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Food Science & Nutrition Technology
ISSN: 2574-2701

Study of Presence of Selected Heavy Metals in the Fish of Lake Victoria as a Predisposing Factor to Lifestyle Diseases in the 21st Century

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Research Article
Volume 6 Issue 3
Received Date: April 08, 2021
Published Date: May 27, 2021
DOI: 10.23880/fsnt-16000271

Abstract

Journal of contemporary issues facing the 21st century is heavy metals poisoning, especially in foods consumed, and resulting into lifestyle diseases such as cancers. “What we eat, in what quantity, and how that food is produced, can be the difference between life and death.” Fish in Lake Victoria form the major source of protein among the majority of dwellers around this Lake. “In many places fish become so contaminated by the filth on which they feed as to be a cause of disease. This is especially the case where the fish come in contact with the sewage of large cities. When used as food they bring disease and death on those who do not suspect the danger.

There are a majority of agricultural and industrial activities taking place at the lake side, and along the river banks leading into the lake resulting in contamination of aquatic animals, fish inclusive. These toxins can be transferred into the human body through consumption of the affected fish or aquatic animals in these water bodies.

This research uses Atomic Absorption Spectroscopy to determine the presence and the levels of the Pb, and Cd in fish of Lake Victoria. ANOVA F-test was conducted to determine whether the distribution of selected heavy metals in separate fish tissues was dependent on the species of fish. The analysis was also used determine whether the concentrations of the heavy metals were dependent on fishing grounds. The F-test was conducted at (α=0.05) 95% confidence interval. Using the mean concentrations of the selected heavy metals in vivo, graphical analysis of the data was obtained using Microsoft Excel sheet (Version 2013) and comparatively determined using bar graphs. This research is important as it will help various locals on the choice of healthy meals by informing them whether the most commonly preferred fish dish is still healthy. It will also help various researchers in finding the solution to various lifestyle diseases and infections associated with various meals taken in a lifetime.

Keywords: Heavy Metals; Fish of Lake Victoria; Lifestyle Diseases

Introduction

Research Background

Scientists, medical practitioners have long delved into a study of the relationship between what we eat, and human health. This has also led into a series of studies relating health not only to what people eat, but also to where the food eaten comes from and under what conditions it is acquired.

As stated in a declaration by various American Scientists entitled A Declaration for Interdependence, 2008 *“what we eat, in what quantity, and how that food is produced, can be the difference between life and death. It can maintain our health or ruin it* [1-5].

For centuries, fish has been a major source of protein to those dwelling along the rivers and lakes; and the oceans and seas. Fish in Lake Victoria form the major source of protein among the majority of dwellers around this Lake. There exists a variety of fresh water fish in the Lake Victoria, upon which a majority of the residents depend as a source of food on a daily basis; ranging from *Oreochromis niloticus* (tilapia), *Lates Niloticus* (Nile Perch), sardines. However, the most commonly preferred fish varieties are *Oreochromis niloticus* (Tilapia) and Lates Niloticus (Niles Perch). Economically, the *Lates Niloticus* (Nile Perch) variety is preferred due to its size and weight. A full grown *Lates Niloticus* (Nile Perch) can grow up to 1.2 meters long with a mass of up to 89kg [6]. However, tilapia is loved most by small scale consumers due to its testier nature compared to its counterpart-the *Lates Niloticus* (Nile Perch) [7]. The tilapia is also loved since it does not have a strong and repelling smell that the *Lates Niloticus* (Nile Perch) has when cooked.

These fish varieties (Tilapia and *Lates Niloticus* (Nile Perch) have formed the major percentage of the fish consumed by a majority of people around the lakes and in the cities far from the lake [7]. However, "in many places fish become so contaminated by the filth on which they feed as to be a cause of disease. This is especially the case where the fish come in contact with the sewage of large cities. The fish that are fed on the contents of the drains may pass into distant waters and may be caught where the water is pure and fresh. Thus when used as food they bring disease and death on those who do not suspect the danger" [1]. This research aimed at studying the presence of heavy metals in these two varieties of fish in Lake Victoria as they are the most commonly consumed by many locals around the lake. The various sections of the two sample fish varieties will be discussed largely in this report comparatively to determine the levels of the heavy metals in these fish of Lake Victoria.

