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Mercury Distribution and Concentration in Nile Tilapia (*Oreochromis Niloticus*) and Catfish (*Clarius Gariepinus*)

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Abstract:
Mining activities from the recent past to the present pose a direct threat to the environment of Dunkwa-on-Offin and its neighbouring towns. The implication is that, the river and its fishes may be contaminated as a result of use of mercury by artisanal miners in their operations locally known as 'galamsey'. It is perceived that uptake of mercury by planktons and fishes in the River Offin would be lethal to human beings, since the indigenes depend on the river as source of fish (protein). Little knowledge about mercuric toxication by artisanal gold miners and the indigenes makes it difficult to discourage the' galamsey' mines from the practice. In this study, analysis of the water, benthic feeders (Catfish) and surface feeders (Nile Tilapia) fish samples caught at decreasing distance from the point of 'galamsey' operations on the river was undertaken to determine the levels of mercury in the gills, liver, and muscle of the fishes. The total concentration of mercury in the samples from the River Offin, were determined, computed and compared with W.H.O quality guideline values. Mercury level in both water and the fish from the Offin River exceeded the W.H.O, values. The results indicated that the water and fish are contaminated with mercury and therefore pose health hazards, and should not be used for drinking and food, respectively.

Keywords: *Amalgamation, Atomic Absorption Spectrophotometry, Toxicity, Mercury Analysis, Automatic Mercury Analyser, and Membrane.*

1.Introduction

Mercury is a toxic trace element and its toxicity is high, ranging from mild effects to chronic situations and more importantly, damage to sensitive and vital organs (Arif *et al.,* 2015). While its release into the environment has been found to be naturally minimal, various anthropogenic activities have led to the release of tons of mercuric species into the environment (Moon-Kyung, K and Kyung-Duk, Z. 2012). Typical example is artisanal gold mining, known as "galamsey" in the Ghanaian parlance, which inculcates the use of mercury, whose use is currently banned in the industry, in the gold extraction processes called amalgamation [(Osuteye, (2015), Canli *et al.,* (2010)]. The setup of the artisanal gold mining process is such that mineral-rich ores/rocks are crushed and washed to obtain the gold which is extracted with mercury (Bansah *et al.,* 2016). Through the roasting of the amalgam in open air to produce pure gold, elemental mercury evaporates into the air and it is later deposited onto land (Osuteye, 2015). It is then recycled through biogeochemical processes which create several entry pathways into the food chain. Thus, a large quantity of water is needed for the process. This implies that alluvial sites are most conducive for the artisanal gold mining (UNDP, 2016). The wastewater or effluent are then discharged into nearby rivers or abandoned to seep into the soil which eventually ends up contaminating underground water bodies. The implication is that contamination of the fishes from the Offin River is a possibility due to the activities of the "galamsey" operators (Kusi-Ampofo, S. & Boachie-Yiadom, T. 2012). The situation could be precarious as it may imply that people who consume fish from the Offin River might be "eating" the heavy metal, and the highly toxic element, mercury. It is necessary, therefore, to empirically ascertain this assertion of mercury toxication of fishes (both surface water and benthic feeders) so as to provide needed measures to remedy the situation. It is general knowledge that mercury is a poisonous trace element which is very deadly to humans and poses serious threat to the ecosystem (Armah *et al*., 2016) . While people believe the use of mercury in gold mining is not good, artisanal gold miners seem not to realize the danger their activities pose, probably due to the silent nature of mercuric toxication effect and lack of evidential facts that will completely nullify their perceptions (Charles *et al.,* 2013). Perceptions might be true or false, although a lot of research has been undertaken on the environmental processes and risk of mercury (Rice *et al*., 2014). Much of these studies have not been conducted on the quantification of mercury in fishes at the various points along the Offin River. Scientific research is the only sure way to determine the certainty and accuracy or otherwise of perceptions. The present study, therefore sought, by applying scientific methodology, to ascertain the possibility of mercury toxication in the Dunkwa section of the Offin River. This study, therefore, sought by determining the total mercury concentration in Nile tilapia (*Oreochromis niloticus*) and Catfish (*Clarias gariepinus).* The specific objectives of the study were to 1) The mercury content of the water at various points along the Dunkwa section of River Offin; 2) The presence and levels of mercury in the gill, liver and muscle of Nile tilapia (*Oreochromis niloticus*) and Cat fish (*Clarias gariepinus*); 3) The total concentrations of mercury in Nile tilapia (*Oreochromis niloticus*) and Catfish (*Clarias gariepinus*) from the Dunkwa section of River Offin (Dunkwa –on- Offin, Upper Denkyira East District, 2016).

2.Materials And Methods

2.1. Study Area

Upper Denkyira East Municipal Assembly whose administrative capital is Dunkwa – on - Offin is located in the central region of Ghana (Fig. 1). The Municipal was established in 2007 from the then Upper Denkyira District. The district is located within latitude 5^{o} 30' and 6^{o} 02 N of the equator and longitudes 1^{o} and 2^{o} W of the Greenwich Meridian (upperdenkyiraeast.ghanadistricts.gov.gh). The municipal covering a total land area of 1,020 km^2 shares boundaries with Adansi South in the north, Assin North Municipal in the east, Twiffo Atti-Morkwa District in the west and in the west to Upper Denkyira (GSS, 2014).

