxide anion (O_2^-), hydrogen peroxide (H_2O_2) or the hydroxyradical (OH^-) as well as other partially reduced molecules (Valavanidis et al., 2006).

The measurement of levels of lipid peroxidation and the activities of antioxidant stress enzymes are often used as complementary procedure in monitoring the extent of oxidative stress in cells. Lipid peroxidation results from the damage of the phospholipid bi-layer of cell membranes and is considered a biomarker of damage (Geffard, 2001). This damage produces a number of by-products, one of which is the aldehyde, malondialdehyde (MDA). MDA is formed from the breakdown of polyunsaturated fatty acids (PUFA) and it serves as a convenient index for determining the extent of lipid peroxidation (Jamil, 2002). Together with levels of MDA, activities of antioxidant stress enzymes such as catalase (CAT) and superoxide dismutase (SOD) are often monitored in aquatic and terrestrial animals in other to determine the extent of stress (Otitolohu and Olagoke, 2011; Esiegbe et al., 2013). These enzymes are produced naturally in the body to counter the onslaught of oxidative stress precursors such as free radicals, singlet oxygen, superoxides, peroxides and other breakdown and reactive products of toxicants (Azqueta et al., 2009). SOD breaks down ROS into peroxides which are further detoxified by CAT into water and oxygen. Inhibition of SOD therefore is linked with CAT because it leads to reduced hydrogen peroxides, the substrate on which the CAT acts (Amaeze et al., 2014). CAT works by breaking down superoxides, helping the body to convert hydrogen peroxide into water and oxygen, thus preventing the formation of carbon dioxide bubbles in the blood (Livingstone et al., 1990). Catalase also uses hydrogen peroxide to break down potentially harmful toxins in the body, including alcohol, phenol, and formaldehyde (Papagiannis et al., 2004).

Serum enzymes such as alanine aminotransferase (ALT) and aspartate aminotransferase (AST), which primarily measures of liver damage, have also been employed to measure damage of organs like kidney and gills (Bernet et al., 2001; Yang and Chen, 2003). ALT is found mainly in the liver, but also in smaller amounts in the kidneys, heart, muscles, and pancreas, with low levels normally found in the blood (Reev et al., 1980).

Most increases in ALT levels however are caused by liver damage (Reev et al., 1980). When the liver is damaged or diseased, it releases ALT and AST into the bloodstream, which increases their peripheral levels. Thus, these proteins are also employed together with other battery of assays as biomarkers in measuring health status of organisms. Fish under stress mobilizes triglycerides and protein to meet an increased demand for energy resulting from increased physical activity, bio-transformation and excretion of xenobiotics (Alkahem et al., 1998). Both the aminotransferases (alanine and aspartate) function as a link between carbohydrate and protein metabolism by the interconversion of strategic compounds like α-ketoglutarate and alanine to pyruvic acid and glutamic acid, a process known as transamination (Knox and Greengard, 1965). Aminotransferases respond to any stress or altered physiological condition (Knox and Greengard, 1965).

The use of a biochemical approaches has been advocated to provide an early warning of potentially damaging changes in stressed fish. Changes in the concentrations and activities of enzyme often directly reflect cell damage in specific organs (Casillas et al., 1983). The measurement of biomarker responses offer to demonstrate that toxicants have entered an organism, are being distributed within the tissue and are eliciting a toxicological effect on biological structures and functions (McCarthy and Shugart, 1990). Organisms' responses are measurements of cellular and physiological processes that are normal components of an organism's attempt to deal with metabolic processes and to maintain a constant internal balance. These processes fluctuate within some normal (homeostatic) range for an organism. If an organism is exposed to a pollutant, it may respond to the exposure by compensatory increases or decreases in one or several of the organism's cellular or physiological processes. Under stress conditions the body mechanisms are altered to combat the effect of the pollutants/ stressors in order to maintain equilibrium in the organism (Siva, 1980). Monitoring of the biomarkers in living organisms including fish is a validated approach and serves as early warning of adverse changes and damage resulting from chemical exposure (van der Oost et al., 1996).