Statement of the Problem

In the year 2020, a local Kenyan newspaper, highlighted the plight of the Lake Victoria, mentioning the dangers posed by various industries which disposed their raw untreated wastes into the Lake. As mentioned by Paul W [3] in *Daily Nation Newspaper* issue, a majority of industries released their industrial effluent into the lake without treating their wastes, and into rivers around the lakes which eventually found their way into the lake showing that the contamination was spreading from the shores heading towards the middle of the lake". This posed a great danger to residents and animals using the lake as a source of water and habitat. This thus prompted a need to study the health of the fish consumed from the lake.

Justification of the Research

Pollution in Lake Victoria has become a major challenge for the counties depending on it and the country at large [8]. There are a majority of agricultural activities taking place at the lake side, and along the river banks leading into the lake [2]. The use of agricultural chemicals in such gardens resulted into accumulation of various toxic chemicals, including heavy metals in these water bodies. Moreover, there are oil spillages as a result of washing of automotives in the lake and rivers leading into the lake. However, "industries are a leading source of raw untreated wastes that pollute the lake. As a result, aquatic animals, fish inclusive, were at a risk of taking in these toxins into their systems. These toxins can thus be transferred into the human body through consumption of the affected fish or aquatic animals in these water bodies [3].

This research is important as it will help various locals on the choice of healthy meals by informing them whether the most commonly preferred fish dish is still healthy. It will also help various researchers in finding the solution to various lifestyle diseases and infections associated with various meals taken in a lifetime.

Objectives

The general objectives of this research were:

- ✓ To determine the presence of selected heavy metals in fish of Lake Victoria

The specific objectives of this research were:

- ✓ To determine which fish variety (tilapia or Nile Perch) is highly exposed to the selected heavy metals
- ✓ To determine the specific tissue with the highest concentration of the selected heavy metals
- ✓ To determine which fishing ground is more affected by the selected heavy metals poisoning in fish
- ✓ To determine the relationship between fishing grounds and the selected heavy metal poisoning

Literature Review

General Overview of Heavy Metals and Their Toxicological Effects on Health

Metallic elements form a very key part of the surrounding. The availability of these metals is unique in that it is not easy to completely eliminate them from the environment once they come into it. Heavy metals are an important group of toxic substances we come across in many occupational and environmental activities. With the progressing applications of a large number of metals in industry and in our daily life, complications coming from harmful heavy metals pollution of the environment have taken different angles (Table 1).

Generally, the toxicity of metal ions to mammalians systems is because of chemical reactivity between the metal ions and cellular structural proteins, enzymes and membrane system. The organs targeted by specific metal toxicities are majorly those organs that are able to accumulate the highest concentrations of the metal in question [9].

Metal	Target Organs	Primary Sources	Clinical effects
Cadmium	Renal, Skeletal Pulmonary	Industrial Dust And Fumes And Polluted	Proteinuria, Glucosuria, Osteomalacia,
		Water And Food	Aminoaciduria, Emphysemia
Lead	Nervous System, Hematopoietic	Industrial Dust And Fumes And Polluted	Encephalopathy, Peripheral Neuropathy, Central Nervous
	System, Renal	Food	Disorders, Anemia.

Table 1: Clinical aspects of chronic toxicities [9].

Lead (Pb)

Lead is an element of the periodic table with atomic number 82 and atomic weight of 207. It is a d-block element with an electronic configuration of [Xe] $4f^{14}5d^{10}6s^{2}6p^{2}$. It exists in three oxidation states: Pb (0), the metal; Pb (II); and Pb (IV). According to Abadin H, et al. [10] the most dominant state of lead in the environment is Pb (II) (Table 2).