2.2. Sampling

Fish and water samples, were taken from the Offin River two times at 4-weeks intervals between first and second samples. A total of forty eight (48) fishes comprising of twenty-four (24) Nile tilapia (*Oreochromis niloticus*) and twenty-four (24) Cat fish (*Clarias gariepinus)* were randomly selected; with One hundred and forty four (144) samples representing the gills, livers and muscles taken. Triplicate of each sample was done to rule out experimental bias or random errors.

2.3. Water Sampling

Water samples were taken early in the morning at 100 m intervals starting from the point source. Samples were taken by using 1 litre (L) sterilized plastic bottles and transported in cool ice chests to the laboratory for analysis.

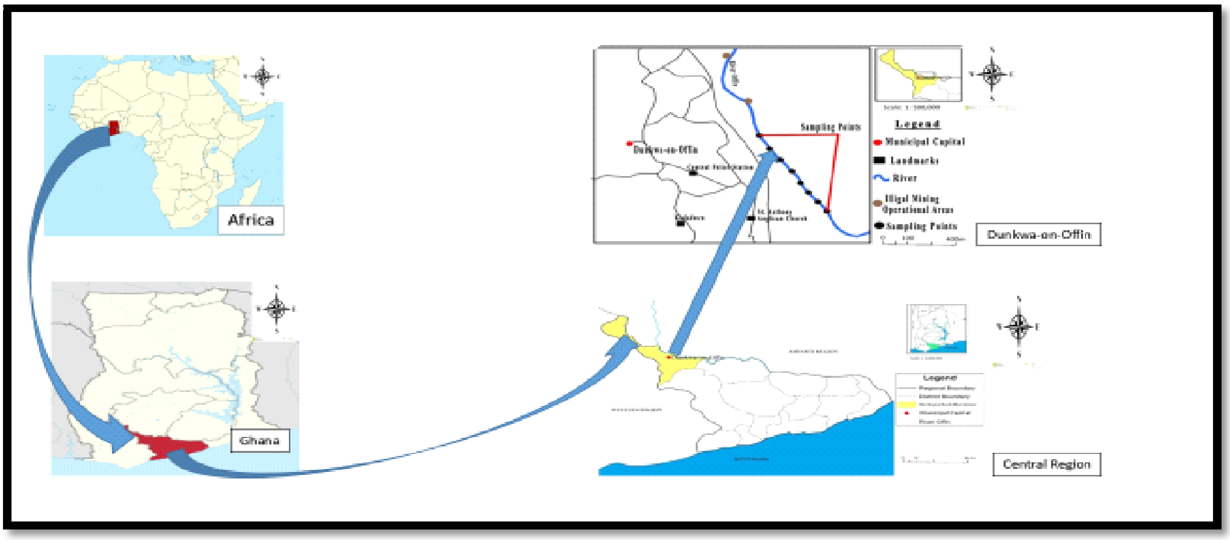

Figure 1: Geographic Location of the Study Area along with the Sampling Point in Dunkwa-on-offin in Ghana

2.4. Selected Fish Species

With proper investigation and observation, Tilapia (*Oreochromis niloticus*) and Catfish (*Clarias gariepinus*) were selected as sample species. Tilapia (*O. niloticus*) is a cichlid fish native to Africa that can be found in freshwater habitats including rivers, lakes, sewage canals and irrigation channels (AU-IBAR, 2016). Tilapia is omnivorous when young, while in later stages it consumes large quantities of phytoplankton (Haque *et al*., 2016) [Fig. 2a]. African Catfish inhabits lakes, ponds, rivers and swamps, and due to its pseudo-lungs, long body shapes and capacity to produce large amount of mucus, it can survive for a long time in stagnant water and even out of water (AU-IBAR, 2015). It is an opportunistic feeder with remarkable array of feeding adaptation, and found to feed on detritus, filamentous algae, zooplankton, macrophytes, aquatic and terrestrial insects, fish, nematodes, arthropods, molluscs, crustaceans, birds, reptiles and amphibians (Bruton, 2010) [Fig. 2b]. Therefore, high catch rate, good size and good fillet, have made these species important for the fishing community around Dunkwa section of River Offin.

	
Figure 2a: Tilapia (Oreochromis Niloticus) With Scale Ratio Of 1:3 Mm	*Figure 2b: Catfish (Clarias Gariepinus) With Scale Ratio Of 1:3 Mm*

2.5. Fish Harvesting

For the sampling of fish, European gillnets of mesh size 16 and 22.5 mm manufactured by Viet Au Ltd, Vietnam (measured from knot to knot) were used to catch Nile Tilapia (*Oreochromis niloticus*) and Catfish (*Clarias gariepinus*) along the Dunkwa section of River Offin about 500 meters away from the point source of the 'galamsey' operations with 100 meters interval downstream up to 800 meters. Due to the operations of the miners, there were heavy disturbances and agitation of the water near the point source of the 'galamsey' activity, making the fishes swim downstream. Therefore, the first point of fish catch was 500 meters downstream from the point of disturbance and subsequently at 100 meters interval up to 800 meters downstream. Total length (from snout to the caudal fin) and total weight of the specimens were measured to the nearest centimetre and gram, respectively. The fishes were dissected using the EMERGE Protocol (Diogo, *et al.,* 2016). New aluminium foil was used as a cover on the dissecting bench, for dissection of each fish. All the dissecting instruments were cleaned with distilled water, and new surgical blades were set in the scalpel for each fish. Plastic Ziploc bags, scale envelopes and plastic vials were properly marked with a distinct code for each fish. Gill samples (second gill arch on the right side) were collected in pre-weighted plastic vials. Liver samples were collected in a piece of aluminium foil wrapped carefully and marked, and then placed in the pre-marked Ziploc bag. Muscle samples were taken from the area between the dorsal and adipose fin and above the dorsal line, after removing the skin, case being taken to prevent any contamination. Each sample was packed in a separate aluminium foil, marked, and place inside the pre-marked Ziploc bag. Then all the samples of a fish were again placed in a bigger Ziploc bag, marked with the same code as to the fish sample code and names of sampled fish (Table 1).The samples were then placed in the freezer.

