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**BACTERIOLOGICAL AND HEAVY METAL STATUS OF WATER AND FISH SAMPLES FROM JEBBA LAKE – NIGERIA**

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***ABSTRACT***

Quantitative and qualitative analysis of bacterial isolates in water and fish samples

**(*Oreochromis niloticus*** and ***Clarias gariepinus***) from Jebba Lake were carried out using primary isolation media and microbact identification kits. The concentration of heavy metals, Lead (Pb), Copper (Cu), Cadmium (Cd), Chromium (Cr) and Arsenic (As) were determined using Atomic Absorption Spectrophotometer (AAS). Samples were collected from five (5) different stations. Station Jl.1 and Jl.2 are located at the upper course of the lake and were characterized by high human activities (washing, bathing, mining and animal husbandry operations) especially in sample station Jl.2. Sample station Jl.3 has low human activities, however it has a tributary with high mining activities. Station Jl.4 has high domestic washings but low animal husbandry operation and low mining activities. Station Jl.5 has low domestic washings, low animal husbandry operation and low mining activities. Mean faecal coliform count of sample station Jl.1 (580.83 CFU/100ml) and station Jl.2 (700.83 CFU/100ml) were above maximum permissible limit for Federal Environmental Protection Agency (FEPA). Faecal coliform count of sample stations Jl.3, Jl.4 and Jl.5 were below maximum permissible limit. Maximum faecal coliform count during the wet season was 1600.00 CFU/100ml, while the maximum count during the dry season was 920.00 CFU/100ml. Bacterial species such as ***Aeromonas caviae*, *Aeromonas hydrophila*, *Pseudomonas fluorescens* – 25, *Escherichia coli*, *Moraxella* species, *Mannheimia (pasturella) haemolytica*, *Pseudomonas aeruginosa*, *Pseudomonas fluorescens* – 35, *Escherichia hermannii*** were found in water samples and species such as ***Vibrio alginolyticus*, *Moraxella* species, *Escherichia hermannii*, *Vibrio parahaemolyticus*, *Aeromonas hydrophila*** were isolated from fish intestines and gills. Concentration of Cu, Cr and As in water was observed to be within permissible limit but the concentration of Pb and Cd were above tolerable limit. In fish organs, the concentration of heavy metals were within permissible limit except that of Pb and As in ***Oreochromis niloticus*** fish intestines (ONFI) (0.38±0.00 and 0.03±0.00 respectively) and ***Clarias gariepinus*** fish intestines (CGFI) (0.40±0.00 and 0.03±0.01 respectively) which were above maximum permissible limit by standard organizations.

**Key words:** Jebba Lake, water, fish, *Oreochromis niloticus*, *Clarias gariepinus*, bacteria, heavy metals

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# INTRODUCTION

Water is essential to life, but many people do not have access to clean and safe water for drinking, irrigation and fish production. As such, many die of waterborne or water related bacterial infections. According to WHO, the mortality of water associated diseases exceeds 5 million people per year (Joao, 2010). Water quality in many lakes and rivers has been impaired by high level of contaminants either by direct dumping of refuse and defecation by animals or through runoff. Faecal coliform counts and *Escherichia coli* detection is the most reliable tool for assessing health risk posed by pathogens in water (Byamukama *et al*., 2000).

Heavy metal pollution in aquatic environment is also a major concern on a world scale, because they are indestructible and most of them have toxic effects on organisms (ÖztÜrk *et al*., 2009). Heavy metals bioaccumulate in fish tissues and the accumulation of these heavy metals over time in fish leads to the suppression of fish immunity hence allowing the normal flora to cause ulceration and possible septicemia (Mutuku, 2010). Jebba Lake is surrounded by cattle ranches and other human activities like washing of automobiles (popularly called “car wash”), bathing, electricity generation and illegal mining activities. The aim of this study was to evaluate the bacteriological and heavy metal status of water and fish samples from Jebba Lake and their suitability for human consumption.