Substance	Specific gravity	Melting pt.	Boiling pt.	Chemical property
Lead	11.34	327°C	1,740°C	NR[1]
Lead acetate	3.25	280°C		Dec-02
Lead acetate trihydrate	2.55	75°C	200°C	Dec
Lead chloride	5.85	501°C	950°C	NR
Lead nitrate	4.53	470°C		Dec
Lead subacetate	NR	75°C		Dec
Tetraethyl lead	1.659	–136.8°C	200°C	NR
Tetramethyl lead	1.995	–30.2°C	110°C	NR

Table 2: General properties of lead and its compounds [11].

Pb is found in concentrated and easily accessible Pb ore deposits that are widely distributed throughout the world. As an element, Pb does not degrade [12]. However, particulate matter contaminated with Pb can move through the air, water and soil. Atmospheric degradation is the largest source of this element found in the soil. This is because the element can easily and continuously be transferred between air, water and soil by natural chemical and physical processes such as weathering, run off, precipitation, and dry deposition of dust.

However, soil has been found to be the most important sink for the compounds. The existence of this element and its compounds in water is a function of the water pH and greatly dissolves in alkaline water [13].

Health Effects of Lead

Lead and its compounds are toxic and can be retained by the body, accumulating over a very long period of time. This phenomenon, as described by Augustyn A [13] is known as cumulative poisoning- until lethal. Quantity is reached. The toxicity of lead compounds increases as their solubility increases, meaning that the more soluble the lead compound is, and the more toxic it is.

People who are exposed to lead have a range of illnesses and are at high risk of contracting fatal diseases. According to WHO report, “Young Children are particularly vulnerable to the toxic effects of lead and can suffer profound and permanent adverse health effects, particularly affecting the development of the brain, and the nervous system [14]. Lead however is also harmful to adults and can cause long term harm in them, including increased risk of high blood pressure, and kidney damage. Exposure of pregnant women to high levels of lead can be fatal to the extent of causing miscarriages, still birth and low body weight. Once lead enters the body, it is distributed to organs such as the brain, kidneys, liver and the bones. The body stores lead in the teeth and the ones where it accumulates over time. Constant accumulation of the lead in the body may raise it toxic levels. To some point, the lead stored in the bones may return into the bloodstream during pregnancy. This thus exposes the baby to the toxicity of this heavy metal. Based on World Health Organization Reports

[14] citing The Institute for Health Metrics and Evaluation (IHME) estimated that in 2017, lead exposure accounted for 1.06 million deaths and 24.4 million years of healthy life lost (disability- adjusted life years (DALYs) worldwide due to long-term effects on health. The highest burden was in low- and middle-income countries. IHME also estimated that in 2016, lead exposure accounted for 63.2% of the global burden of idiopathic developmental intellectual disability, 10.3% of the global burden of hypertensive heart disease, 5.6% of the global burden of the ischemic heart disease and 6.2% of the global burden of stroke [15].

Cadmium (Cd)

Cadmium, bearing the chemical symbol Cd is an element in the periodic table of group IIB and bears the atomic number 48 and a mass number of 112.4. It is a d-block element with the electronic configuration of [Kr] $4d^{10}5s^2$. It is an odorless, silvery white metal. It is malleable and a steady solid at room temperatures. It burns in oxygen giving a grey powder. Majority of Cd compounds exhibit a steady oxidation number of +2. Cd is soluble in dilute nitric acid, in hot sulfuric acid, and in ammonium nitrate. It is however insoluble in water [16]. Cd is not usually found in the natural environment existing as a raw metal, however, it is found as complex oxides, sulfates, and carbonates in zinc, lead and copper ores. It is mainly produced as a byproduct of mining, smelting and refining of zinc. Most of the Cd produced is applied in the manufacture of Nickel- cadmium batteries. Cd is released into the environment by various natural and anthropogenic sources to the atmosphere, aquatic and terrestrial environments, mostly in form of cadmium oxide particles. However, almost half of the Cd found in waters, especially rivers, come as a result of weathering of the rocks, while the rest of the Cd in water is generally attributed to industrial effluents. The most frequent sources of cadmium contamination are related to its application in industry as a corrosive reagent, as well as its use as stabilizer in PVC products, color pigments, and Ni-Cd batteries. Friberg LT, et al. [17] stated that Cadmium (Cd), alongside arsenic, lead, mercury, and chromium, is a heavy metal that does not have a physiological function and is often considered a toxicant [17].

