Original Article

Assessment of the level of some heavy metals in commonly consumed local fish species displayed for sale in Port Harcourt, Nigeria

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Abstract

Background: The incessant crude oil spillage into the water bodies of the Niger delta region of Nigeria has raised fears that the fish caught in the water bodies would be heavily contaminated with heavy metals. This study tested five commonly consumed local fish species for their lead, cadmium, mercury, and arsenic content.

Methods: Samples of dark tilapia (*Sarothendon gallelacus*), light tilapia (*Oreochronis niloticus*), two-fin catfish (*Clarias gariepinus*), "Zeghe" (*Hydrocynus forskahlii*) and three-fin catfish (*Auchenoglanis occidentalis*) bought from three fish markets (Creek Road, Mile One and Iwofe) were used for the study. The levels of the heavy metals in the fish samples were assessed in an accredited laboratory, while the human health implications of the contaminants were determined using the relevant international regulatory standards.

Results: The fish samples contained detectable levels of the assessed metals. The mean concentration of cadmium in the fish samples was 0.29mg/kg; while the mean concentration of arsenic was of 1.85mg/kg. The average concentrations of lead and mercury in the fish samples were below the regulatory limits, whereas the mean concentration of cadmium was three times the WHO permissible limit of 0.1mg/kg. The concentrations of cadmium were highest in the light tilapia, and in the fish bought from the Mile One market, and lowest in the three-fin catfish, bought from the Creek Road market.

Conclusion: The levels of the assessed heavy metals were significantly less than expectation. The levels of cadmium in the samples were however high enough to cause severe adverse health effects, hence the need for a more comprehensive public health response in managing crude oil spills.

Keywords: Chemical contaminants, fish, Nigeria, *Oreochromis niloticus*, Rivers State, WHO permissible limit

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Introduction

In recent years, an average of 300 crude oil spills are reported in the Niger Delta region of Nigeria,[1] and it is estimated that more than 13 million barrels (1.5 million tons) of crude oil have been spilled into the Niger Delta environment, since commercial oil exploitation started in the region in 1958; a yearly average of about 240,000 barrels.[1] These oil spills affected at least 1500 communities in the eight crude oil producing states in Nigeria; they are mainly from the 5284 oil wells that were drilled (as at 2006) and the 7000 km of crude oil pipeline that crisscrosses the Niger Delta region.[1]

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The crude oil spills contaminate the environment, especially the water bodies where fishing, the main occupation of the people of the region takes place. Crude oil is a mixture of many chemicals, many of which are known to be toxic and persistent in the environment such that they remain in the environment long after the cleanup of the oil spill.[2] Some components of crude oil are also known to bioaccumulate in fish and food crops such that they continue to constitute a hazard to health, even when the prevailing environment is adjudged to be within the acceptable standard.[3]

Considering the quantity of crude oil that has been spilled into the Niger Delta environment, and the fact that most of the fishes consumed in the region are caught in the water bodies of the region, we suspect that most of the local fish species consumed in the region contains dangerous levels of chemicals. We tested this hypothesis by analyzing the fish displayed for sale in three major markets in Port Harcourt, the main urban center of the region. The result of the study would help draw attention to the more covert effects of crude oil spills in the region, possibly enough to attract better public health response.

Materials and Methods

This study was carried out in Port Harcourt, the capital of Rivers State, one of the 36 states that make up the Nigerian federation, and the hub of the oil industry in Nigeria. The population of Port Harcourt has increased significantly from 1,382,592 in 2006, as a result of massive migration into the city, due to increased insecurity in the hinterland of the Niger Delta region, and the incessant crude oil spills that made it very difficult for the people of the region to earn a livelihood in their rural communities.[1] Fish is the main source of protein in the staple foods of the inhabitants of Port Harcourt. A good proportion of the fish eaten in Port Harcourt is supplied by artisanal fisherfolks, who ply their trade in the various water bodies that crisscross the Niger Delta region.[1]

A cross-sectional, analytical study design was used. The fish samples were bought from the open market, transported in an iced cooler to an accredited laboratory where they were analyzed for possible contamination, while an impact assessment was carried out to ascertain the health implications of the contaminants identified in the fish samples.