# STUDY AREA

The study area is Jebba Lake which is located in central area of Nigeria. It lies between Latitude 8.99° and 10.31° N and Longitude 4.79° and 5.01° E. It has a perimeter of about 567 km and an estimated area of 12,992 km2 (Adeogun *et al*., 2016). Sample station 1 (Jl.1) is at Faku with minimal animal husbandry operation but much human activities such as domestic washings and high fishing activities. It is also the station that is directly below power generation station. The water in this station is used raw for drinking purposes by the villagers. Station 2 (Jl.2) is at Manyarrah which is characterized by high irrigation activities, high mining activities, high animal husbandry operation, car wash centre, fishing activities among others. It is at the lower course of Faku. Station 3 (Jl.3) is at New Awuru where human activities is reduced; however it has a tributary (river Oli) with high mining activities. It is at the lower course of Manyarrah. Station 4 (Jl.4) is at Old Awuru with high domestic washings but low animal husbandry operation and low mining activities. It lies adjacent to old Awuru market and is at the lower course of New Awuru. Station 5 (Jl.5) is at Maisamari karemi, the lower course of old Awuru with low domestic washings, low animal husbandry operation and low mining activities.

# MATERIALS AND METHODS

**Sample Collection:** The Lake was sampled from January to December 2017, to represent dry and wet seasons. Water samples for bacteriological study were collected using 150 ml sterilized container while fish samples were collected using sterilized plastic container. After collection, samples were stored in an ice-chest and transported to the laboratory for bacteriological analysis.

Two (2) litre capacity polyethylene sampling bottles were used to collect water samples (4 times) at each sampling station for heavy metal study. The pre-cleaned

sampling bottle was immersed below surface to collect water sample. These water samples collected at each sampling sites were mixed in a plastic bucket and a

representative sample of one liter was transferred into a polyethylene bottle.

Samples were acidified with 2 ml of 10% HNO3 and transported to the laboratory for further analysis according to the procedure of ÖztÜrik *et al*., (2009).

# BACTERIAL ANALYSIS

**Determination of faecal coliforms in water using Most Probable Number (MPN) technique**

Faecal coliform count was carried out using most probable number technique

(APHA, 2003). To carry out this test a three series of five tubes each containing 10 ml, 1ml and 0.1 ml portions of the sample were inoculated with sterilized

macConkey broth. Pure sterilized macConkey broth was inoculated with sterile

distilled water to serve as a control. Inoculated tubes were then incubated at 37 °C for 24 hours. Using a sterilized wire loop, transfer were made from all tubes showing acid and gas production (An indication of the presence of total coliform) to tryptose bile broth and incubated at 44 °C for 24 hours. Gas production in a fermentation tube within 24 hours was considered as a positive reaction for faecal coliforms.

The estimated number of faecal coliforms present was read from a tabulated probability table using corresponding results of various combinations of

positive and negative reactions from each of the three batches according to the method of APHA (2003).

# Enumeration of total viable count (TVC) in water samples

A 1.0 ml of water sample was serially diluted into 9.0 ml sterilized distilled water. After dilution, 0.1 ml of each serially diluted sample was inoculated on sterilized plate count agar and spread evenly on the surface of the media using sterilized bent

glass rod (Standard plate count technique) according to the method of Ogbondeminu *et al.* (1991) and Ijah *et al.,* (2008). These inoculated plates were then incubated at 35oC + 2oC for 24 h. After incubation, the number of colonies were counted using colony counter. Colony forming units (CFU) of bacterial in the

water sample were then calculated and recorded as colony forming units (CFU) = colony count x dilution factor / inoculum volume.

# Bacterial Identification in water and fish samples

Bacterial identification was carried out following standard procedures of

Cheesbrough (2002), Johnson *et al*., (2003) and Bergey’s manual of systematic bacteriology (Krieg & Holt, 1994). Enrichment media (Selenite F broth, tryptic soy broth (TSB), alkaline peptone water (APW)) were inoculated with samples (water and fish samples) and incubated at 37oC. After 6-8 hours, this broth cultures were re-inoculated into appropriate medium (Nutrient agar, MacConkey agar, Sorbitol MacConkey agar, Eosin Methylene blue agar, Starch Ampicillin agar, Bismuth sulphite, Thiosulfate Citrate Bile Salt Sucrose agar). These inoculated plates were incubated at 37oC for 24 hours using an incubator. After incubation, colonies were picked, re-inoculated into fresh media and incubated at 37oC again to obtain pure colony. A gram stain, oxidase test and motility test were carried out on the pure colonies and these were further identified biochemically using Microbact Identification Kits 12A and 12B (MB1132A/ Australia).

# Heavy metal analysis

Water and fish samples were digested according to APHA (2005) for heavy metal analysis. After digestion, the filtrate of each sample was analyzed for heavy metal using Atomic Absorption Spectrophotometer (PG instrument model, AA500

Spectrophotometer).