Toxicological Health Effects of Cadmium

Primarily, exposure to Cd results from ingestion of contaminated foods and water. These maycome as a result of consuming food with high accumulation of Cadmium oxides leading to heavy metal poisoning [18]. Cadmium can pile up in plants and animals with a long lifespan for about 20-30 years as stated in a case study by Genchi G, et al. [18]. The study further stated that cadmium is a toxic non-essential metal that poses health risks for both plants and animals [18]. Due to this, pollution into lakes with cadmium may result into accumulation of cadmium residues in aquatic animals which constantly interact with this heavy metal in water. Upon exposure to these accumulated levels of Cadmium in fish meal, there is potential danger of cadmium poisoning. Exposure to this heavy metal can be related to various types of cancers, osteoporosis, damage to the liver and kidneys [15]. Cadmium poisoning mainly target the Reactive Oxygen Species (ROS) which are manufactured by the mitochondria; thus damage to this organelle is also witnessed in a majority of test patients [19].

Methodology

Conceptual Framework

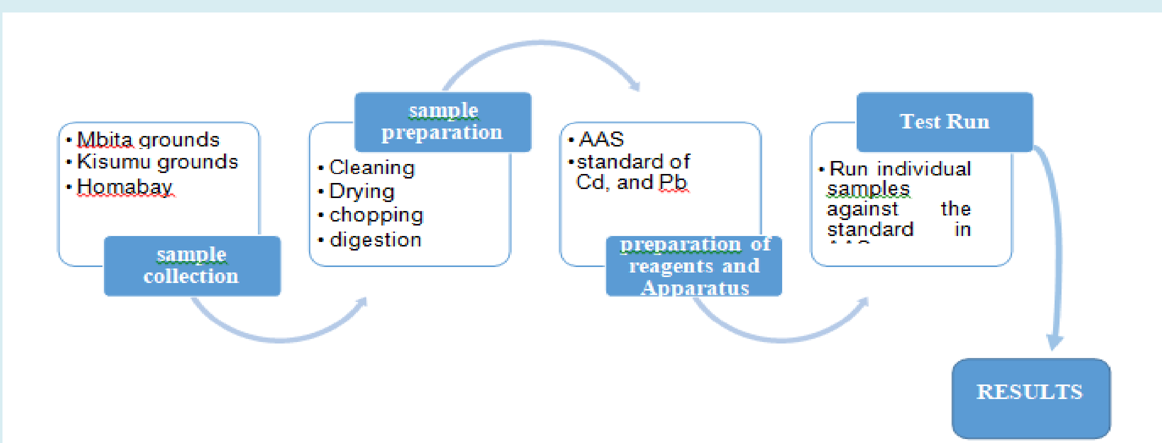


Figure 1: A stepwise Process flow diagram per operation.

Site Description

Three sites were selected for the study, each of which being known for its proficiency in good fishing grounds around the Lake Victoria (Table 3). Lake Victoria is the largest fresh water fishing ground in Eastern Africa, serving three countries namely, Uganda, Kenya and Tanzania [20]. This makes it the main fishing ground for the three countries, and the largest source of fresh water fish in the region (Figure 2).

