Element Concentrations of Some Aquatic Organisms from Seven Different Aquatic Habitats in Ghana

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ABSTRACT: The study was conducted in six water bodies along the coast of Ghana namely: Pra estuary, Benya lagoon, Fosu lagoon, Nakwa lagoon, Volta estuary and Keta lagoon. The effect of contamination with five essential nutrients known to be harmful to human health when taken in quantities higher than the recommended daily intakes was examined. The results indicate that all the six aquatic ecosystems have higher levels of aluminium and bromine than the recommended daily intakes. However, calcium, copper and vanadium concentrations in the standard water bodies were lower than the recommended daily intakes. The aquatic species commonly exploited as sources of protein, namely *Macrobrachium vollenhovenii, Crassostrea tulipa, Sarotherodon melanotheron and Chonophorus lateristriga* living in these ecosystems had higher levels of contamination with aluminium, bromine and copper than the recommended daily intakes. Vanadium levels in *S. melanotheron* from Benya, Fosu and Keta lagoons as well as in *Crassostrea tulipa* from Nakwa lagoon was higher than the recommended daily intake of 1.8 mg/l. However, calcium concentrations in all the fin-fish and invertebrate organisms from the six aquatic habitats were significantly lower than the recommended daily intake of 1,000 mg/l. It was concluded that the high levels of essential nutrient concentrations (except calcium and, in some few cases, vanadium) could pose health threats to consumers. It is recommended to perform further studies on the other water bodies along Ghana coast of, to assess the biota contamination levels.

Keywords: Lagoon, estuary, aquatic ecosystem, fin-fishes, Gastropods and Crustacean; Recommended Daily Intake (RDI).

INTRODUCTION

The effect of essential nutrients on aquatic organisms is of great concern to consumers of these species notably fish and shellfishes. The source of the essential nutrients found in these organisms is the water body they inhabit.

In Ghana, most of the coastal water bodies, estuaries and lagoons, encountered considerable human activities that could introduce essential nutrients as contaminants. Some of these water bodies are the Pra estuary at Shama; Benya lagoon at Elmina; Fosu lagoon in Cape Coast; Nakwa lagoon, at Nakwa; Volta estuary at Anyanui and the Keta lagoon at Keta. However, the levels of essential nutrients in these water bodies and in the fish species that inhabit them are not known.

The amount of minerals present in the body in human, and their metabolic roles, varies considerably. Minerals provide structure to bones and teeth and participate in energy production, the building of protein, blood formation, and several other metabolic processes. Minerals are categorized into major and trace minerals, depending on the amount needed per day. Major minerals are those that are required in the amounts of 100 mg (milligrams) or more, while trace minerals are required in amounts less than 100 mg per day. The terms major and trace, however, do not reflect the importance of a mineral in maintaining health, as a deficiency of either can be harmful. (ADA 2002 and USDA 2002).

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It is generally recommended that people eat a well-balanced diet to meet their mineral requirements, while avoiding deficiencies and chemical excesses or imbalances. However, supplements may be useful to meet dietary requirements.

Although trace elements play key roles in a variety of processes necessary for life, the occurrence of overt simple or uncomplicated deficiencies of any of the trace elements is relatively uncommon. However, there are situations that may make a trace element nutritionally significant. These include:

- Inborn error of metabolism that affects absorption, retention, or excretion
- Alterations in metabolism and/or biochemistry as a secondary consequence to malnutrition, disease, injury, or stress
- Marginal deficiencies (slight deviation from an optimal intake of an essential nutrient) induced by various dietary manipulations or by direct or indirect interaction with another nutrient or drug.
- The enhanced requirement for a trace element caused by a sudden or severe change in the system requiring that element.

The insufficient intake of a specific trace element becomes obvious only when the body is stressed in some way that enhances the need, or interferes with the utilization, of that element. (Nielsen, 1993).

Trace minerals can be toxic at higher intakes, especially those minerals whose absorption is not regulated in the body (e.g., selenium and iodine). Thus, it is important not to habitually exceed the recommended intake levels. Although toxicity from dietary sources is rare, certain genetic disorders can make people vulnerable to overloads from food or supplements. One such disorder, hereditary hemochromatosis, is characterized by iron deposition in the liver and other tissues due to increased intestinal iron absorption over many years. Chronic exposure to trace minerals through cooking or storage containers can result in overloads of iron, zinc, and copper (Wardlaw, 1999, ADA 2002 and USDA, 2002). In Ghana routine check of the levels of these elements is lacking, as regulation of essential elements in food especially, in fish is completely not in existence. The influx of environmental pollution activities such as mining around our water bodies calls for concern. In view of the above mentioned points it serves it right for this research to be undertaken to give the general populace background information about the subject matter.