The bagrid catfish (*Chrysichthys nigrodigitatus*) was chosen for the study because of its potential as a bioindicator species being common and often abundant, having a wide distribution in Nigerian coastal ecosystem (Ikusemiju, 1975; Fagade, 1980). This study was conducted to assess the levels of lipid peroxidation and biochemical changes that occur in the liver tissue and serum (enzyme levels) by measuring the levels of TBARS (commonly measured as MDA) and activities of CAT, ALT and AST as biomarkers, in *C. nigrodigitatus* living in the polluted Agboyi Creek. The levels in the catfishes at Agboyi creek when compared with those from non-polluted waters like Epe lagoon could validate their use for water quality assessments.

MATERIALS AND METHODS

Description of study area

Agboyi Creek is located at the western side of Lagos and northern section of Lagos lagoon, (Longitude 6° 35'N; latitude 3° 25'E) (Figure 1). The creek derives its source from Ogun River and receives input from Ogudu Creek towards the middle of its course before it empties into the Lagos lagoon at Oworonshoki. It serves as a major drainage channel for the area, receiving domestic wastes and industrial effluents which are discharged from nearby industries at Maryland, Isheri, Magodo and Ogudu areas of Lagos State (Onyema and Ojo, 2008). It has a length of 7.63 km. It is a major drainage channel for industries located in Ikeja, Agege, Ogudu areas and the municipal water plant at Iju. The sampling station is at the southern end of the creek between the connection to Ogudu Creek and the opening of the Agboyi creek into Lagos Lagoon. Epe Lagoon (Longitude 6° 35'N; latitude 3° 25'E) was selected as a control station given the similarity of both water bodies and does not receive effluents from major industries.

Field sample collection

Six live specimens of adult *C. nigrodigitatus* of an average body weight and length of 148.4 g and 22.9 cm, respectively, were caught from Agboyi Creek (Latitude 06° 34.183'N; Longitude 003° 24.621'E), representing polluted site, and Epe Lagoon (Latitude 06° 34.649'N; Longitude 003° 56.921'E), representing control or unpolluted site, with hook and line. The fishes were placed in 10 L plastic buckets and water from their natural habitat was added. All buckets were kept cool and aerated during return trip back to the laboratory. Surface water samples from both sites were collected using 2 L plastic kegs and transported cool in icepacks to the laboratory for analysis as well. Some physicochemical parameters were determined *in situ* using Horiba U50G Multi water sampler.

Analytical procedures

Surface water physicochemical characteristics

Water temperature, pH, electrical conductivity, dissolve oxygen (DO), total suspended solids (TSS), total dissolved solids (TDS and salinity were measured *in situ*. The chloride ion levels, sulphate, total nitrate, ammonia and phosphate concentrations in the water samples were determined using standard volumetric analytical procedures (APHA, 2005) at the Central Research Laboratory, Chemistry Department, University of Lagos. Water samples measuring up to 500 ml from each site were filtered and digested using concentrated nitric acid before measuring their absorbance relative to respective metallic standards using Perkin Elmer atomic absorption spectrophotometer as reported by (Don-Pedro et al., 2004).

Fish samples preparation and analysis

Blood samples were collected using sterile syringe (5 ml) followed by dissection to remove liver samples. The liver samples were dissected out of the fish through the ventral side. The liver samples