# Statistical analysis of data

Analysis of variance (ANOVA) was performed to show significant difference

between faecal coliform counts at different sample stations of Jebba Lake. Student t- test was carried out to show significant difference between faecal coliform

counts of the seasons and also used to determine significant difference in

concentration of heavy metals in water between seasons. Analysis of variance (ANOVA) showed significant difference between total viable counts at different sample stations of the lake. Duncan Multiple Range test was carried out to determine significant difference between fish organs.

# RESULTS

**Mean faecal coliform counts (cfu/100ml) of water from Jebba Lake using Most Probable Number (MPN) technique**

Table 1 shows mean faecal coliform counts of water from Jebba Lake. It was

observed that sample station 2 had the highest count (700.83 cfu/100ml), while station 5 had the lowest count (200.92 cfu/100ml). In general, station 1 and 2

which are at the upper course had higher coliform counts than station 3, 4 and 5,

which are at the lower course. Analysis of variance (ANOVA) shows a p-value of 0.013201. There is significant difference (P < 0.05) between coliform counts at different sample stations. From the table, it was also observed that the faecal coliform count at stations 1 and 2 were above maximum permissible limit of 5.0 x

102 cfu/100 ml according to FEPA (2003).

# TABLE 1

**Mean faecal coliform counts (cfu/100ml) of water from Jebba Lake using Most Probable Number (MPN) technique**

|  |  |  |  |
| --- | --- | --- | --- |
| **Sample****station** | **Min - Max** | **Mean ± SD** | **Max permissible limit****(cfu/100ml)** |
| Jl.1 | 6.00 - 1600.00 | 580.83 **±** 475.50 | 500a |
| Jl.2 | 20.00 - 1600.00 | 700.83 **±** 531.27 | 500a |
| Jl.3 | 12.00 - 920.00 | 368.92 ± 317.72 | 500a |
| Jl.4 | 31.00 - 920.00 | 368.92 ± 317.72 | 500a |
| Jl.5 | 14.00 - 540.00 | 200.92 ± 171.12 | 500a |

a = FEPA 2003

# Seasonal faecal coliform counts of water from Jebba Lake using MPN technique

Results of **s**easonal variations (Table 2) shows that the faecal coliform count

during the wet season was higher (649.13 MPN/100ml) than that of the dry season

(219.30 MPN/100ml). However t-test analysis showed no significant difference (P>0.05) between faecal coliform counts of the wet and dry season.

# TABLE 2

**Mean seasonal feacal coliform counts of water from Jebba Lake using Most Probable Number (MPN) technique**

|  |  |  |
| --- | --- | --- |
|  | **Wet** | **Dry** |
| Minimum count | 84.00 | 6.00 |
| Maximum count | 1600.00 | 920.00 |

 Mean ± SD 649.13±428.90 219.30±239.11

# Mean total viable count (TVC) of water from Jebba Lake

Table 3 shows total viable count (TVC) of water from Jebba Lake. Station 3 (New

awuru) in Jebba Lake had the highest total viable count (4.9 x 105) and this is

followed by station 2 (Faku) which is 3.0 x 105 cfu/100m and station 1 (2.7 x 105 cfu/100 m). Station 4 (Old Awuru) has the lowest count (2.3 x105 cfu/100 m). Analysis of variance revealed a p-value of 0.900178. There is no significant difference (P>0.05) between total viable counts at different sample stations.

# TABLE 3

**Mean total viable count (TVC) (cfu/100 m) of water from Jebba Lake**

|  |  |  |  |
| --- | --- | --- | --- |
| **Sample station** | **Minimum** | **Maximum** | **Mean** |
| Jl.1 | 4.2x102 | 2.6x106 | 2.7x105 |
| Jl.2 | 4.9x102 | 2.2x106 | 3.0x105 |
| Jl.3 | 6.2x102 | 3.0x106 | 4.9x105 |
| Jl.4 | 1.2x103 | 2.1x106 | 2.3x105 |
| Jl.5 | 8.5x102 | 1.9x106 | 2.7x105 |
| **Max permissible limit** **(CFU/100ml)**  |  |  | **1.0x105** |

**Bacterial species isolated in water and fish samples from Jebba Lake**

Bacteria species isolated from water and fish samples revealed the presence of *Escherichia coli, Aeromonas hydrophila, Escherichia hermannii, Moraxella* species, *Pseudomonas fluorescens – 25, Pseudomonas fluorescens – 35,*

*Mannheimia (pasturella) haemolytica, Vibrio parahaemolyticus, Vibrio alginolyticus* among others as shown in Tables 4 and 5.