Two finfish and two invertebrate: gastropods and crustacean species commonly exploited as sources of protein for the coastal consumers and, to a less extent, others are the black-chin tilapia (*Sarotherodon melanotheron* Cichiidae) the gobies (*Chonophorus lateristriga*. Gobiidae); lobster/ shrimps (*Macrobrachium vollenhovenii* Palaemonidae) and oysters (*Crassostrea tulipa* Ostreidae) ((Hegner and Engemann, 1969; Dankwa *et al*., 1999). The objective of this research was to determine the essential nutrients levels in the selected fish species and water samples from the same water body habitat and their interrelationship with physiochemical factors.

MATERIALS AND METHOD

Study Areas

Pra Estuary

The Pra Estuary is the easternmost and the largest of the three principal rivers that drain into the area south of the Volta divide (Figure 1). Rising south of the Kwahu Plateau and flowing southward, the Pra enters the Gulf of Guinea east of Takoradi. The river rises in the Kwahu Plateau near Mpraeso and flows 240 km southward to enter the Gulf of Guinea at Shama.

The area of study is located at 5oN, 1o35'-1o40'w. The area happens to be the second largest discharge of fresh water into the gulf of Guinea from Ghana. The flow of water has a double maximum as a result of the rainfall pattern at the catchments area. The bay curves an average of 2.5 km2 with average depth of 1.5 m; hence volume of system is 3.75 x 106 m3.

Benya Lagoon is one of the many lagoons along the Gulf of Guinea in the ancient city of Elmina. It is about ca. 62 m and located in Ghana N 5° 5' 0'' W 1° 22' 0'' 5.08333/-1.36667, GeoNameId: 2303164 and hydrographic (FAD, 1990).

Fosu Lagoon

Fosu Lagoon is one of the many lagoons along the Gulf of Guinea in the ancient city of Cape Coast, Ghana in West Africa. Cape Coast lies along the Atlantic Ocean and is on the longitude 1° 15′West of the Greenwich Meridian and the latitude 5° 5′ North of the Equator .

Nakwa Lagoon is also located in Ghana - 5° 12'N; 0° 55'W and found in central region close to saltpong beach (FAD, 1990).

Volta Estuary is located in Ghana. Ghana's Volta Reservoir (discharge through Akosombo Dam). Previously began at now-flooded-junction of White Volta and Black Volta Rivers. Altitude is 14.3 m (Akosombo taihace) with total length of 86 km (from Kpong dam to sea). Drainage area is about 390 000 km^2 with surface area of 44 km^2 discharges into the Atlantic Ocean - 5° 46'N; 0° 40'E. Volume of discharge at mouth: 1 150 m3/sec (highly regulated by Akosombo Dam) with Keta and Songaw Lagoon Complex near mouth. Upper reach now permanently flooded by Volta and Kpong Reservoirs (FAD, 1990).

Keta Lagoon is located in Ghana in the city of Keta at the Volta Region - 5° 55'N; 0° 56'W**.** It has a Surface area of 330 km^2 with maximum length of 29 km and maximum width of 13 km. the major inflowing river outflow from Avu Lagoon and outflow short channel to Atlantic Ocean. It catchment area is about 3 600 km^2 (FAD, 1990).

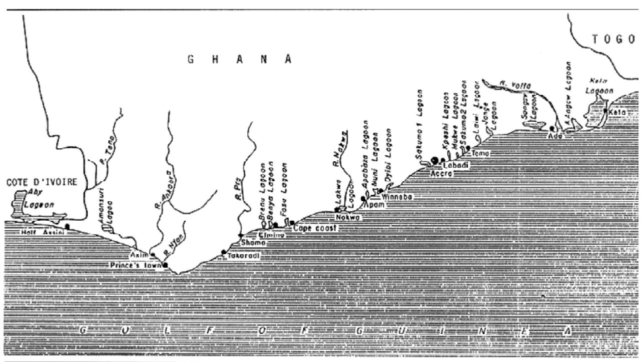

Figure 1: The Principal Lagoons Of Ghana, Souce: Fad, 1990

METHODOLOGY

Collection of Samples

Determination of Physico-Chemical Factors

The physico-chemical factors determined in the water bodies mentioned above were pH, Dissolved Oxygen content, Refractive index, Salinity, and Turbidity.