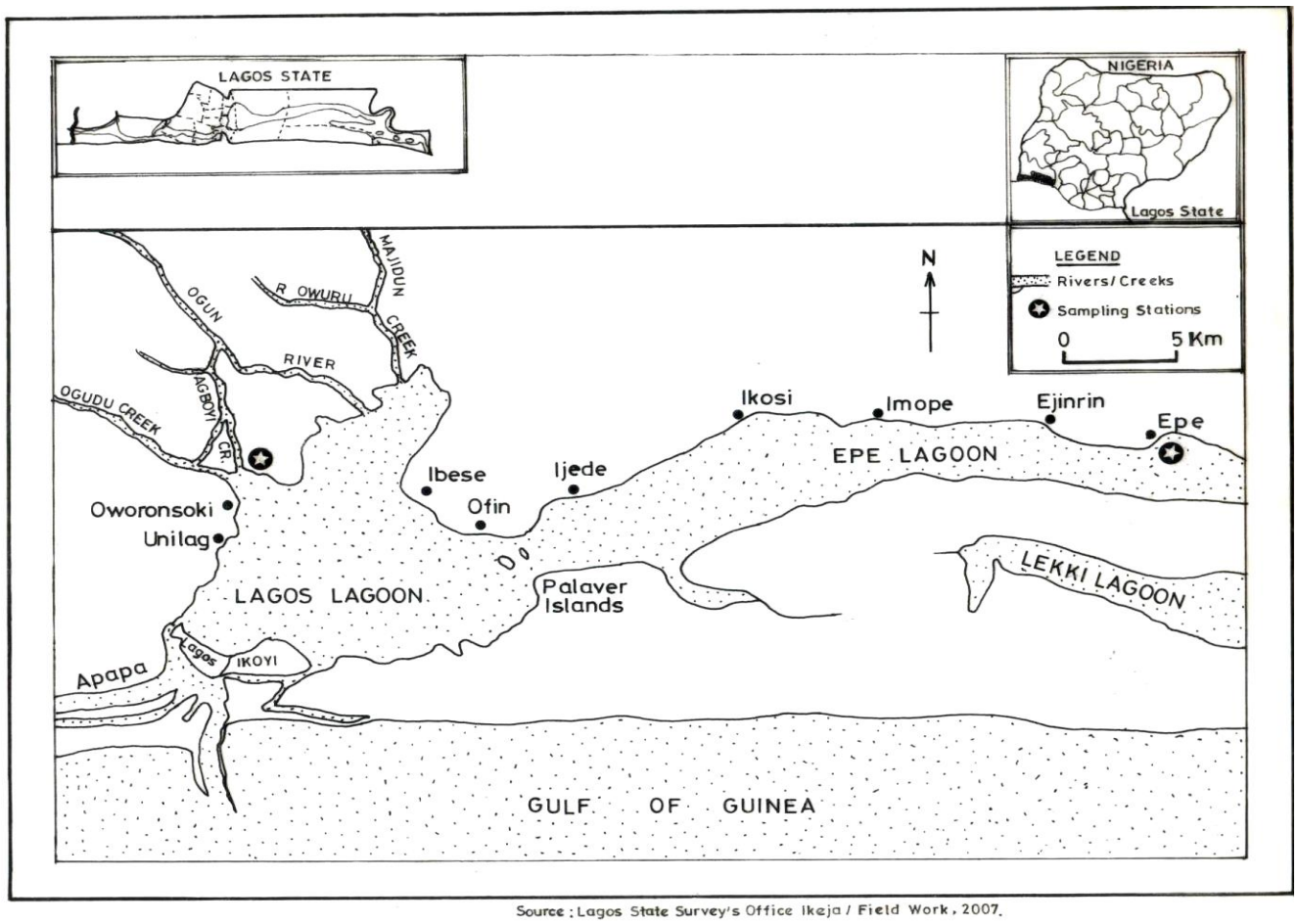

Figure 1. The sampling stations at Agboyi Creek and Epe Lagoon.

were washed with normal saline solution and placed in a small plastic container with tight cover and preserved in a (-20°C) until analysis. The collection, handling and dissection of the fishes were in line with the ethical standard approved by the University of Lagos. Each liver sample was retrieved from the freezer, 0.5 g weighed out and homogenized when cold and dissolved inphosphate buffer saline (1 to 10 w/v, that is, to 0.5 g of liver sample, 5.0 ml of phosphate buffer was added). The homogenate were then centrifuged at 10,000 rpms for 10 min. The supernatant were collected and stored in the fridge for estimation of Catalase (CAT), thiobarbituric acid reactive substances (TBARS) and total protein.