Five different species of fish, identified by fish mongers in three major fish markets in Port Harcourt as commonly consumed by the residents of Port Harcourt, were procured for the study. The fish species are dark tilapia (*Sarotherodon galilaeus*), light tilapia (*Oreochromis niloticus*), two-fin catfish (*Clarias gariepinus*), "Zeghe" (*Hydrocynus forskahlii*), and three-fin catfish (*Auchenoglanis occidentalis*).

Three sets of the fishes were bought from the Mile One, Creek Road, and Iwofe markets. The Creek Road fish market is in the old Port Harcourt town. It is the most established fish market in Port Harcourt, supplied by more established fisherfolks who have the resources to fish beyond the inland water bodies. On the other hand, the Mile One and the Iwofe markets were established to serve the suburbs of Port Harcourt. These markets are predominantly supplied by artisanal fisherfolks who mainly ply their trade in the inland water bodies.

Fish displayed for sale in these markets were bought, placed in an iced cooler, and transported to a laboratory accredited by the Nigeria's Federal Ministry of Environment, where the gills, liver, intestine, and skeletal muscle of the fish samples were analyzed for their lead, cadmium, mercury, and arsenic content, using standard methods that include atomic absorption spectrophotometry and X-ray fluorescence spectrometry.

The data collected for the study were checked for consistency and completeness before being analyzed using IBM's SPSS statistical package, Version 20. Summary measures were calculated for each outcome of interest, the relationship between the concentration of the assessed chemicals and the morphology (length and weight) of the fish was tested using ANOVA, while the test of significance was conducted using the relevant statistical test, at 95% confidence interval, with $P \leq 0.05$ considered statistically significant.

The mean concentration of the assessed chemicals in the fish samples was compared with the international guideline values to ascertain if they met the regulatory standard whereas the health implications of eating the fish were assessed by determining the total daily intake of the assessed chemicals from eating the fish, and then finding the health effects of the total daily intake, based on the published studies.

For the health impact assessment, the average daily per capita fish consumption was set at 68.5 g/day, from the annual per capita fish consumption of 25 kg, as was used in a similar study,[4] while the harmful effects of the chemicals were determined by the effects of consuming the quantity of the chemicals in the fish, as determined by the relevant toxicological studies that took into consideration the bioavailability of the metals in fish.[5] Consequently, the concentration of lead in the fish considered to be harmful was set at 0.2 mg/kg of the fish,[6] the concentration for cadmium was set at 0.1 mg/kg,[7] the value for mercury was set at 0.5 mg/kg,[8] while the concentration of arsenic considered dangerous to health was set at 1 mg/kg of the fish, and a tolerable intake level of 0.003 mg/kg body weight.[9]

Ethical consideration

The approval to undertake the study was sought and obtained from the Ethics Review Committee of the University of Port Harcourt, Port Harcourt while informed consent was sought and obtained from the fish sellers.

Table 1: The concentrations of the assessed heavy metals in the various fish samples

Species of fish (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	As (mg/kg)	Hg (mg/kg)
Oreochromis niloticus	0.008	0.78	3.32	<1.0
Sarotherodon gallelacus	0.008	0.38	1.31	<1.0
Hydrocynus forskahlii	0.008	1.18	3.12	<1.0
Clarias gariepinus	0.008	0.13	0.5	<1.0
Auchenoglanis occidentalis	0.008	0.002	0.99	<1.0
Mean concentration	0.008	0.29	1.85	<1.0

Results

The concentrations of the assessed heavy metals in the various fish samples are shown in Table 1. The fish samples were found to contain detectable levels of cadmium and arsenic, while lead and mercury were found in very low levels in the samples at 0.008 mg/kg and <1.0 mg/kg, respectively. The concentration of cadmium in the fish samples ranged from 0.002 mg/kg in the three-fin catfish (*A. occidentalis*) to 0.78 mg/kg in the light tilapia (*O. niloticus*), with a mean concentration of 0.29 mg/kg whereas the concentration of arsenic in the fish samples ranged from 0.05 mg/kg in the two-fin catfish (*C. gariepinus*) to 7.53 mg/kg in the light tilapia (*O. niloticus*), with a mean concentration of 1.85 mg/kg.