(a) Dissolved oxygen content was determined with oxygen meter, by inserting the probe into the water body at each of the two sites and the value read on the scale. This was repeated and the average recorded.

(b) pH was measured using a pH meter: the pH was determined and averaged after the collection of the samples immediately. The water collected from each of the two stations was put into a stoppered plastic bottle (500 ml capacity) and sent to the laboratory for further analysis.

(c) Refractive indices were measured with a refractometer. A sample of water was collected from each of the two sites in the water bodies and sent to the laboratory. The refractive indices were measured in duplicate and the average recorded.

(d) Salinity was measured using a salinity meter. At each of the two stations in the water bodies, a sample of water was collected with a dropper and placed on the window of the salinity meter, and the window was closed and held tightly. The mouth piece was pointed towards a source of light (the sun), and viewed through the eye piece. The salinity value ($\%_0$) was then read on the salinity scale and recorded. This was repeated and averaged.

(e) Turbidity was determined using a turbidimeter. The probe of the turbidimeter was inserted into a sample of water collected from each of the two stations in the water bodies, and the values averaged and recorded in parts per million (ppm).

Tilapia and Goby Samples

Approximately 1kg of each species (*Sarotherodon melanotheron* and *Chonophorus lateristriga*) was collected from each habitat, where they occurred, using cast nets. The tilapia specimens were scaled and gutted but the goby was not. (This is the same way the respective fish species are treated before they are cooked and eaten). Each species was dried in an oven at 40°C to a constant weight. Approximately 500g of each was weighed and stored in well-labeled white polyethylene bags and later sent to the Chemistry Department of the Ghana Atomic Energy Commission (GAEC) in Accra, for analysis.

Lobster/shrimps and Oyster Samples

About 1 kg of *Macrobrachium vollenhovenii* was obtained from fishermen operating in the habitat where they had been caught with special traps. The exoskeleton, the head, appendages and tail fan were removed. The meat was then dried in an oven at 40 °C until a constant weight was obtained. Approximately 500g of the dry meat was weighed, kept in labeled white polyethylene bags and sent to GAEC, Accra, for analysis.

Samples of oysters (*Crassostrea tulipa*) were collected from the two stations in each habitat where available. They were washed clean and shucked. Approximately 1 kg (1,000 g) was dried in an oven at 40 °C to a constant weight. About 500 g of the dry meat was similarly placed in a well – labeled white polyethylene bag and sent to GAEC for analysis.

Water Samples

Two water samples were collected, from the two sites in each of the habitats, into 1-litre polyethylene bottles that had been washed with acetone to remove any grease, then with dilute nitric acid (HNO_3) to dissolve any metal and later rinsed with distilled water. Each bottle was labeled and kept in a fridge; and later (about 8 hour's interval) sent to GAEC, Accra for analysis.

Sample Preparation

Finfish and Invertebrate Samples

The determination of essential nutrients in the fish samples was done by use of Neutron Activation Analysis (NAA) using thermal neutron from a low flux Am-Be radioisotope, as outlined by Tolgyessy and Kyrs (1989); Nyarko *et al.* (2004) and Adomako *et al.* (2008).

Water Samples

Exactly 0.5 ml of each water sample was pipetted (using calibrated Eppendorf tip ejector pipette) into clean pre-weighed 1.5 ml rabbit capsule (sample vials) and reweighed and heat-sealed using soldering rod. Four of these sample vials were also placed into a 7.0 ml volume rabbit capsule and heat-sealed. Three replicates of each sample were prepared.

Sample Analysis

The determination of the trace elements was done by use of Neutron Activation Analysis (NAA) using thermal neutron from a low flux Am-Be radioisotope. Theoretically, neutron activation analysis is based on the measurement of characteristic gamma-rays from a radionuclide formed from the specific neutron reaction which can be used to measure the amount of element, using the usual radioactive decay law (Tolgyessy and Kyrs 1989, Adomako *et al.* 2008).

Irradiation Source

The irradiation source is a 20 curie Am-Be radioactive neutron source. The thermal neutron flux at the irradiation site is 1.124 x 105 ns-1cm^{-2}. (Nyarko *et al.* 2004).