Figure 3: Dissection of Fish with the Scale Ratio. 1:3 Mm

S/N	Fish Sample Code	Fish Name and Part
1	Tg	Tilapia gills
2	Tl	Tilapia liver
3	Tm	Tilapia muscle
4	Cg	Catfish gills
5	Cl	Catfish liver
6	Cm	Catfish muscle

Table 1: Code and Names of Sampled Fish

2.6. Laboratory Analysis

For mercury analysis, portions of gills, liver, and muscle each equivalent to 2 grams were removed from each species of fish. There were a total of 72 samples for Tilapia and 72 for Catfish. Thus, these were 24 gills, 24 livers and 24 muscle samples for each of the fish samples taken. The gills, liver and muscle of the tilapia and catfish were prepared and analyzed for the presence and level of total mercury at the Chemistry Department Laboratory, Kwame Nkrumah University of Science and Technology, Kumasi.

2.7. Operation Of Cold Vapour Atomic Absorption Spectrophotometry (AAS)

2 g of which each sample was weighed into a nickel sample boat followed by heating in oxygen abundant furnace to release the mercury. After this the products were carried through oxygen to attract any halogens or oxides of nitrogen and sulphur on the catalyst in the catalytic section of the furnace (Premi *et al*., 2016). Mercury is trapped from the remaining vapour by the amalgamation cell. Mercury vapour is released by heating of the amalgamation cell prior to flushing of the system with oxygen to eliminate remaining gases and decomposed products. Flowing oxygen carries the mercury vapour through an absorbance cell positioned in the light path of a single wavelength atomic absorption spectrophotometer. Absorbance was measured at the 253.7 nm wavelength as a function of the concentration in the sample. Detection limit of 0.005 ng of mercury was achieved with 25 cm path length cell with a 2 cm cell allowing a maximum concentration of 20 µg of mercury (Bitzer *et al.*, 2015).

2.8. Analysis Of Mercury Content In Water Sample

The concentrations of mercury in the water samples were determined using Cold Vapour-Atomic Absorption Spectrophotometry (CV-AAS). The AAS was calibrated using standard solution of the mercury under investigation. The concentrations of the mercury were determined at 253.7 nm wavelength. For the determination of the total mercury, about 100 mL of the water sample was measured into two 50 mL volumetric flasks. The flask was rinsed three times with the samples before pouring the actual samples into them. One mL of concentrated HNO3 was added to the samples and allowed to digest for one hour. Filtration was done using 0.45 µm membrane filter paper. Samples were then analysed using the Cold Vapour-Atomic Absorption Spectrophotometry (CV-AAS) at 253.7 nm wavelength.

2.9. Mercury Analysis in Fish Samples

Cold Vapour-Atomic Absorption Spectrophotometer (CV-AAS) and Automatic Mercury Analyzer model HG 5000 equipped with mercury lamp operated at 253.7 nm (manufactured by Tekran Instrument Corporation, Canada) were used to determine the overall mercury levels in all the 2 grams each of fish parts (liver, muscle and gills). Dissolution of fish muscles, gills and liver for total mercury determination was done using Anton Paar microwave (Manufactured by Anton Paar, Austria).

2.10. Statistical Analysis

Data obtained from the determinations were analyzed using Microsoft Excel and one-way randomized analysis of variance (ANOVA) and differences were ascertained at 5% (95% confidence interval). Data trends were represented in Tables and Graphs.

3.Results And Discussion

Mercury content in water samples at different distances downstream from the point source of mining activity on River Offin

Fig. 4 shows that mercury content in water samples taken from sections of River Offin at distances downstream from the source of mining activity ranged from 0.03 mg/L at 800 m to 0.06 mg/L at 100 m with mean value of 0.04 mg/L. The same mean value of 0.04 mg/L was recorded at 400 m, 500 m, 600 m and 700 m and 0.05 mg/L at both 200 m and 300 m. All these mean mercury contents in water samples were above the WHO (2011) permissible limit recommended for drinking water (0.001 mg/L).