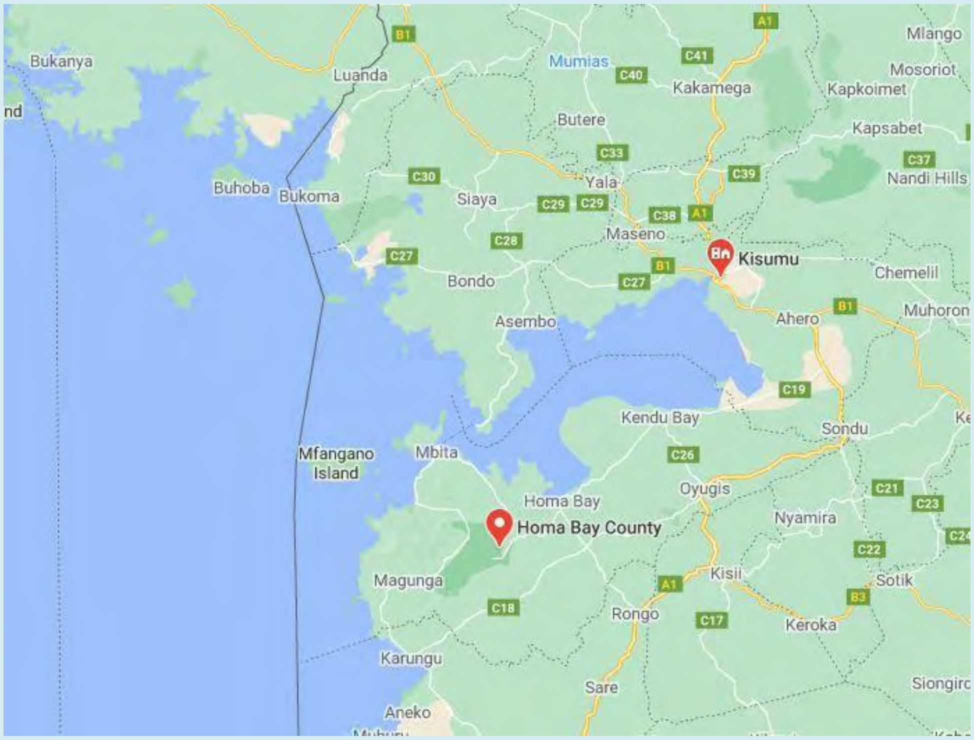


Figure 2: Fishing grounds in vivo [21].

Sampling sites	Most dominant fish species [20]		Major chemical Industries [21]
	Species	Percentage	
S1-Kisumu fishing grounds	*Rastreonobola agentea* (Omena)	53.20%	Kibos sugar and allied industries Gulfhub chemicals Monija Industries ltd.
	Lates Niloticus (Nile Perch)	33.40%	Crown paints
	Oreochromis niloticus (Tilapia)	4.31%	
	Lates Niloticus (Nile Perch)	43.1	

Table 3: Categories of sampling sites based on types of most abundant fish species and industrial distribution around them.

Experimentation

Heavy metals in study were dissolved in the sample solutions, meaning that they could not be determined by physically selecting or choosing them from the sample solution. Moreover, their particles were less than 0.45µm hence acquiring via filtration using Watt man filter paper was not possible. However, the heavy metals have specific emissions on an Atomic Absorption Spectrophotometer (AAS), thus were identified through the emissions.

Atomic Absorption Spectrophotometer

- Wattmann No.1 filter papers
- 6 petri dishes
- Surgical blade/craft knife
- Standard cuvettes(405.8nm, 217.0nm, and 217.0nm)

Reagents to be used

- Standard solutions of Pb
- Standard solutions of Cd

- Analytical grade Nitric acid
- 70% perchloric acid($HClO_4$)