Sample Irradiation

Each of the samples was sent by the pneumatic transfer system into the Am-Be source for irradiation for one hour and left overnight for cooling or decaying process to take place (Nyarko *et al.* 2004). The samples were then counted the next day for 600 and 60 seconds for medium and short lived (table 1) and its intensities saved for further analysis.

Data Processing

Counting of signals was done by an ENERTEC High Germanium (HPGe) detector of 3000 (+ve) bias and a resolution of 2.55keV for 1332KeV photo peak of Co-60. A Microsoft window based software MAESTRO was used for spectrum analysis ie. (Qualitative and quantitative analysis) (Adomako *et al.* 2008, Yoh *et al.* 2003).

DATA ANALYSIS

Data obtained were subjected to the appropriate statistics and compared with the World Health Organization (WHO) standards for the essential nutrients study. SPSS 8.0, was used to calculate the mean and standard deviation of the values.

RESULTS

Physico-chemical Factors of the Water Bodies

Tables 2a and 2b indicate summaries of the physicochemical parameters for the rainy and dry seasons, respectively. Dissolved oxygen content and salinity values in the various water bodies did not show significant differences in the two seasons, with the values in the rainy season being slightly lower than those in the dry season. There

Table 1
The Irradiation Scheme Adapted for the Measured Radionuclide's in Aquatic Organism and Water Samples

Product radionuclide (n, γ)	*Type and half life of (n,γ) product radionuclide*	*Neutron flux time ×10^11 ns^-1 cm^-2*	*Irradiation time Ti*	*Decay time Rd*	*Counting Tc / s*
^{28}Al, ^{80}Br	Short Lived	1	2 mins _	≤60 s	300
^{52}V	1m _ T1=2 < 20 m				

were significant differences in the pH between the two seasons. The dying season had pH ranging 7.12 to 8.80. In the case of the wet season pH reduced to 6.15 to 8.15 due to dilution. There were no significant refractive index values of the water bodies. However, turbidity values were slightly higher in the rainy season. Hence the results obtained for the rainy and dry seasons were combined and the averages computed.

Concentration of Essential Nutrients

The concentration of essential nutrients and fish biota commonly consumed in the local communities are shown in Table 3. The essential nutrients studied were aluminium (Al), bromine (Br), calcium (Ca), copper (Cu) and vanadium (V).

Aluminium Concentration

Aluminium concentration in the six aquatic ecosystems studied was higher than the recommended daily intake of 0.2 mg/L. The concentration ranged from 6.34 ± 0.23 mg/L in the Volta estuary at Anyanui to 10.37 ± 0.49 mg/L in Fosu lagoon. Benya lagoon had the second highest concentration of 9.48 ± 0.37 mg/l followed by Keta lagoon which had 9.34 ± 0.58 mg/L, Pra estuary recording 7.96 ± 0.24 mg/L and the least at Nakwa lagoon of concentration 7.87 ± 0.71 mg/L. The differences were not significant.

The oysters (*Crassostrea tulipa*) from the Benya lagoon had significantly (P < 0.05) highest aluminium contamination of 554.92 ± 1.84 mg/L, followed by *C. tulipa* from Nakwa lagoon (459.25 ± 1.51 mg/L). The least aluminium concentration in oysters was from the Volta estuary (340.67 ± 1.30 mg/L).

Aluminium content of the tilapias (*Sarotherodon melanotheron*) in Keta lagoon was significantly (P < 0.05) highest (306.61 ± 1.28 mg/L), while those from the Pra estuary had the least of 2.83 ± 1.03 mg/L. *S. melanotheron* from Fosu lagoon recorded the second highest of 304.59± 40.27 mg/L aluminium content, while the cichlids from Benya lagoon contained 241.94 ± 1.35 mg/L and those from Nakwa lagoon had 240.76 ± 1.34 mg/L.

Aluminium concentration in the prawn (*Macrobrachium vollenhovenii*) from the Pra estuary was 153.36 ± 0.83 mg/L, while gobies (*Chonophorus lateristriga*) from the Keta lagoon had 233.49 ± 1.18 mg/L).

Bromine Concentration

Bromine concentration in the water bodies exceeded the recommended daily intake of 1-3 mg/L, and was significantly (P<0.05) highest in the Volta estuary (200.0 ± 28.00 mg/L) and least in the Fosu lagoon (11.54± 1.53 mg/L). Benya lagoon had 98.99± 2.8 mg/L. Nakwa lagoon contained 28.43± 1.42 mg/L, followed by Keta lagoon with 28.08± 1.84 mg/L and Pra estuary (16.47±1.45 mg/L) in descending order.