Protein determination

The protein levels were also determined in the supernatant, with bovine serum albumin (BSA) standard (Bradford, 1976). The results were expressed in mg of protein/ml.

Catalase assay

Catalase activity in supernatant was determined according to the method of Aebi (1974) by monitoring the initial rate of disappearance of hydrogen peroxide (initial concentration 10 mmol) at 240 nm (ε = 40 /M/cm) in an OPTIMA SP-3000 PLUS spectrophotometer. The reaction volume containing 50 mM/0.1 ml phosphate buffer at 7 pH, 0.2 ml of supernatant and 1.8 ml of 30 mM H_20_2 or 0.9 ml of 30 Mm H_20_2. Blank were run without supernatant or containing phosphate buffer. The activity of the enzyme was expressed as µmol H_2O_2/min/mg protein.

Malonaldehyde/ TBARS assay

The level of tissue lipid peroxidation was determined by assessment of MDA as total thiobarbituric acid (TBARS)-reactive products (Buege and Aust, 1978). The absorbance was read at 535 nm against blank containing water using OPTIMA SP – 3000 PLUS spectrophotomer. The concentration of the malonaldehyde produced was determined based on the molar extinction coefficient for MDA-TBA of 1.56×10^5 /M/cm. 1 Mm EDTA was added to a 0.5 ml of the supernatant and was mixed with 1.0 M cold 10% (W/V) trichloroacetic acid (TCA) to precipitate protein. The solution was mixed and centrifuged for 10 min at 5,000 g. The supernatants from the TCA extract were combined with the same volume of TBA and heated in boiling water for 15 min. Control sample contained water instead of supernatant. The TBARS values were expressed as nmol/mg protein. Each sample was run twice to enhance accuracy

Table 1. Physicochemical properties of surface water samples from both stations.

S/N	Parameters	Agboyi Creek	Epe Lagoon	(NESREA 2011) Limit
1	Water Temperature (^{o}C)	31.5	29.7	<40
2	pH	7.6	7.4	6.5-8.5
3	Electrical Conductivity (μScm^{-1})	8.500	1.675	-
4	Dissolved Oxygen (ppm)	3.40	4.4	4.0
5	Total Suspended Solids (ppm)	4.170	39	-
6	Total Dissolved Solids (ppm)	4.150.0	1.080	2.000
7	Salinity (‰)	5.8	1.45	-
8	Chloride (ppm)	3.300.0	500.0	
9	Sulphate (ppm)	72.8	62.10	500
10	Nitrate	18.62	3.40	20
11	Ammonia (ppm)	0.10	ND	-
12	Phosphate (ppm)	4.08	0.34	3.5
13	Iron (ppm)	15.72	0.24	0.5
14	Copper (ppm)	4.65	0.001	0.01
15	Manganese (ppm)	2.16	2.4	-
16	Zinc ppm)	65.6	0.001	0.2
17	Lead (ppm)	0.24	ND	0.1
18	Mercury (ppm)	ND	ND	0.01
19	Cadmium (ppm)	ND	ND	0.01

of readings, implying two replicate per fish samples.

Amino transaminase (AST) and alanine amino transaminase (ALT) assay

Blood samples were extracted from six fish samples each from both stations into heparin's sample bottle. The samples were allowed to coagulate at room temperature for 2 h. The serum were obtained by centrifugation of an amount of blood at 3000 rpm for 10 min and were prepared for the analysis of the activities of AST and ALT using Reitman and Frankel (1957) method, with reagents supplied in RANDOX assay kit.

Statistical analysis

Statistical differences between physicochemical properties of water samples from both water bodies and biochemical parameters in the sampled fishes were analyzed by two-way analysis of variance (ANOVA) and significant differences were examined by post hoc analysis using SSPS statistical software version 16.0. Data are presented as mean ± standard deviation (SD).