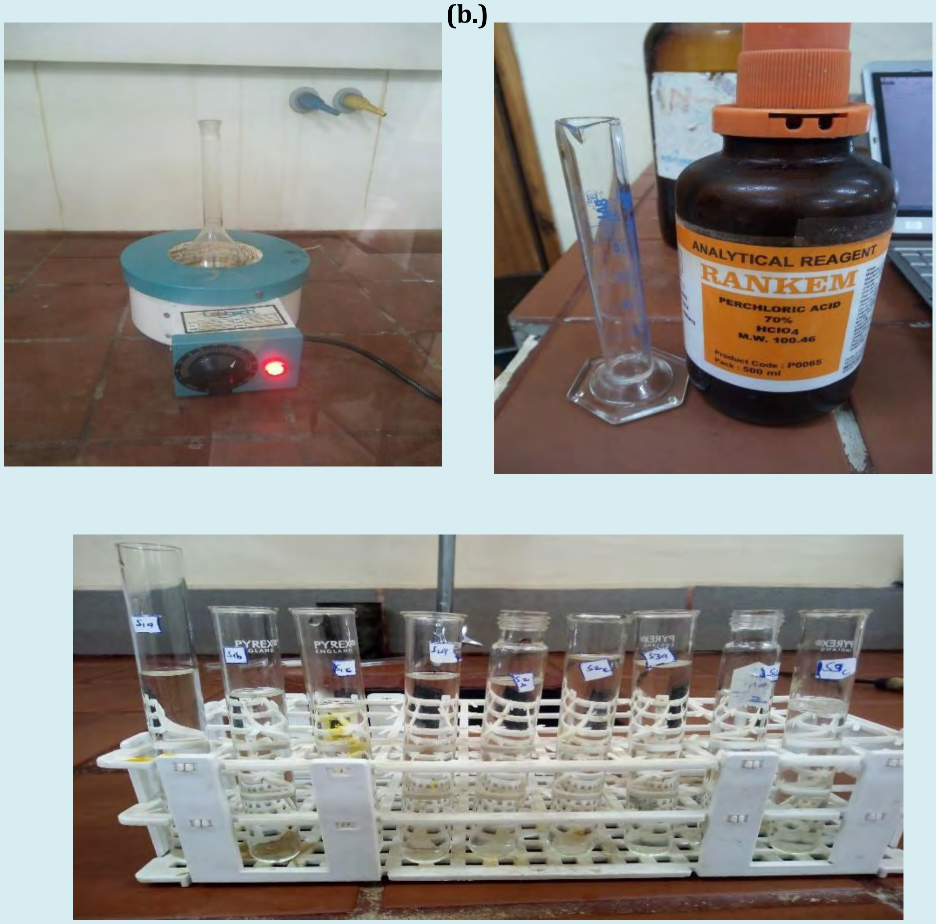
Calibration of Solutions: Standard solutions of each sample of Pb, and Cd were prepared according to the manufacturers' calibration procedures for Atomic Absorption Spectrophotometer to be used. Known concentrations of the metal solutions were also prepared from their respective salts.

Sample Collection and Preparation: Samples were collected from the locations in Figure 3 above, washed with clean water and descaled. The samples were then chopped into halves and muscle samples (a), gill samples (c) and skin samples(d) taken from each fish samples, dried for 10 minutes in the electric oven set at 105°C (b.)

Figure 3: prepared samples (Photos taken by Fredrick O. Odhiambo at UEAB chemistry lab).

Experimental Procedure

Samples under study were first digested using wet digestion method [22] (Figure 4). About 2g of samples was put into a 250ml volumetric flask and followed by 15ml of HNO3. This mixture was then allowed to stand for 1hour then carefully heated over water bath in a fume chamber until all the red fumes of Nitric acid disappeared. The flask was then allowed to settle and cool at room temperature then 15ml of $HClO_4$ was added (b.). The flask was then heated again over the water bath up to evaporation point, leaving a small volume which was then filtered using Wattman No.1 filter paper. The volume was topped up using distilled water to a volume of 250ml. The concentrations of the various heavy metals in vivo were finally determined by setting them in an AAS with the recommended wavelengths (Table 4).



(a.) (b.) (c.)

Figure 4: Wet digestion of the samples (Photos taken by Fredrick O. Odhiambo at UEAB chemistry lab) Table 4. Recommended wavelengths and flame gases [23].

Element	Wavelength(nm)	Flame gases	Analysis technique
Lead	324.7	Air Acetylene	Direct flame absorption
Cadmium	228.8	Air acetylene	Direct flame absorption

Table 4. Recommended wavelengths and flame gases [23].