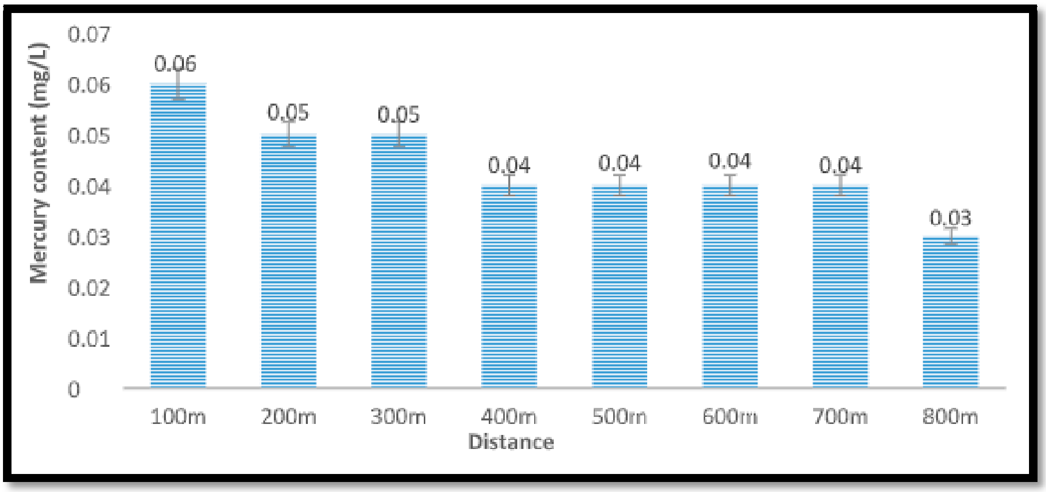

Figure 4: Mercury Content in Water Samples Taken at Different Sections Downstream from a Source of Mining Activity on River Offin

3.1. Mercury Content In The Gill Of Tilapia At Different Distances From The Point Source Of Mining Activity On River Offin

Based on the distances of the sampling points from the mining activities Tilapia sampled at 500m away from the point source contained the highest mean value of mercury (3.35 mg/kg) in the gill followed by samples taken at 600 m which recorded mean mercury value of 3.19 mg/kg (Fig.5). At 800m away, gill recorded the least mean value of mercury of 2.7 mg/kg. Mercury content in the gill ranged from 2.7 to 3.35 mg/kg with total mean of 3.05 mg/kg. These mean values recorded were significantly greater than the permissible limit of WHO / FAO (2016), and EC, 2010. The differences between the values of mercury content in gill from the sampling locations were close to each other and this is emphasised by small variations in the standard deviation (Table 2). There was no significant difference between the mercury content in the gills (p= 0.19).

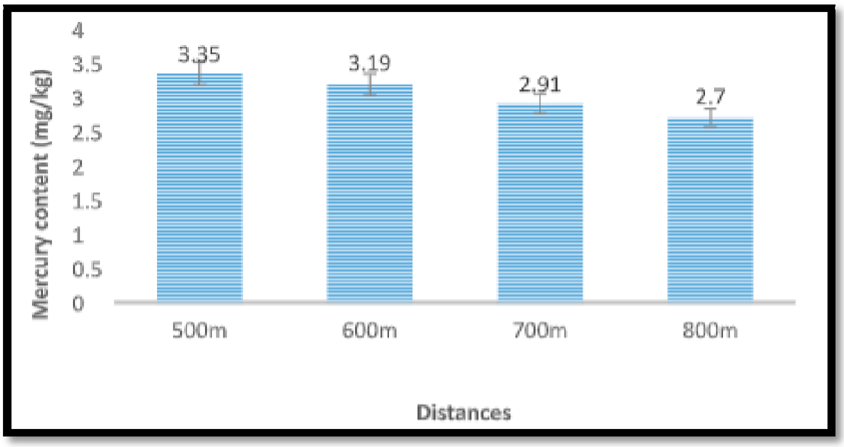

Figure 5: Mercury Content in the Gill of Tilapia (Oreochromis Niloticus) Caught at Different Points Downstream along River Offin from a Source of Mining Activity

3.2. Mercury Content in the Liver of Tilapia at Different Distances Downstream from a Point Source of Mining Activity on River Offin

The mercury content in the liver of Tilapia was in the range of 2.98 mg/kg at 800m to 4.23 mg/kg at 500m with overall mean of 3.60 mg/kg. The mean mercury content recorded at 500m (4.28 mg/kg) was highest and the lowest mean mercury of 2.98 mg/kg was recorded at 800m (Fig.6). All the mean values recorded for mercury content in liver were above the permissible limit of WHO/FAO (2016) and the EC, 2010. Differences in mercury concentration of the liver of Tilapia caught at different distances from the point of mining activity along River Offin were insignificant. However, the ANOVA indicates that the differences in mercury concentration of the liver of the first investigated at various distances from the point source were significant (p = 0.0002).

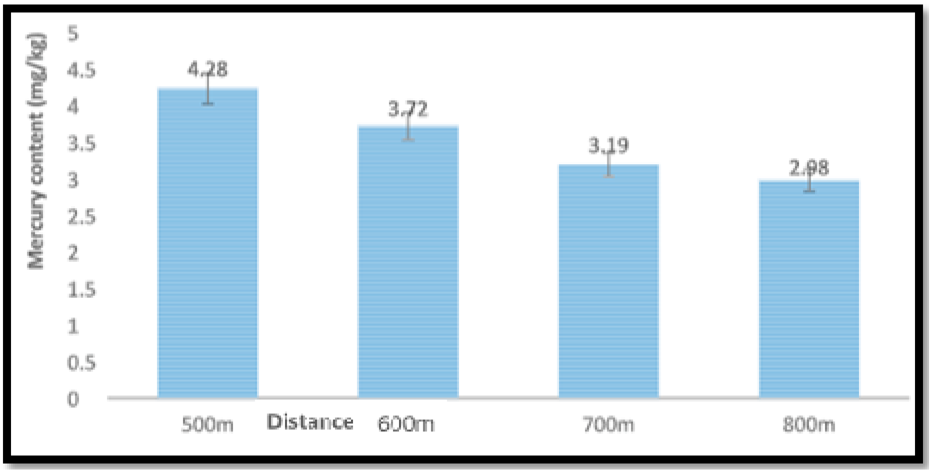

Figure 6: Mercury Content in Liver of Tilapia Caught at Different Distances along River Offin from Point of Mining Activity

3.3. Mercury Content in the Muscle of Tilapia at Different Distances from the Point Source of Mining Activity along River Offin

Mercury content in the muscle of Tilapia sampled at the various distances from the point of mining activity on River Offin ranged from 0.86 mg/kg at 800 m to 1.97 mg/kg at 500 m with total mean of 1.35 mg/kg. All the mean values recorded for mercury content in muscle were above the permissible limit of WHO/FAO 2016; EC, 2010 except at 800m where mercury content in muscle (0.86 mg/kg) was below the allowable limit (1.0 mg/kg) [Fig.7] .The ANOVA showed that the variations in mercury content of the muscle samples were significant (p = 0.0002).