Crassostrea tulipa from the Benya lagoon had significantly (P < 0.05) highest bromine concentration of 149.02 ± 5.72 mg/L followed by oysters from Nakwa lagoon (100.08 ± 4.26 mg/L). Those from Volta estuary recorded the least (3.37 ± 0.06 mg/L).

In the cichlids, bromine content was significantly (P <0.05) highest for the Benya lagoon population (81.97 ± 4.71 mg/L) and least for the Pra estuary tilapias (8.09 ± 1.40 mg/L. The Keta lagoon *S. melanotheron* contained 44.77 ± 4.45 mg/L, Nakwa lagoon recorded 33.96± 3.29 mg/l, while the Fosu lagoon tilapias had the lowest value of 17.91 ± 2.09 mg/L of bromine content. *Macrobrachium vollenhovenii* from the Pra estuary had 54.58 ± 3.16 mg/L bromine. *Chonophorus lateristriga* from the Keta lagoon contained 2.72 ± 1.31 mg/L bromine.

Calcium Concentration

Generally, calcium concentrations in the estuarine ecosystems were significantly (P < 0.05) higher in water (200.0± 30.00mg/L) than in the lagoons waters (0.004 ± 0.00mg/L - 3.86 ± 0.37 mg/L). The values ranged from 0.004 mg/L in the Keta lagoon to 3.86 ± 0.37 mg/L in the Nakwa lagoon. In the case of organisms, the situation was opposite where lagoons recorded higher concentration (3.03 ± 0.08 to 12.71 ± 0.14) of Ca than estuarine ecosystem (2.42±0.05 to 8.55±0.11 mg/L). Benya lagoon had greater calcium concentration (1.56 ± 0.05 mg/L) than Fosu lagoon (0.04 ± 0.01 mg/L) table 3.

Oysters from Benya lagoon contained 4.48 ± 0.01 mg/L of calcium, while those from the Volta estuary had 3.37n ± 0.06 mg/L.

In the cichlids, the value was highest for the Fosu lagoon animals (12.71±0.14mg/L), Pra estuary (8.55±11mg/L), Nakwa (8.49 ± 0.01mg/L) and Keta lagoon tilapias had 8.41± mg/L. These values were not significant. Calcium concentration in the prawn from Pra estuary was 2.42 ± 0.05 mg/L, while the concentration in the guppy from Keta lagoon was 5.24 ± 0.04 mg/L of calcium.

However, concentrations of calcium in the six ecosystems and in their fish biota were much lower than the recommended daily intake of 1000 mg/L.

Copper Concentration

Concentrations of copper in the water bodies were rather low, ranging from 0.002 mg/L in Benya lagoon to 0.008 mg/L in the Pra estuary. Nakwa lagoon had 0.004 mg/L, Volta estuary (0.005mg/L), Fosu lagoon (0.006 mg/L) and Keta lagoon had 0.007 m. Copper content was significantly highest in the prawn from Pra estuary (204.41±13.93 mg/L).

The concentration of copper in oysters from the Volta estuary (49.46±9.42 mg/L) was greater than that of oysters from Benya lagoon (43.86±6.57 mg/L) while oysters from Nakwa lagoon recorded the least of 29.32±4.39 mg /L.

In the tilapia populations, the copper content ranged from 3.53 ± 0.19 mg/L in the Benya lagoon to (71.71 ±10. 76 mg/L) in the Pra estuary. Other values in descending order were 12.97 ± 1.19 mg/L in the Keta lagoon, 10.87 ± 1.16 mg/L in the Fosu lagoon and 9.35 ± 1.14 in the Nakwa lagoon. The value in the Pra estuary was significantly ($P < 0.05$) higher than those for the other habitats.

The goby from the Keta lagoon had 4.37 ± 0.06 mg/L of copper. The concentrations of copper in the six water bodies were lower than the recommended daily intake of 2.0 mg/L. However, copper contents of the fish species were much higher than the recommended daily intake.

Vanadium Concentration

Vanadium concentration in the water bodies was lower than the recommended daily intake 0f 1.8 mg/L, and ranged from 0.01mg/L each in Fosu and Nakwa lagoons to 0.09 ± 0.03 mg/L in the Volta estuary. The Pra estuary had 0.07 ± 0.04 mg/L, while Keta lagoon contained 0.02 ± 0.02 mg/L. Vanadium content in oysters from Nakwa (2.13 ± 0.33 mg/L) was slightly higher than that of oysters from the Benya lagoon (1.40 ± 0.22 mg/L); Volta oysters had 1.94 ± 0.21 mg/L vanadium.