There are wide variations in the concentrations of cadmium and arsenic found in the fish bought in the different markets. The concentrations of the two heavy metals in the fish bought in the Mile One market were significantly higher than those bought in the other two markets. The cadmium content in the light tilapia (*O. niloticus*), dark tilapia (*Sarotherodon gallelacus*), "Zeghe" (*H. forskahlii*), and the three-fin catfish (*A. occidentalis*) that were bought in the Mile One market was 2.35 mg/kg, 1.14 mg/kg, 0.53 mg/kg, and 0.39 mg/kg, respectively, which is significantly higher than the respective mean cadmium concentration of 0.78 mg/kg, 0.38 mg/kg, 0.18 mg/kg, and 0.13 mg/kg for all the fish samples bought in all the three markets. The concentrations of arsenic in the light tilapia and "Zeghe" bought in the Mile One market are also the highest with respective concentrations of 7.53 mg/kg and 5.22 mg/kg, compared to the mean concentrations of 3.32 mg/kg and 3.12 mg/kg, respectively. The concentrations of arsenic in the dark tilapia and the three-fin catfish bought in the Iwofe market are the highest with respective concentrations of 1.8 mg/kg and 1.63 mg/kg, compared to the mean concentrations of 1.31 mg/kg and 0.99 mg/kg, respectively.

Table 2 shows the concentrations of assessed heavy metals, compared to the maximum permissible limits. The average concentrations of lead and mercury in the samples were below the regulatory limits, whereas the mean concentration of cadmium of 0.29 mg/kg is about three times the WHO permissible limit of 0.1 mg/kg. The maximum concentration of arsenic (7.53 mg/kg) found in the light tilapia bought in the Mile One market is seven times higher than the WHO permissible limit of 1 mg/kg.

Discussion

The study showed that the fish samples contain barely detectable levels of mercury and lead and more significant levels of cadmium and arsenic, but not in the levels that were expected before the study. Studies had indicated that crude oil spills cause significant increases in the concentrations of the assessed metals in fish, directly from the spill[2] and through the bioaccumulation of the heavy metals.[3] The considerably low levels of the assessed metals in our fish samples can be explained by the feeding habits of the fish[4,10] and the response of both the fish[4,10] and the fisherfolks[11] to crude oil spillage. Fish are known to swim away from oil spill sites,[10] while studies have shown that the fisherfolks of the Niger Delta region increasingly ply their trade outside the inland water bodies, where the fish are driven to in response to the incessant crude oil spills into the inland water bodies.[11]

The feeding habits and behavior of the fish are also good explanations for the unexpected low levels of the assessed metals that were recorded in our study. The concentrations of the heavy metals were considerably higher in the light tilapia (*O. niloticus*), which is probably not to be expected, considering that scaled fish are thought to contain less environmental contaminants because their scales are believed to protect them from absorbing the contaminants.[12] This was, however, not the case with the light tilapia assessed in our study, probably because tilapias are very hard and feed more on the planktons and aquatic plants that are often severely affected in an oil spill.[4] In addition, tilapias are less likely to swim away from oil spill because they prefer swallow water and are not comfortable in brackish water.[13] On the other hand, the concentrations of the heavy metals were lower in the two-fin catfish (*C. gariepinus*) and in the three-fin catfish (*A. occidentalis*), which are unexpected, considering that they are without scales.[12] The explanation might be due to the ability of the catfish to escape oil spill sites, including crawling through dry land, using their auxiliary breathing apparatus.[10]