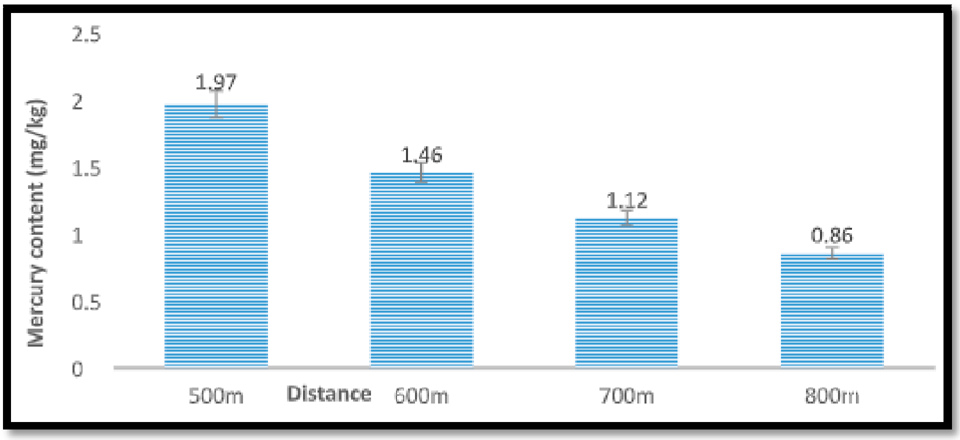

Figure 7: Mercury Content in Muscle of Tilapia Caught at Various Distances from the Point of Mining Activity along River Offin

Tilapia	Distance (m)	Mean ± SD (mg/kg)	Range (mg/kg)	Overall mean (mg/kg)
Gill	500	3.35 ± 0.014	2.71 – 3.35	3.05
	600	3.19 ± 0.0064		
	700	2.91 ± 0.0025		
	800	2.71 ± 0.245		
Liver	500	4.28 ± 0.25	2.98 – 4.28	3.54
	600	3.72 ± 0.91		
	700	3.19 ± 0.08		
	800	2.98 ± 0.05		
Muscle	500	1.97 ± 0.0071	0.86 – 1.97	1.35
	600	1.46 ± 0.02		
	700	1.12 ± 0.06		
	800	0.86 ± 0.007		
	Permissible limit		Reference	
Mercury	0.5 mg/kg		WHO/FAO (2016)	
	1.0 mg/kg		Puri, P.J.*et al.,* (2011)	
	0.5 mg/kg		EC, 2010	
Catfish	Distance (m) (mg/kg) (mg/kg) (mg/kg)	Mean ± SD		Overall mean
Gill	500	2.76 ± 0.41	1.83 – 3.17	2.47
	600	3.17 ± 0.76		
	700	2.1 ± 0.11		
	800	1.83 ± 0.14		
Liver	500	5.3 ± 0.59	3.44 - 5.3	4.53
	600	4.88 ± 0.91		
	700	4.51 ± 0.93		
	800	3.44 ± 0.45		
Muscle	500	1.95 ± 0.16	0.97 – 1.95	1.28
	600	1.18 ± 0.06		
	700	1.03 ± 0.07		
	800	0.97 ± 0.04		
Mercury	Permissible limit		Reference	
	0.5 mg/kg		WHO/FAO (2016)	
	1.0 mg/kg		Puri, P. J. *et al* (2011)	
	0.5 mg/kg		EC 2010	

Table 2: Mercury Content in Samples of Tilapia and Catfish from Sampling Points at Different Distances Downstream from Mining Activity along River Offin

3.4. Mercury Content in the Gill of Catfish at Different Distances from the Point Source of Mining Activity River Offin

The mercury content in the gill of catfish caught at different distances downstream from the point of mining activity along River Offin ranged from 1.83 mg/kg (800 m) to 3.17 mg/kg (600 m) with overall mean level of 2.47 mg/kg (Table 2). At 600 m, the mercury content in gill recorded the highest value of 3.17 mg/kg and the lowest value of mercury (1.83 mg/kg) in the gill was recorded at 800 m (Fig.8). These mercury values recorded were far above the permissible limits shown in (Table 2). ANOVA showed that there were no significant differences in the mercury content in the gills ($p = 0.19$).