The vanadium concentration values in the cichlid populations ranged from 1.36 ± 0.15 mg/L in the Pra estuary to 10.68 ± 0.31 mg/L in the Fosu lagoon. The contents in descending order for the other water bodies were 5.20 ± 0.27 mg/L for Keta lagoon, 3.96 ± 0.29 mg/L for the Nakwa lagoon and 3.25 ± 0.34 mg/L for Benya lagoon.

Goby from Keta lagoon had 1.34 ± 0.19 mg/L vanadium content, while prawns from the Pra estuary recorded 0.18 ± 0.02 mg/L vanadium.

DISCUSSION

The lack of significant difference in the physico-chemical parameters studied excerpt pH suggests they may not have marked influence on the presence of the essential nutrients and their subsequent absorption by the animal biota in the various water bodies. This justifies the combination of the data in the two seasons (rainy and dry). The huge significant between the pH will be basically due to the drying effect which will lead to basic in nature. In the wet season dilution takes place and however, alkalinity reduces leading to lower pH recorded. The nutrients studied bioaccumulate in fish species through the processes of feeding and respiration.

The concentration of aluminium in the water bodies, as well as in the aquatic animals, far exceeds the recommended daily intake of 0.2 mg/L for that nutrient. Consequently, the local population should be warned to avoid eating these fishes (tilapia, oyster, prawn and goby) from all the six aquatic habitats studied.

Table 2 a)
Summary of Physicochemical Factors Studied in the Rainy Season in the Various Coastal Water Bodies

Physicochemical factors	*Pra estuary*	*Benya lagoon*	*Fosu lagoon*	*Nakwa lagoon*	*Volta estuary*	*Keta lagoon*
Dissolved oxygen (g/l)						
Minimum	6.8	6.2	6.3	6.2	5.0	7.0
Maximum	8.7	8.2	8.7	8.6	8.1	7.9
Average	7.79	7.28	7.38	7.38	6.75	7.50
pH						
Minimum	5.01	7.03	7.24	7.46	6.94	7.62
Maximum	6.77	7.92	8.92	7.65	7.57	7.85
Average	6.15	7.54	8.15	7.54	7.25	7.74
Refractive index						
Minimum	1.333	1.338	1.334	1.336	1.333	1.337
Maximum	1.333	1.339	1.337	1.339	1.335	1.337
Average	1.333	1.338	1.335	1.338	1.334	1.337
Salinity (%o)						
Minimum	0.0	22.0	2.0	15.0	8.0	20.0
Maximum	0.0	31.0	20.0	36.5	13.0	24.0
Average	0.0	26.8	9.3	27.0	10.5	21.0
Turbidity(ppm)						
Minimum	24.0	10.0	35.0	10.0	11.0	9.0
Maximum	80.0	87.6	52.0	48.0	35.0	35.6
Average	52.0	48.8	43.8	29.0	23.0	22.3

Table 2 b
Summary of Physicochemical Factors Studied in the Dry Season in the Various Coastal Water Bodies

Physicochemical factors	*Pra estuary*	*Benya lagoon*	*Fosu lagoon*	*Nakwa lagoon*	*Volta estuary*	*Keta lagoon*
Dissolved oxygen (g/l)						
Minimum	5.6	4.5	1.9	5.5	4.5	6.9
Maximum	9.0	6.7	7.9	7.5	6.8	7.9
Average	8.9	6.3	7.5	7.14	6.2	7.6
pH						
Minimum	6.04	6.14	4.12	4.40	6.78	6.98
Maximum	9.60	8.50	9.79	10.20	9.62	10.32
Average	7.67	7.33	7.12	8.37	7.93	8.80
Refractive index						
Minimum	1.332	1.333	1.332	1.337	1.334	1.335
Maximum	1.332	1.339	1.339	1.339	1.335	1.336
Average	1.332	1.336	1.335	1.338	1.334	1.336
Salinity (%o)						
Minimum	0.1	23.4	0.2	10.5	1.0	1.8
Maximum	1.0	33.8	1.0	27.0	2.0	2.0
Average	0.3	27.7	0.5	25.5	1.5	2.0
Turbidity (ppm)						
Minimum	20.0	4.0	31.0	9.0	9.0	7.0
Maximum	64.0	50.0	90.0	46	62.0	17.0
Average	36.5	26.0	66.3	31.8	29.8	10.3