# TABLE 4

**Bacterial species isolated from Jebba Lake water sample**

|  |  |
| --- | --- |
| **Sample station** | **Name of organisms** |
| Jl.1 | *Aeromonas caviae, Aeromonas hydrophila, Pseudomonas fluorescens – 25,**Escherichia coli, Moraxella* species, *Mannheimia (pasturella) haemolytica, Pseudomonas aeruginosa, Pseudomonas fluorescens – 35, Escherichia hermannii* |
| JL2 | *Aeromonas hydrophila, Pseudomonas fluorescens – 25, Burkholderia**pseudomallei, Mannheimia (pasturella) haemolytica, Pseudomonas aeruginosa, Escherichia hermannii, Escherichia coli, Moraxella* species, *Actinobacillus* sp. |
| JL3 | *Pseudomonas aeruginosa, Aeromonas hydrophila, Pseudomonas fluorescens –**25, Yersinia pestis, Escherichia coli, Actinobacillus* sp. |
| JL4 | *Aeromonas caviae, Mannheimia (pasturella) haemolytica, Aeromonas**hydrophila, Burkholderia pseudomallei, Pseudomonas fluorescens – 25, Pseudomonas aeruginosa, Escherichia coli, Moraxella* sp. |
| JL5 | *Aeromonas hydrophila, Pseudomonas fluorescens – 25, Mannheimia* *(pasturella) haemolytica, Escherichia hermannii, Actinobacillus* sp.  |

**TABLE 5**

**Bacterial species isolated in fish samples from Jebba Lake**

|  |  |
| --- | --- |
| Fish organs | Name of organisms |
| ONFI | *Vibrio alginolyticus, Moraxella* species, *Escherichia hermannii,**Escherichia coli, Salmonella salmonicida* |
| ONFG | *Cepacia meningocepticum, Moraxella* species, *Pasturella**multocida, Pseudomonas fluorescens – 25, Escherichia hermannii* |
| ONFM | ND |
| CGFI | *Vibrio alginolyticus, Aeromonas hydrophila, Escherichia coli**,Vibrio parahaemolyticus* |
| CGFG | *Vibrio parahaemolyticus, Aeromonas hydrophila, Bacillus species* |
| CGFM | ND |

**Key:** ONFI = Oreochromis niloticus fish intestines, ONFG = Oreochromis

niloticus fish gills, ONFM = Oreochromis niloticus fish muscles, CGFI = Clarias gareipinus fish intestines, CGFG = Clarias gareipinus fish gills, CGFM = Clarias

gareipinus fish muscles, ND = Not detected.

# Heavy metal concentration in water from Jebba Lake sample stations

Figure 1 shows heavy metal concentrations in water from Jebba Lake sample

stations. Sample station Jl.2 had the highest concentration of lead, copper and cadmium, (0.380mg/l, 0.774mg/l, 0.227mg/l respectively) while station Jl.3 had the highest concentration of chromium and arsenic (0.066 mg/l and 0.143 mg/l respectively).

**Fig.1:** Heavy metal concentration in water from Jebba sample station

# Seasonal heavy metal concentration in Jebba Lake water

Seasonal concentration of heavy metals in the lake shows that the wet season had higher concentration of lead, copper, cadmium, and arsenic than the dry season, while the concentration of chromium was higher during the dry season (0.06 mg/l)

than the wet season (0.04 mg/l). Student t-test analysis revealed significant difference (P<0.05) in concentration of all the heavy metals between the two

seasons (Table 6).

# TABLE 6

**Seasonal heavy metal concentration in Jebba Lake water**

|  |
| --- |
| **Heavy metal concentration (mg/l)** |
| **Season** | **Pb** | **Cu** | **Cd** | **Cr** | **As** |
| **Wet** | 0.21±0.00 | 0.91±0.00 | 0.22±0.00 | 0.04±0.00 | 0.12±0.00 |
| **Dry****P-value** | 0.08±0.00<.0001 | 0.21±0.00<.0001 | 0.04±0.00<.0001 | 0.06±0.00<.0001 | 0.03±0.00<.0001 |

Note: P < 0.05 is significant

**Heavy metal concentration in organs of *Oreochromis niloticus* (ON) from Jebba Lake**

Result in Table 7 shows that *Oreochromis niloticus* fish intestines (ONFI)

recorded the highest concentration of the metals than other organs. This is followed by the fish gills and then the fish muscles had the lowest concentrations.