RESULTS

Physicochemical characteristics of the sampling sites

The physicochemical parameters measured in the surface water of Agboyi creek and Epe lagoon is shown in Table 1. The two way analysis of variance indicated that the differences in the overall physicochemical characteristics for both water bodies did not differ significantly (P= 0.057). The pH values observed at both water bodies were slightly alkaline but were within permissible NESREA limit of 6.5 to 8.5. The surface water conductivity was 5 times higher in Agboyi creek, compared with the value at Epe Lagoon. Similarly, values of salinity, total dissolved solids and total suspended solids at Agboyi creek were higher compared with the same parameters at Epe Lagoon. The total dissolved solids (TDS) value at Agboyi was more than 2 times the NESREA limit for water quality. Agboyi creek also recorded high chloride levels which were more than 6 times the value at Epe lagoon. The nutrient concentrations (that is, sulphate, nitrate and phosphate) at Agboyi creek were also higher when compared with those at Epe Lagoon. The phosphate level at Agboyi was higher than the NESREA limit of 3.5 ppm while the nitrate levels were close to the limit. Some heavy metals measured were detected in both water bodies (Fe, Cu, Mn, Zn and Pb) but were significantly higher at Agboyi creek (F=1.792 Fcrit =5.987, df=1, p=0.23).

Catalase activities in the catfishes

The mean catalase activity in the tissue of *C. nigrodigitatus* in both water bodies were not significantly different (P>0.05) (Figure 2).

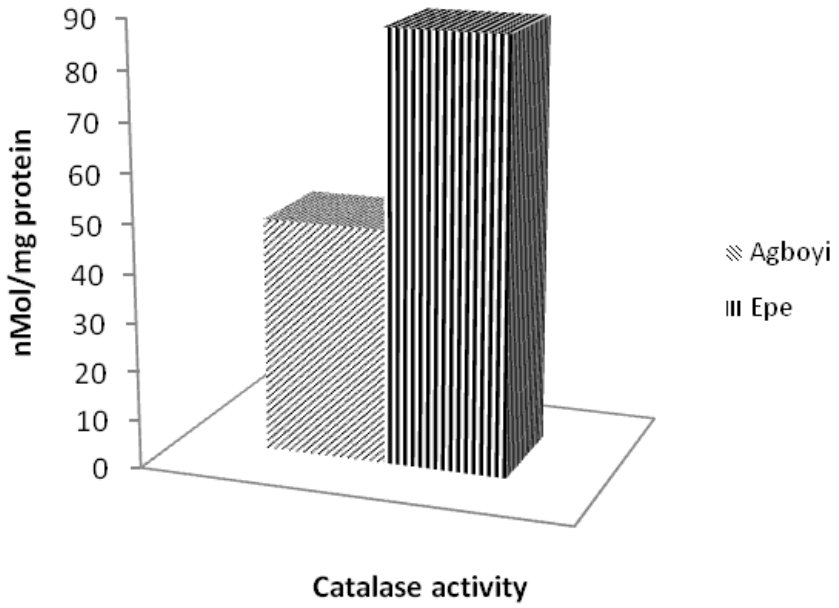

Figure 2. Inhibition of Catalase (CAT) activity in the liver samples of catfishes in Agboyi creek relative to Epe lagoon (Control site). The values are significantly different (F=0.409, Fcrit = 6.608, df =1 p= 0.55).