Results

Results from AAS Analysis

Source	Sample	Part	Lead(mg/kg)	**Cadmium(mg/kg)**
Winam Gulf	Tilapia	Muscle(s1a)	5.8±1.26	0.1±0.04
		Skin(s1b)	1.3±1.0	0.3±0.05
		Gills(s1c)	3.42±0.21	0.02±0.04
	Nileperch	Muscle(s2a)	3.5±0.41	2.5±0.13

		Skin(s2b)	4.17±0.39	1.9±0.30
		Gills(s2c)	2.75±1.57	3.0±0.14
Homa-Bay Town	Tilapia	Muscle(s3a)	2.1±0.01	0.03±0.01
		Skin(s3b)	1.1±0.21	0.01±0.01
		Gills(s2c)	2.3±0.21	0.02±0.002
	Nile perch	Muscle(s4a)	2.7±1.21	0.006±0.003
		Skin(s4b)	1.0±0.01	0.004±0.001
		Gills(s4c)	2.9±1.03	0.005±0.005
WORLD HEALTH ORGANIZATION TOLERABLE LIMITS [24]			2.0mg/kg	0.05mg/kg

Table 5: The means of the various concentrations obtained from the AAS analysis (table 5) were calculated and used for the comparative statistical analysis.

Source	Sample	Part	Pb(ū=mg/kg)	Cd(ū=mg/kg)
Winam Gulf	Tilapia	Muscle(s1a)	5.8	0.1
		Skin(s1b)	1.3	0.3
		Gills(s1c)	3.42	0.02
	Cumulative mean		3.51	0.14
	Nile perch	Muscle(s2a)	3.5	2.5
		Skin(s2b)	4.17	1.9
		Gills(s2c)	2.74	3
	Cumulative mean		3.47	2.46
	Mwinam		3.49	1.3
Homa-Bay	Tilapia	Muscle(s3a)	2.1	0.03
		Skin(s3b)	1.1	0.01
		Gills(s2c)	2.3	0.02
Cumulative mean			1.83	0.02
	Nile perch	Muscle(s4a)	2.7	0.006
		Skin(s4b)	1	0.004
		Gills(s4c)	2.9	0.005
	Cumulative mean		2.2	0.005
	$M_{Homabay}$		2.015	0.o125

Table 6: Mean concentration of heavy metals in fish samples (ū=LC +UC /2) where ū is the mean concentration, LC is the lower limit of the sample result and UC is the upper limit of the samples result.
M_{Winam} =Cumulative mean of selected heavy metals in fish from Winam Gulf.
$M_{Homabay}$ =Cumulative mean of selected heavy metals in fish from Homa-Bay fishing ground.

Statistical Analysis

The Anova F-Test: ANOVA F-test was conducted to determine whether the distribution of selected heavy metals in separate fish tissues was dependent on the species offish. The analysis was also used determine whether the concentrations of the heavy metals were dependent on fishing grounds. The F-test was conducted at (α=0.05) 95% confidence interval

Dependence on Fish Variety

Winam Gulf(mg/kg)	Homabay(mg/kg)
5.8	2.1
1.3	1.1
3.42	2.3
0.1	0.03
0.3	0.01
0.02	0.02

Table 7: Fish Variety.

The F-test was conducted using data from the mean concentration of the selected heavy metals in Tilapia from both sampling sites to test whether the mean distribution of the heavy metals was dependent on the variety of fish regardless of the sampling site. Since the fish variety used was tilapia, it was hypothesised that regardless of the different fishing grounds, the mean distribution of the selected heavy metals was equal. A sample size of 12(n) was used with Winam Gulf and Homabay bearing a sample sizes of n_1=6 and n_2=6 respectively.

$H_0=M_1=M_2$ (Distribution of the metals is dependent on variety of fish regardless of the fishing grounds from where the samples are obtained)
H_1=Not all means are equal

$F=\frac{MST}{MSE}$ Where MST=2.408, and MSE=2.676

F=0.8997

At α=0.05, with df_1=1 and df_2 =10, the F value was 4.96.

Since 4.96>0.8997, the H_0 was rejected. This means that the distribution of the selected heavy metals in fish was not dependent of fish variety.

Dependence on Fishing Grounds

Tilapia(mg/kg)	Nile Perch(mg/kg)
2.1	2.7
1.1	1
2.3	2.9
0.03	0.006
0.01	0.004
0.02	0.005

Table 8: Fishing grounds.