Concentration of lead (Pb) in ONFI was above maximum permissible limit of 0.3

mg/kg according to UNEP (1985). Concentration of copper (Cu) was within permissible limit of 3.0 mg/kg according to FEPA (2003). Cadmium (Cd) was also within the permissible limit of 0.5mg/kg according to WHO (2003). Chromium (Cr) was also found to be within permissible limit of 0.15 mg/kg according to FEPA (2003). Duncan multiple range test showed significant difference (P<0.05) in the concentration of heavy metals in the intestines, gills and muscles of *Oreochromis niloticus.*

# TABLE 7

**Heavy metal concentration in organs of *Oreochromis niloticus* from Jebba**

#  Lake

|  |
| --- |
|  **Heavy metal concentration (mg/kg)**  |
| **Fish organs** |  | **Pb** | **Cu** | **Cd** | **Cr** | **As** |
| **Intestines** | ONFI | 0.38±0.00a | 1.47±0.00a | 0.27±0.00a | 0.15±0.00a | 0.03±0.00a |
| **Gills** | ONFG | 0.19±0.00b | 0.75±0.00b | 0.11±0.00b | 0.09±0.00b | 0.01±0.00b |
| **Muscles** | ONFM | 0.05±0.00c | 0.17±0.00c | 0.04±0.00c | 0.03±0.00c | 0.00±0.00c |

Key: ONFI = *Oreochromis niloticus* fish intestines, ONFG = *Oreochromis niloticus* fish gills,

ONFM = *Oreochromis niloticus* fish muscle.

Means with dissimilar letter (s) differ significantly according to Duncan’s Multiple Range Test (DMRT). Significant at P≤0.05

**Heavy metal concentration in organs of *Clarias gariepinus* (CG) from Jebba Lake**

In Jebba Lake, the intestines of *Clarias gariepinus* had higher concentration of the

heavy metals than other organs. This is followed by the gills and the muscles had the least concentration of heavy metals. Concentration of lead (Pb) and Arsenic

(As) in CGFI were observed to be above maximum permissible limit of 0.3 mg/kg

and 0.02 mg/kg respectively, according to UNEP (1985). The concentration of heavy metals in the fish organs was in this order: As < Cr < Cd < Pb < Cu. Duncan multiple range test showed significant difference (P<0.05) in the concentration of heavy metals in the organs of *Clarias gariepinus*. This result is shown in Table 8.

# TABLE 8

 **Heavy metal concentration in organs of *Clarias gariepinus* from Jebba Lake**

|  |
| --- |
| **Heavy metal concentration (mg/L)** |
| **Fish organs** |  | **Pb** | **Cu** | **Cd** | **Cr** | **As** |
| **Intestine** | CGFI | 0.40±0.00a | 1.49±0.00a | 0.35±0.00a | 0.15±0.00a | 0.03±0.01a |
| **Gills** | CGFG | 0.18±0.00b | 0.66±0.00b | 0.15±0.00b | 0.09±0.00b | 0.02±0.01b |
| **Muscles** | CGFM | 0.04±0.00c | 0.17±0.00c | 0.02±0.00c | 0.01±0.00c | 0.00±0.00c |

Key: CGFI = *Clarias gariepinus* fish intestines, CGFG = *Clarias gariepinus* fish gills, CGFM = *Clarias gariepinus* fish muscles

Means with dissimilar letter (s) differ significantly according to Duncan’s Multiple Range Test (DMRT). Significant at P≤0.05

# DISCUSSION

The results of mean faecal coliform count of water samples (Table 1) showing stations 1 and 2 (at the upper course) having higher coliform counts than stations 3, 4 and 5 (at the lower course) may be due to increased human activities like washing, bathing and activities of miners in sample stations 1 and 2 compared to the other sample stations. These increased faecal bacteria counts above permissible limit are serious indications of potential health risk. Stations 3, 4 and 5 had counts that are within acceptable limit. This may be as a result of self-purification as the lake flows down to the lower course and also the absence of pronounced source of pollution into the lake. This result agrees with Lejeune *et al*., (2001) which states that “the presence of bacteria in natural aquatic ecosystem is dependent upon the rate of contamination and the equilibrium that is established between bacterial proliferation in the environment and the rate of their elimination”

Result for seasonal faecal coliform counts of water (Table 2) showed that faecal coliform count during the wet season was higher than that of the dry season;

this may be due to runoff from adjacent farms into the lake during the wet season as against that of the dry season.