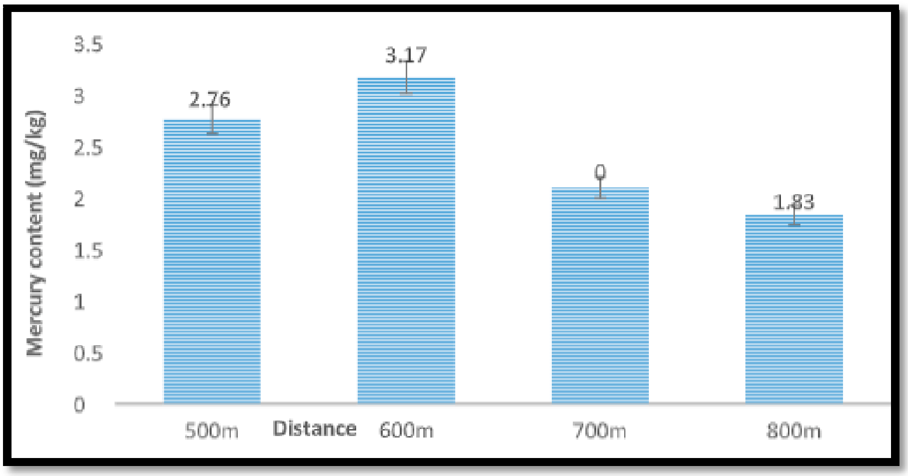

Figure 8: Mercury Content in the Gill of Catfish Caught at Distances along River Offin Downstream from Point of Mining Activity

3.5. Mercury Content in the Liver of Catfish Caught at Different Distances Downstream from the Point Of Mining Activity on River Offin

Mercury content in the liver of catfish caught at 500 m had the highest value of 5.3 mg/kg whilst those caught at 800 m downstream had the minimum value of mercury (3.44 mg/kg) in liver (Fig.9). The overall mean was 4.53 mg/kg. All the mean values determined at each point were higher than the permissible limit of WHO/FAO (2016), and the EC, 2010 (Table 2). The trend shown in the mean mercury content in the liver of catfish based on the distances from the point source of mining activity was in descending order i.e. 5.30 mg/kg (500m) < 4.88 mg/kg (600m) > 4.51 mg/kg (700m) > 3.44 mg/kg (800m). This trend shows that the mercury content in liver decreased with increase in distance from the point of mining activity. There was significant difference among the mercury content in the liver of the catfish ($p = 0.02$).

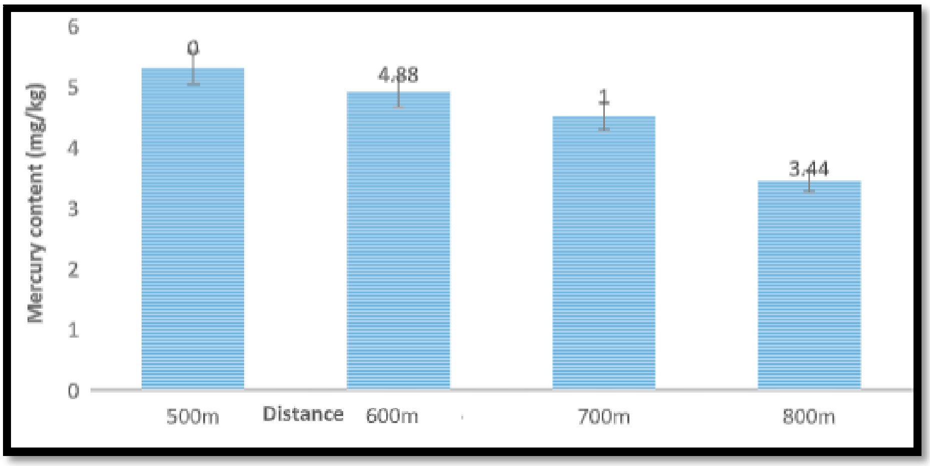

Figure 9: Mercury Content in the Liver of Catfish Caught at Distances along River Offin Downstream from the Point of Mining Activity

3.6. Mercury Content in the Muscle of Catfish at Different Distances from the Point of Mining Activity on River Offin

Assessment of mercury content in muscle of catfish sampled at different distances downstream from the point of mining activity along River Offin showed that the content in muscle of catfish caught at 500 m recorded the highest value of 1.95 mg/kg whilst 0.97 mg/kg was the least value recorded at 800 m (Fig. 10). The overall mean was 1.28 mg/kg. The values for mercury content in muscle for the various distances show less dispersion about the overall mean value (Table 2). These mean mercury values in muscle of catfish recorded were higher than the permissible limit of WHO/FAO (2016) and the E.C, 2010 (Table 2). There was significant difference in the mercury content in muscle of catfish caught at the different distance from the point of mining activity ($p = 0.015$).

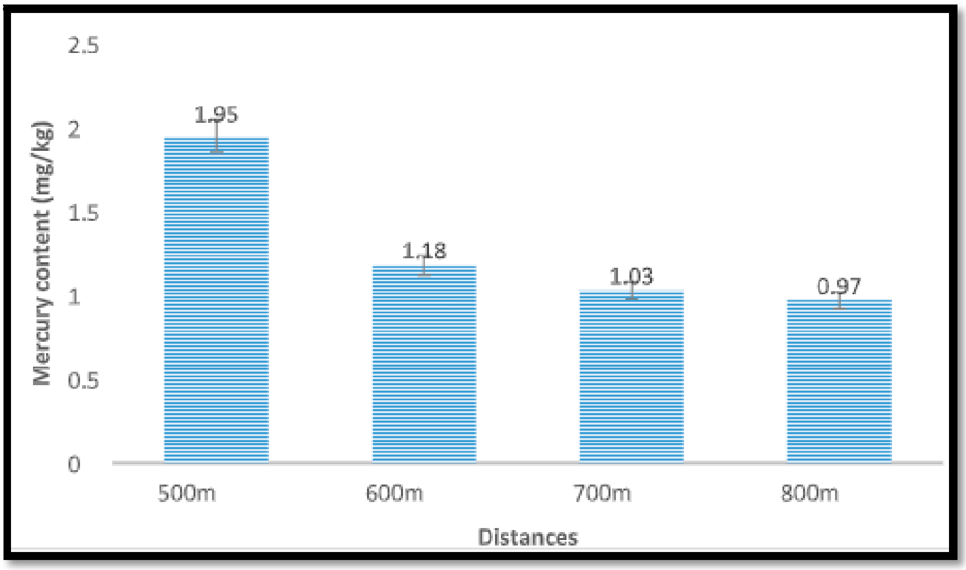

Figure 10: Mercury Content in the Muscle of Catfish Caught at Different Distances Downstream from the Point of Mining Activity on River Offin