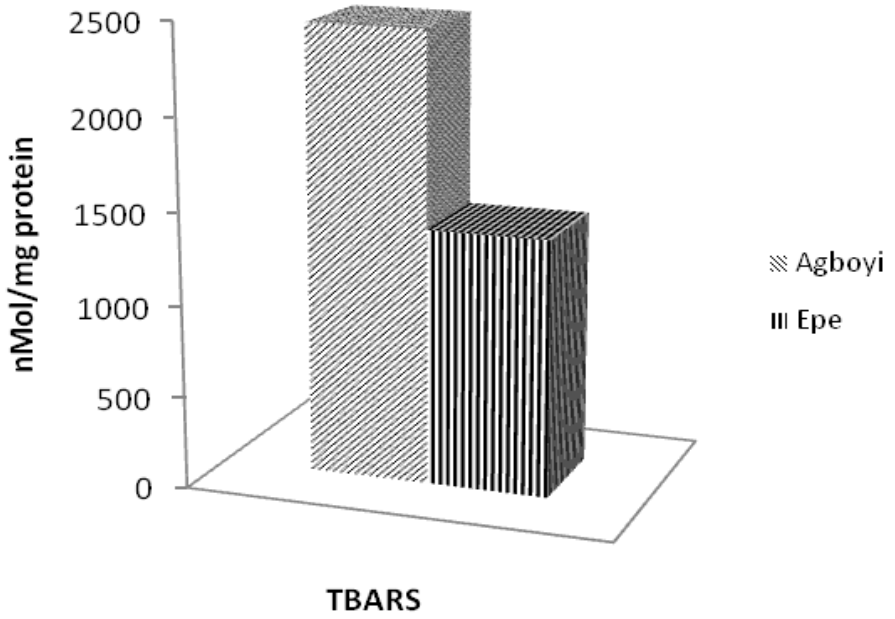

Figure 3. Lipid peroxidation (TBARS) concentration in the liver samples of Catfishes in Agboyi creek and Epe lagoon (Control site). The values are significantly different (F=1.739, Fcrit = 6.608, df =1 p= 0.24).

Lipid peroxidation levels in the catfishes

The mean hepatic content of TBARS as measured with the level of MDA in catfishes at Agboyi creek was 2,455.43± 1,577.42 nmol/mg protein, while level at Epe lagoon samples was 1,398.31± 1,584.64 nmol/mg protein (Figure 3). The t test indicated that the values of MDA in both water bodies were not significantly different

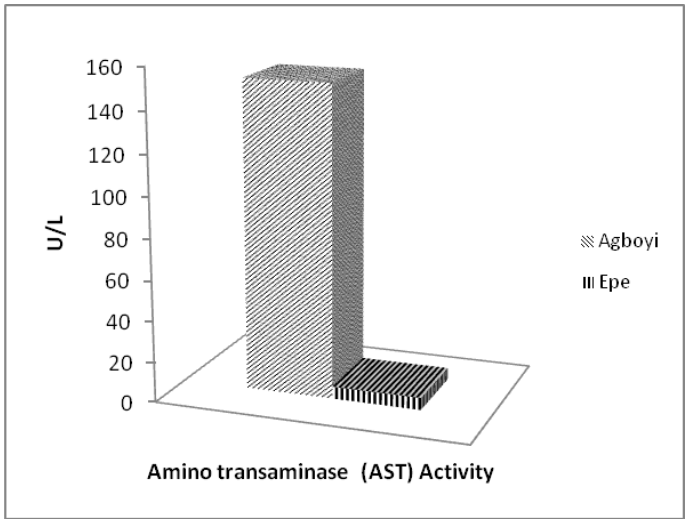

Figure 4. AST activities in the serum of catfishes in Agboyi creek and Epe lagoon (Control site). The values are significantly different (F=20.179, Fcrit = 6.608, df =1 p= 0.01)

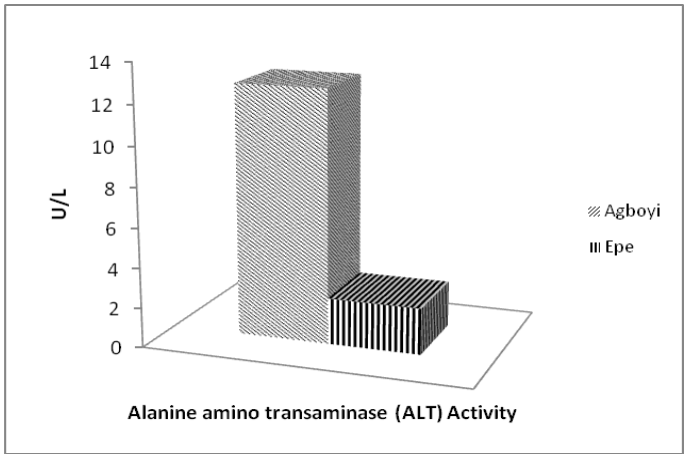

Figure 5. ALT activities in the serum of catfishes Agboyi creek and Epe lagoon (Control site). The values are significantly different (F=1.739, Fcrit = 6.608, df =1 p= 0.24)

(P>0.05).