Table 3
Mean Concentration of Essential Nutrients in Some Coastal Water Bodies of Ghana (2008-2009)

Water body / Fish	*Essential nutrient concentrations (mg/L)*				
	Aluminium (Al)	*Bromine (Br)*	*Calcium (Ca)*	*Copper (Cu)*	*Vanadium (V)*
Pra Estuary					
- Prawn	153.36 ± 0.83	54.58 ± 3.16	2.42 ± 0.05	204.41 ± 13.93	0.18 ± 0.02
- Tilapia	2.83 ± 1.03	8.09 ± 1.40	8.55 ± 0.11	71.71 ± 10.76	1.36 ± 0.15
- Water	7.96 ± 0.24	16.47 ± 1.45	200.0 ± 30.00	0.08 ± 0.00	0.07 ± 0.04
Benya Lagoon					
- Oyster	554.92 ± 1.84	149.02 ± 5.72	4.48 ± 0.10	43.86 ± 6.57	1.40 ± 0.22
- Tilapia	241.94 ± 1.35	81.97 ± 4.71	12.45 ± 0.14	3.53 ± 0.19	3.25 ± 0.34
- Water	9.48 ± 0.37	98.99 ± 2.8	1.56 ± 0.05	0.002 ± 0.00	×
Fosu Lagoon					
- Tilapia	304.59 ± 40.27	17.91 ± 2.09	12.71 ± 0.14	10.87 ± 1.16	10.68 ± 0.31
-Water	10.37 ± 0.49	11.54 ± 1.53	0.04 ± 0.01	0.006 ± 0.00	0.01 ± 00.00
Nakwa Lagoon					
- Oyster	459.25 ± 1.51	100.08 ± 4.26	3.03 ± 0.08	29.32 ± 4.39	2.13 ± 0.33
- Tilapia	240.76 ± 1.34	33.96 ± 3.29	8.49 ± 0.01	9.35 ± 1.14	3.96 ± 0.29
- Water	7.87 ± 0.71	28.43 ± 1.42	3.86 ± 0.37	0.004 ± 0.00	0.01 ± 00.00
Volta Estuary					
- Oyster	340.67 ± 1.30	3.37 ± 0.06	3.37 ± 0.06	49.46 ± 9.42	1.94 ± 0.21
-Water	6.34 ± 0.23	200.0 ± 28.00	200.0 ± 28.00	0.005 ± 0.00	0.09 ± 0.03
Keta Lagoon					
- Goby	233.49 ± 1.18	2.72 ± 1.31	5.24 ± 0.04	4.37 ± 0.06	1.34 ± 0.19
- Tilapia	306.61 ± 1.28	44.77 ± 4.45	8.41 ± 0.11	12.97 ± 1.19	5.20 ± 0.27
- Water	9.39 ± 0.58	28.08 ± 1.84	0.004 ± 0.00	0.007 ± 0.00	0.02 ± 0.02
*RDI	0.2 mg/L	1-3 mg/L	1000 mg/L	2 mg/L	1.8 mg/L

* RDI means Recommended Daily Intake.

× Means not analyzed

Aluminium is reported to be toxic in its trivalent form, which is most soluble in water. It may cause pathogenic disorders principally neurodegenerative disorders such as Parkinson's, Alzheimer's and Lou Gehrig's diseases (Lima *et al.* 2007). The higher aluminium concentration in the aquatic animals than in the water bodies could be due to bioaccumulation of this nutrient by the fish species as the animals feed and respire.

Similarly, the higher bromine concentration of the water bodies and their fish biota studied, compared to the recommended daily intake of 1-3 mg/l (Acu, 2010) calls for caution when dealing with fishes (both fin and shell fishes) from these habitats. According to this source, higher intake of bromine has several negative effects including drowsiness, fatigue, nausea, vomiting, skin rash, acne, blurred vision, dizziness, hallucinations, increased thirst, hunger and urination; pancreatitis, muscle weakness, poor memory, and so on, in children.

Bromine is generally a recommended nutritional supplementation against stomach problems and promotes better tolerance to the above disorders. Bromine, as in potassium bromide (KBr) and sodium bromide (NaBr) form, has anti-seizure properties but the excess must be avoided, since it is harmful to human health.