3.7. Mercury Content in Gill, Liver and Muscle of Tilapia Samples from River Offin

Mercury content in the liver of Tilapia recorded the highest value of 3.54 mg/kg and the lowest mean mercury value of 1.35 mg/kg recorded for muscle (Fig. 11). Differences were ascertained to be lowest in muscle followed by gill and liver and this was emphasised by variations in standard deviation (Table 3). There was significant difference among the mercury content in the various parts of the Tilapia sample ($p = 0.005$).

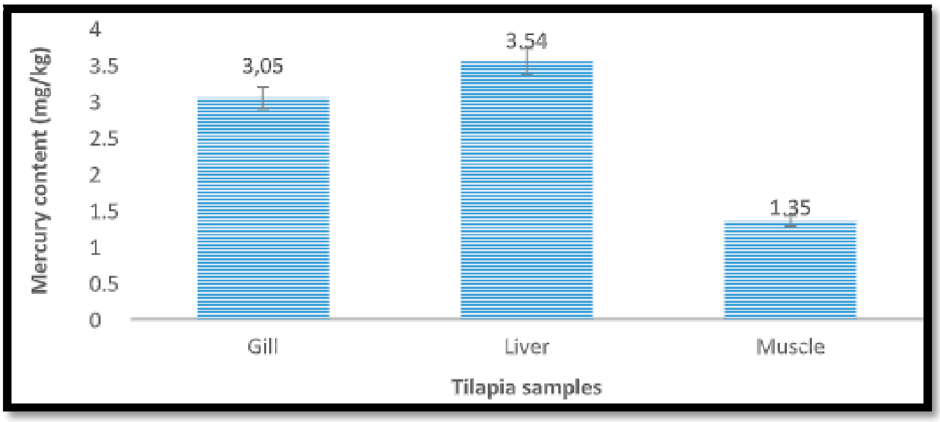

Figure 11: Mercury Content in Tilapia Samples from River Offin

3.8. Mercury Content in Gill, Liver and Muscle of Catfish from River Offin

As depicted in Fig.12, the mercury content in the liver of catfish had the highest value of 4.53 mg/kg followed by gill (2.47 mg/kg) and muscle had the least value of 1.28 mg/kg. These mean mercury values were higher than the permissible values of WHO/FAO (2016), and EC, 2010 (Table 3). There was significant difference among the mercury content of the various parts of the catfish ($p = 0.03$).

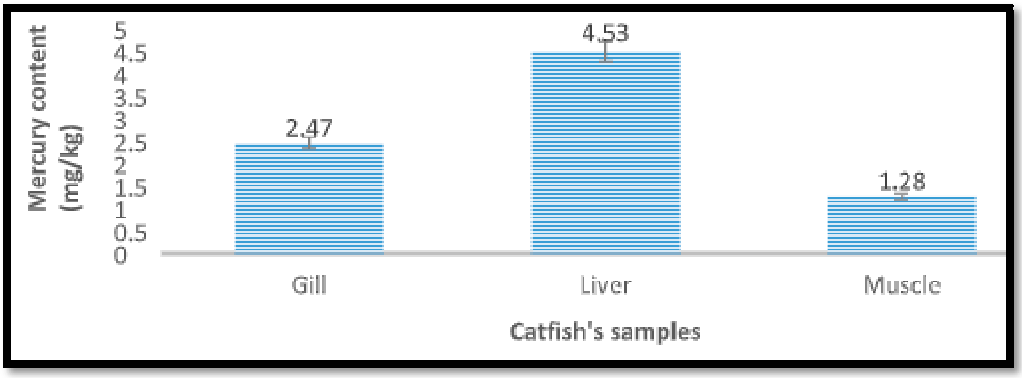

Figure 12: Mercury Content in the Gill, Liver and Muscle of Catfish from River Offin

Tilapia parts	Mean ± SD (mg/kg)	Range (mg/kg)	Overall mean (mg/kg)
Gill	3.04 ± 0.15	1.35 – 3.54	2.64
Liver	3.54 ± 0.25		
Muscle	1.35 ± 0.014		
Catfish parts			
Gill	2.47 ± 0.09	1.28 – 4.51	2.75
Liver	4.53 ± 0.693		
Muscle	1.28 ± 0.014		

	Permissible limit	Reference
Mercury	0.5 mg/kg	WHO/FAO (2016)
	1.0 mg/kg	Puri, P.J et al., 2011
	0.5 mg/kg	EC, 2010

Table 3: Mercury Content in Samples of Tilapia and Catfish from River Offin

3.9. Total Mercury Content in Tilapia and Catfish

The overall mercury concentration in the fish types showed that catfish recorded the higher (2.75 mg/kg) and tilapia recorded the lower value of 2.64 mg/kg as shown in (Table.3). These values were above the WHO/FAO (2016), and the EC, 2010. The difference between the means for overall mercury content in the fish types was not significant (p = 0.32).