Serum enzyme levels in catfish from both sampling sites

The mean activities of AST in the serum of *C. nigrodigitatus* were significantly higher at Agboyi creek (12.67 ± 15.04 and 151.67 ± 76.76 U/L, respectively) (Figure 4). ALT activities were also significantly higher at Agboyi when compared to the same enzymes at Epe lagoon (2.33 ± 0.52 and 6.00 ± 3.46 U/L, respectively) (Figure 5).

DISCUSSION

The evidence from the physicochemical assessments of surface water samples from Agboyi creek and Epe lagoon clearly shows some level of deviation from the set limit, with the former having values which differed more from the NESREA standard. Overall, the physicochemical characteristics indicate that Agboyi creek is disturbed as a result of anthropogenic activities along its course. Apart from the activities within the creek such as dumping of solid wastes, sand mining, domestic sewage and effluents discharge from cottage industries in the upstream Ogun river, this creek is also influenced by pollution from the neighbouring Odo Iyalaro creek which receives effluents from the Ogba-Ikeja industrial estates. The continuous input of these contaminants inevitably impacts on its physical parameters and in turn its biota. According to Nwankwo (1995), storm water channels, creeks and creeklets acts as conduits for land based human-induced activities into the coastal waters of Nigeria. The very high level of suspended solids in the creek can be attributed to among other factors, the artisanal sand mining activities prevalent in the area. This raises the turbidity of the water and therefore may interfere with light penetration for photosynthetic activities. Impairment of photosynthesis would ultimately disrupt the ecological process and food web structure of the creek. The high levels of sulphate and phosphates at Agboyi creek, relative to the control, Epe Lagoon and the NESREA standard, are indicative of input of sewage rich in organic matter and perhaps, to some extent, fertilizer runoff from farms in the hinterland. The concentrations of heavy metals, Fe, Cu, Pb and Zn in Agboyi creek, were higher than the NESREA standards. Heavy metals in the Lagos Lagoon and associated creeks have been associated with the discharge of effluents from the adjourning industries (Oyewo, 1998). Essential heavy metals, such as Cu and Zn, are required in various physiological and metabolic processes. However, at excessively high concentrations, they become toxic, damaging the plasma membrane and other cell components, altering enzymes, and producing cytotoxic
species such as reactive oxygen radicals (Lowry et al., 1951). Many studies conducted during recent years show that heavy metals accumulation may lead to oxidative stress, with an overproduction of ROS that can alter various organic molecules such as nucleic acids, proteins and membrane lipids (Sevcikova et al., 2011; Oliva et al., 2012). Effects of pollutants on ecosystems and communities originate from effects on individual organisms and ultimately, all effects of pollutants are the result of the interaction between a foreign chemical and one or several biomolecules in an individual. This interaction may lead to a disturbance in the cell function, which in turn, may be important enough to alter the function of the organ (Hogstrand, 2000).

It is proposed that measurement of antioxidants in fish tissues may prove to be a useful biomonitoring procedure of exposure to aquatic pollutants (Sevcikova et al., 2011). A number of investigators have employed biochemical biomarkers in both *in situ* and *ex situ* conditions to measure the effect of exposure to toxicants (Esiegbe et al., 2013; Doherty, 2014). However, there are so many natural variables that can mask the effects of pollutants, so that it is very difficult if not impossible to attribute a change in an ecosystem to a single chemical or even an effluent (Hogstrand, 2000). The activities of anti oxidative stress enzymes as well as lipid peroxidation levels are the most commonly employed biochemical tools for toxicant effect monitoring (Timbrel, 2000). Different enzymes and non-enzymatic compounds participate in the antioxidant chain in biological systems. Among them, super oxide dismutase (SOD), converts superoxide anion (O^{-2}) to H_2O_2 while CAT reduces H_2O_2 to water (Timbrel, 2000).