The rather low levels of calcium concentration in both the water bodies and their inhabitants (fin- and shellfish populations), fall far below the recommended daily intake of 1,000 mg/L and hence must be ignored for now. Calcium is known for its important role in the development of bones and teeth in humans, especially in children and pregnant women. The low concentrations in the fish samples suggest these fish species cannot be relied on as sources of calcium, implying that the inhabitants of the localities should be advised to look elsewhere for dietary calcium supplement rather than depending on fish from these water bodies. However, in an earlier research conducted on oysters, *Crassostrea tulipa*, from the Benya lagoon and the Pra estuary (Obodai, 1990; Yankson *et al.*, 1994), it was found that the calcium contents were much higher than the recommended daily intake thus making these sources recommend oysters as a source of dietary calcium.

The high copper concentrations observed in the animals studied, compared to the low recommended daily intake of 2 mg/L, raise serious concerns which must be addressed. Copper contents of the animals far exceed those of the water bodies, because fin- and shell fishes (especially the latter) are effective bioaccumulators. Copper is an essential nutrient that is known to have toxic effect when taken in quantities greater than the recommended daily intake, causing grastrointestinal disturbance, inducing nausea and vomiting on short- term exposure; but on long- term exposure to higher concentrations of copper, it could lead to liver or kidney damage (Lima *et al.* 2007). According to this source, people with Wilson's disease may be more sensitive to the effect of copper contamination than healthy people. For now, people could be advised to avoid eating fishes from these habitats to avoid the negative effects of copper referred to above.

Vanadium contents of the water bodies were lower than the concentration in the aquatic animals studied due to bioaccumulation of this essential nutrient. However, most of the fishes studied, for instance, prawn and tilapia from the Pra estuary, oysters from Benya lagoon and guppy from Keta lagoon had lower vanadium concentrations than the recommended daily intake of 1.8 mg/l; but oysters from Nakwa lagoon and Volta estuary as well as tilapias from Benya, Fosu, Nakwa and Keta lagoons must be avoided for their higher vanadium contents than the recommended daily intake. Vanadium, in the peroxide form (V_2O_5), is more toxic than the elemental form. The intake of vanadium is through foodstuffs such as buckwheat, soya beans, olive oil, sunflower oil, apples and eggs. When taken in levels higher than the recommended daily intake, it results in irritation of lungs, throat, eyes and nasal cavities. Other effects include cardiac and vascular disease, inflammation of stomach and intestines, damage to the nervous system, bleeding and throat pains; weakening, sickness and headaches, dizziness and behavioral changes. It can also harm the male reproductive systems (Lenntech, 2009).

Contamination Degree Calculations as Evidence of Anthropogenic Origin of the Heavy Metals in Water bodies

In order to differentiate the fraction of the element concentration originating from natural sedimentary sources from the anthropogenic fraction, normalizing tools are needed. The contamination degree (cd), which is the index of contamination formula for the water sample, was calculated using Equation. 1.

cd = ΣCfi, ...Equ. 1. where cd is the contamination degree, $Cfi = (Cn/Cb)-1$, where Cfi is the contamination factor for the i-th element, Cn is the analytical value of the i-th element, Cb is the upper permissible limit of element in water. In this study guideline values for dietary intake stated above was selected for the calculation of the contamination degree of the water samples (Teng *et al.* 2004).

The calculated contaminated degree values of the studied heavy metals for the various anthropogenic suspected sites are 251.05 (Al), 1911.55 (Br), 2021.32 (Ca), -5.48 (Cu) and -56.85 (V). The contamination degree calculation indicates, Al, Br and Ca are highly polluted whiles Cu and V recorded values less than 1 signifying practically less pollution of the metals in the lagoons in the sampling sites.

CONCLUSION

The hydrographic factors studied did not vary significantly among the two seasons.

Levels of all essential nutrients in the water bodies as well as the biota were higher than the recommended daily intake, except for calcium whose levels in the aquatic ecosystems and fauna were much lower than the recommend daily intake.

Vanadium concentrations were lower in the ecosystems than in the fauna. However, the contents of vanadium in some of the organisms studied (oysters or tilapias) in Fosu, Benya, Nakwa and Keta lagoons were much higher than the recommended daily intake. Contamination degree analysis revealed that Al, Br and Cu are highly polluted whiles Ca and V are not. The implications of the results have been discussed. It is recommended that further studies be carried out into the exact site (location) in the fish where the nutrients bioaccumulate and also the essential nutrients and heavy metal contaminations of other coastal waters of Ghana.

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