The levels of the heavy metals recorded in our study are, however, enough to cause some adverse health effects. The

Table 2: The concentrations of assessed heavy metals, compared to the maximum permissible limits

Heavy metal	Average concentration (mg/kg)	Highest concentration (mg)	Average daily intake (mg/kg)	Maximum permissible limit (mg/kg)
Lead	0.008	0.008	0.00055	0.2
Cadmium	0.029	2.35	0.0020	0.1
Arsenic	1.85	7.53	0.13	1.0
Mercury	<1.0	<1.0	<1.0	<1.0

mean concentrations of cadmium in the fish samples are about three times the WHO permissible limit of 0.1 mg/kg, while the maximum concentration of arsenic found in the samples is seven times higher than the WHO permissible limit of 1 mg/kg. It is advised that fish with concentrations of cadmium or arsenic as high as these should not be eaten because of their potential to cause severe adverse health effects.[7,9]

The concentration of cadmium in the *O. niloticus* sold in one of the markets (2.35 mg/kg) exposed consumers to 0.16 mg of cadmium intake daily, which is more than the 0.03 mg/day reference dose for a 60 kg adult.[7] Cadmium is regarded as a cumulative toxin because of the human body's ability to excrete just 0.001% of the amount ingested in a day. Although it is considered probably carcinogenic, most of the chronic toxicities affect the kidneys, bones, and liver, and present mainly in postmenopausal women as "Itai-Itai" disease with severe osteoporosis and osteomalacia, renal dysfunction, and normochromic anemia.[14]

The concentration of arsenic in the *O. niloticus* sold in one of the markets (7.53 mg/kg) exposed consumers to 0.52 mg of arsenic intake daily, which is more than the 0.012 mg/day reference dose for a 60 kg adult.[9] Chronic exposure to arsenic has been associated with skin lesions, peripheral neuropathy, gastrointestinal symptoms, diabetes, renal system effects, cardiovascular disease, and cancer.[9] Thankfully, these are mostly seen with exposure to inorganic arsenic in drinking water and occupational exposures, and rarely result from consuming fish, which often contain the less toxic organic arsenic compounds such as arsenobetaine.[15]

We observed differences in the levels of the assessed heavy metals in the fish bought from the different markets in Port Harcourt. The concentrations of the heavy metals in the fish bought from the Mile One market were significantly higher than those bought in the other two markets. This difference can be as a result of where the fish sold in the markets were caught. The Creek Road market, the market with the least concentration of heavy metals in its fish samples, is the more established fish market. The market is supplied by better-resourced fisherfolks who have the resources to ply their trade further away from the polluted inland water bodies, where the level of pollution is significantly less.[11]

Our study has some limitations, mainly in the precision of the laboratory measurement of the assessed heavy metals. The laboratory used to analyze the samples was able to measure the level of mercury only up to 0.1 mg, which is the same as the maximum permissive level. These data are not good enough, as all the fish samples had the same level of mercury, which makes the interpretation of the results almost impossible. Improper waste management practices that are common in the Niger Delta region have been shown to contaminate water bodies of the region with mercury,[16] which is further bioaccumulated in fish.[17] We had, therefore, expected to find higher levels of mercury in the fish samples, especially in the more carnivorous catfish. The possible explanation of this, apart from the low precision of the laboratory method, is the possibility that the incessant crude oil spills in the region have been so deadly to fish, especially catfish that only a few live long enough to bioaccumulate mercury.

Conclusion

The levels of the assessed heavy metals were significantly less than the levels expected from the incessant crude oil spills that occur in the Niger Delta region. The level of cadmium in the samples are, however, high enough to cause severe adverse health effects, hence the need for a more comprehensive public health response in managing crude oil spills in Nigeria.

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Conflicts of interest

There are no conflicts of interest.

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