With respect to the case - control model for which the disturbed Agboyi Creek and the relatively undisturbed Epe Lagoon were sampled in this studies, lower activities of CAT was observed in liver of catfishes at in the former compared to the later. This tends to indicate a reduced ability to protect cells against H_2O_2 in the Agboyi catfishes relative to those from Epe lagoon as prescribed by Papagiannis (2005). This finding is similar to those reported by Heart (1995), who found significantly lower CAT activity in brown bullhead livers from the contaminated St. Lawrence River than in livers of bullheads from the relatively uncontaminated Lac La Peche. Also, CAT activity was found lower in the contaminated Black River fish, Ohio and higher in the uncontaminated the Old Woman Creek fish, Ohio by McCarthy and Shugart (1990) as reported by Papagiannis (2005).

The levels of malondialdehyde (MDA), a key product of lipid peroxidation determined as a function of TBARS was higher in catfishes from Agboyi creek compared to those from the control water body. Lipid peroxidation, a well-recognized mechanism of cellular injury is used as an indicator of oxidative stress in cells and tissues (Niki, 2008). It can be inferred that the activities of CAT, being inhibited in catfishes from Agboyi creek were not high enough to prevent lipid peroxidation. This phenomenon was also described for *M. edulis* by Pellerin-Massicotte (1997). TBARS increase in liver of .3fish chronically exposed to pollutants has also been reported (Karakoc, 1997). Chronic exposure to contaminants such as agrochemicals have been associated impairment of liver antioxidative enzymes and increased lipid peroxidation, potentially compromising hepatic cell function (Amaeze et al., 2014).

The results from the serum enzyme assays indicate significantly higher levels of AST and ALT in catfishes from Agboyi creek compared to those from Epe Lagoon. Although, the activity of either enzyme particularly AST may also be elevated also in hepatic disease, the elevation of AST and ALT usually reflect some injury to the liver (Dheer et al., 1987). Some workers have illustrated that enzyme pattern in the serum reflects the physiological state of the organ. For instance increase in serum levels of AST and ALT was observed in serum of fish exposed to 2,3,4 –triaminoazo benzene resulting to the hepatocellular damage (Krishan and Veena, 1980). The increase of plasma AST and ALT have been attributed to the hepatocellular damage or cellular degradation by heavy metals, perhaps in liver, heart or muscle (Yamawaki et al., 1986).

Palace et al. (1996) proposed that organic contaminants which cause oxidative stress could also inhibit the activities of protective enzymatic antioxidants. Therefore, continuous increased exposure of the fish to nutrient enrichment, high concentrations of heavy metals as recorded in this study, together with other toxicants inherent in the water body (Agboyi creek) which was not measured could reduce their antioxidant enzyme activity and increase the stress leading to increased lipid peroxidation as well as impairment in protective enzyme functions.

Conclusion

The findings from this study reinforce the relevance of biochemical responses in fish as a tool for aquatic ecosystem monitoring. It also points the unsustainable manner in which water bodies associated with the Lagos metropolis are being used. There is a need to respond to the numerous findings from investigations in the Lagos lagoon and its associated creeks so as to stem the tide of pollution and therefore enhance the quality of life of aquatic biota and improve the utility of the water bodies for various purposes.

Disclosure of conflict of interest

There is no conflict of interests regarding this article.

Abbreviations: CAT, Catalase; **ALT,** alanine aminotransferase; **TDS,** total dissolved solids; **TSS,** total suspended solids; **TBARS,** thiobarbituric acid reactive substance; **AST,** aspartate aminotransferase.

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