Result for total viable bacteria count in Jebba Lake revealing higher bacteria counts (Table 3) beyond the permissible limit of 1.0 x 105 cfu/100m is not healthy for fish (Buras *et al.,* 1987), who states that the “concentration of 1.0 x 105 cfu/100 ml and above of total viable bacteria count can cause the appearance of bacteria in fish muscles”. Bacteria are critically dangerous pathogens for both cultured and wild fish, responsible for mass losses in fish production (Taghreed, 2020).

The presence of *Escherichia coli, Aeromonas hydrophila, Escherichia hermannii, Moraxella* species, *Pseudomonas fluorescens – 25, Pseudomonas*

*fluorescens – 35, Mannheimia (pasturella) haemolytica, Vibrio parahaemolyticus,*

*Vibrio alginolyticus* among others (Table 4 and 5) in water and fish samples from Jebba Lake presents significant health risk due to the presence of pathogens among the isolates. This result agrees with Byamukama *et al*., (2000), who states that “Faecal coliform counts and *Escherichia coli* detection is the most reliable tool for assessing health risk posed by pathogens in water.”

High concentrations of lead, copper and cadmium observed in station Jl.2 may be due to the washings of ore slurry and automobiles that were carried out around this station. These activities may account for these heavy metals and they can easily be washed down into the lake. This result agrees with Salaudeen *et al*., (2016) who reported that Mining areas are the chief areas where heavy metal pollution readily occurs, in which the surrounding environment receives it first. The high concentrations of lead, copper, cadmium and arsenic observed during the wet season over the dry season may be due to increased introduction of pollutants from adjacent farms due to runoff. This result agrees with the findings of Nsofor and Ekpeze (2014) who reported higher concentration of heavy metals in water during the wet season compared to the dry season. The high concentration of Lead (Pb) observed in the intestines of both *Oreochromis niloticus* and *Clarias gariepinus* above all other heavy metals may also be due to the human activities such as automobile washing. Mining activities such as gold mining practiced in the vicinity of the lake as well as washing of automobiles may create a non-point source pollution where this metal can be easily washed into the lake.

Variation in concentration of heavy metals in the organs of fish may be due to high or low tendency of the organ to absorb and bioaccumulate heavy

metals. It may also be due to individual function of the organ in the body. Higher

concentration of heavy metals in the intestines is consistent with the findings of Ozturk *et al.,* (2009) who reported higher concentration of Lead, Copper,

Cadmium and Chromium in the intestines than in gills and flesh. Intestines are the

ultimate depository of all substances coming into the fish alimentary canal (Olowu

*et al*., 2010).

# CONCLUSION AND RECOMMENDATIONS

Jebba Lake is experiencing pollution due to increasing human activities such as illegal mining activities, the use of fertilizers, pesticides and herbicides on farm lands, animal husbandry operations, oil / lubricants and corrosion of metallic blades of turbines and generating plants. Other sources of pollution into the lake include direct washing of automobiles (motor cars and bikes) into the lake and also washing of domestic utensils. These gave rise to the pollution status of the lake with the concentration of lead (Pb) in the intestines of both *Oreochromis niloticus* and *Clarias gariepinus* being observed to be above Maximum permissible limit. There were also the presence of faecal coliforms and bacterial pathogens in the water and fish samples. No bacterial pathogen was isolated from fish muscles. It is therefore recommended that, the intestines of these fish species that were studied be consciously removed before consumption. Although no bacterial pathogen was isolated from the fish muscles (edible part of the fish), it is advisable that these fish species from the lake be subjected to proper handling (washing, smoking, boiling) before consumption. This is to prevent cross contamination.

Mining activities should follow international best practices; hence direct washing of slurry into the lake should be prevented. Direct washing of cars and

motor bikes into the lake should be checked. Grazing ranches should be

established for animal husbandry operations. Public health enlightenment campaign will be necessary to create awareness on the danger of indiscriminate

dumping of wastes into the lake. Waste management agencies such as FEPA

should be adequately empowered to arrest and prosecute offenders.

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