To test whether the concentrations of the selected heavy metals was dependent on the fishing grounds regardless of the fish variety, one sample site was selected (Homabay Fishing grounds). Different data was taken from tilapia and Nile perch. It was hypothesized that the distribution of the metals depended on the fishing ground, thus the mean values of tissue distribution in the two fish varieties would be equal as they come from the same fishing ground.

$H_0=M_3=M_4$ (The mean distribution of the selected heavy metals in fish species is dependent on fishing grounds from where the fish is obtained)

H_1=Not all the mean distribution of the metals is equal

$F=\frac{MST}{MSE}$ Where MST=0.0924015, and MSE=1.5165

F=0.061

At α=0.05, with df_1=1 and df_2 =10, the F value was 4.96.

Since 4.96>0.061, the Null hypothesis was rejected. This means that despite the fact that the fish varieties were obtained from one similar source, the mean of the selected heavy metals concentration was not equal. This showed that the distribution of heavy metals in fish was not dependent on the fishing grounds from where they were obtained.

Graphical Analysis

Using the mean concentrations of the selected heavy metals in vivo, graphical analysis of the data was obtained using Microsoft Excel sheet (Version 2013) and comparatively determined using bar graphs.

Discussion

The heavy metals a concentration in fish was found to be above the permissible WHO limits (Figure 5) in some fish tissue. For Pb, the concentrations were s1a>s2b>s2a>s1c>s4c>s2c>s4a>s3a>s1b>s3b>s4b. For concentrations of Cd, the variations were as follows: s2c>s2a>s2b>s1b>s1a>s3a>s2c=s1c>s3b>s4a>s4c>s4b. It was realized that the heavy metals distribution in fish samples was not tissue bias, meaning that wall the tissues of the fish species exhibited a random concentration of the selected heavy metals.

In samples from Homabay (Figure 5c,d), it was identified that heavy metals distribution was little with Nile perch bearing the greatest distribution of Pb in its tissues (ū=2.2mg/kg) and tilapia bearing the greatest distribution of Cd (ū=0.02mg/kg).

In samples from Winam Gulf (Figure 5a,b), it was identified that the heavy metals distribution was higher with tilapia bearing the greatest concentration of Pb (ū=3.51mg/kg) and Nile perch bearing the highest concentration of Cd (ū=2.46mg/kg).

Figure 5: Heavy metals distribution in tissues of fish samples.

Cadmium distribution in the fish samples were slightly above the WHO tolerable limits with [24] Nile perch skin sample from Homabay (s4b) bearing the lowest concentrations (0.004mg/kg) and gills of Nile perch from Winam gulf (s2c) are bearing the largest concentrations (3.0mg/kg).

Conclusion

Consumption of fish from Lake Victoria poses a risk of heavy metals poisoning to the consumer. This is evident since the samples taken were found to contain a high concentration of heavy metals (Pb and Cd) above the WHO tolerable limits.

The study showed that there was no particular fish variety that is highly susceptible to heavy metals poisoning, thus all fish are at risk of heavy metals poisoning. Tissues of fish exhibited a random distribution of the heavy metals in study. There was no specific fish tissue that is more susceptible to heavy metals poisoning. The two fishing grounds were found to exhibit random distribution of heavy metals. No particular fishing ground is highly exposed to heavy metals poisoning than the other. All the fishing grounds in study were found to exhibit a random distribution of the metals above WHO limits.

Heavy metals poisoning is not dependent on the fishing grounds in question. Some of the studied heavy metals above in high doses can be quite acute and cause harm to the body leading to acute and chronic toxicities [25]. The high levels of these heavy metals can cause very great health effects and severe poisoning and blood toxicity. Some heavy metals; however essential to the human body, plant and animal life, all heavy metals show their toxicities at various levels in the systems of these organisms. As mentioned by Hadeel M [26] fishes are not excluded in these organisms in which heavy metal poisoning affect adversely, which can lead to "serious problems and ill effects" on different organs in the consuming species.. These toxic heavy metals can enter into these fish species through the drainage, erosion, and atmosphere. However, human activities including release of industrial effluents into the water bodies account to a majority of the heavy metals disposal in the water bodies. These heavy metals thus enter the biogeochemical cycle further entering into the fish [27-30].

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