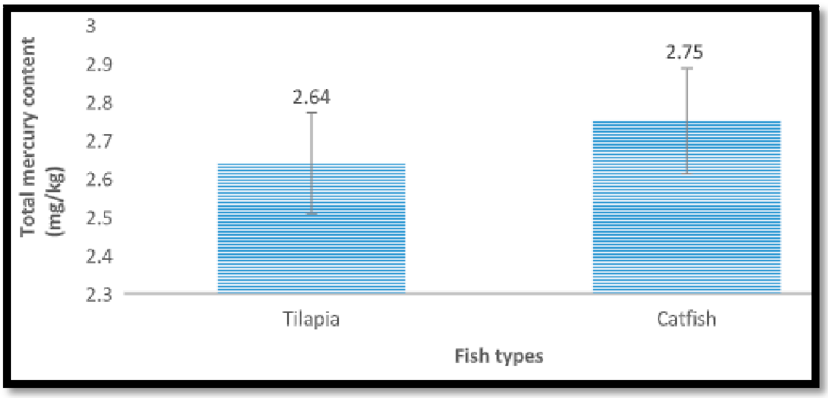

Figure 13: Total Mercury Content in Tilapia and Catfish from River Offin

3.10.Mercury Content in Gill, Liver and Muscle of Tilapia and Catfish

The high toxicity of mercury to humans through industrial waste discharge and activities of "galamsey" operators has made this study significant. This is because fish serves as a source of protein for many Ghanaians. The fish muscle is the part of the fish consumed by humans. The liver is a metabolic organ with the potential of harbouring more mercury. These explains why this organs was evaluated to determine the level of mercury contamination and poisoning in the Dunkwa section of the Offin River. Mercury was detected in both Tilapia and Catfish samples from the river in the study. The concentrations in the gill ranged from: 2.71-3.35 mg/kg (500 m – 800 m), liver: 2.98-4.28 mg/kg (500 m- 800 m) and muscle: 0.86-1.97 mg/kg (500 m – 800 m) for tilapia; for Catfish the concentration in the gills ranged: 1.83-3.17 mg/kg (500 m – 800m), liver: 3.44-5.3 mg/kg (500 m – 800 m) and muscle: 0.97-1.95 mg/kg (500 m – 800 m). Gills and liver recorded higher mercury contamination than muscles (Table 3). The mean concentrations of mercury recorded in the muscles of the two fish species in this study however exceeded the threshold concentration recommended by WHO/FAO (2016) and EC, 2010. Muscles of catfish recorded lower mercury concentration than that of tilapia (Table 3). This observed difference may be due to varying feeding habits [Amanullah, *et al* (2009), Wanganeo, *et al* (2012), Shustov, *et al* (2013)], age, size and length and habitats of the two fish species (Al-shamary, 2013). Mercury concentration in gills reflects mercury levels in the water where the fish lives and liver concentration also represents mercury storage (Culioli *et al.*, 2009). It is in view of this that liver and gills of fish are used more than any other fish organ as indicators for water pollution (Mahboob *et al.*, 2014). This study therefore supports the argument of (Wei *et al.*, 2014) and (Mustafa *et al.*, 2012) who proposed that liver and gills accumulate pollutants at different levels from their environment. Using different fish species, (Kiyono *et al.*, 2013) demonstrated that heavy metals such as mercury accumulate in liver which stores them for detoxification by producing metallothioneins. Between the species, muscles of tilapia recorded the higher mean value of 1.35 mg/kg compared to 1.28 mg/kg in the muscles of catfish. Similar results of a number of fish species were reported by (Mitra, 2013) when muscles were not active tissues in accumulating heavy metals. Presented results in this study show that the mean (2.64 mg/kg) in the tilapia was lower than that found in catfish (2.75 mg/kg) (Table 4). Mercury in fish occurs in the form of methyl mercury. Therefore, mercury concentration in fish is an accurate indicator of exposure to organic or methyl mercury contamination (Rask *et al.*, 2010). In effect, fish diet could be the main source of methyl mercury poisoning to humans. Mercury concentrations found in the fish samples were higher when compared to the permissible limit of WHO/FAO (2016) and the EC, 2010. These results, therefore, support the need for the assessment of human exposure to methyl mercury and its health implications on the populace within the study area. The accumulation of fish mercury concentration decreased with increasing distance from the source of mining activity on the River Offin.

4.Conclusion

Mercury contamination of water and fish of River Offin was investigated in this study. The effect of contamination was studied by the evaluation of mercury accumulation in two species of fish, Tilapia (*Oreochromis niloticus*) and Catfish (*Clarias gariepinus*). Mercury concentrations were compared with quality guideline values which were exceeded for both water and fish samples from the River Offin. For that, mercury concentrations in gill, liver and muscle were determined. High concentrations of mercury were found in the liver and gill of both Tilapia and Catfish, indicating that, the water and fish from the Offin River were contaminated. This could pose health hazards and therefore should not be used for drinking and food, respectively. Since the mercury concentrations in the water and fish samples studied were higher than the maximum permissible levels of WHO and other regulatory bodies; government should enforce the laws to ban the operation of 'galamsey' or institute the use of standard waste treatment plants for the processing of their wastes before they are discharged into the river and the environment.

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6.Conflict Of Interest

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

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