

Evaluation of Heavy Metals Concentrations in *Oreochromis niloticus* and *Clarias gariepinus* from River and Aquaculture Systems within Owerri Metropolis, Imo State Nigeria

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Abstract: People tend to rely upon fish as a source of cheap animal protein and a vital resource to sustain life. *Oreochromis niloticus* (tilapia fish) and *Clarias gariepinus* (cat fish) were collected from two rivers (Nworie and Otamiri rivers) and two fish ponds (FUTO and Philip's fish ponds in Owerri municipal). The heavy metals analyzed were mercury (Hg), cadmium (Cd), iron (Fe), nickel (Ni), zinc (Zn), lead (Pb), and chromium (Cr) using FS 240 Varianatomic absorption spectrophotometer (AAS) SpectrAA. Catfish accumulated high level of Hg concentrations (> 1.40 ppm) in the sample sites, Cd concentration was also high in cat fish (8.33 ppm) sampled from Nworie river while the other sample sites recorded < 1 ppm. Also, Fe recorded concentrations above 4 ppm with highest concentration of 30.8 ppm; however, tilapia fish accumulated more Fe concentrations than the cat fish. Heavy metals values in the fishes were above the maximum permissible limits of established standards for fish consumption. Data collected were subjected to *t*-test and analysis of variance (ANOVA), and there was no statistical difference ($p > 0.05$) between the heavy metals contents of fishes from the rivers and fish ponds studied. The total heavy metals concentrations studied accumulated from the different sample sites were in this order: tilapia fish: Nworie river (5.96 ± 4.36) $>$ Otamiri river (4.87 ± 3.32) $>$ Philip's pond (4.87 ± 3.19) $>$ FUTO pond (1.62 ± 1.40) while in cat fish: Nworie river (4.02 ± 1.66) $>$ Philip's pond (3.60 ± 2.10) $>$ Otamiri river (2.43 ± 1.54) $>$ FUTO pond (2.27 ± 1.38). There is need for periodic monitoring and assessment of heavy metals in water bodies and various aquatic lives that serve as a source of food to human.

Key words: Heavy metals, aquaculture system, rivers, spectrophotometer, bioaccumulation, fish, pollution.

1. Introduction

Fish and fishery products are generally considered as significant part of a healthy diet [4]. Apart from being a source of cheap animal protein in the developing world, they contain other important nutrients, omega 3 fatty acid and are low in saturated fat [23]. In the same manner, fish serves as the main source of protein for the population in Imo state and Nigeria at large. However, fish accumulate significant

amounts of trace elements and heavy metals [14, 18].

Over the last fifty years, there has been an upsurge in the number of chemical compounds identified to be present in natural and artificial waters. Majority of these chemicals discharged into aquatic ecosystems are from different natural and anthropogenic sources such as industrial or domestic sewage, urbanization, storm runoff, leaching from landfills/dump sites and atmospheric deposits [24, 32]. Heavy metals in the aquatic environment affect the aquatic biota and pose a risk to fish consumers, such as humans and other wild life [7]. Heavy metals exhibit toxic effect on aquatic organisms through bioaccumulation and enter

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into the human body after consumption of these organisms thereby causing health hazards. Heavy metal contaminations have devastating effect on the ecological balance, the recipient environment, and a diversity of aquatic organism [6, 30]. Among animal species, fishes are the most susceptible to heavy metal accumulation in the aquatic environment [25].

Heavy metals enter a fish organ through food, zooplankton, phytoplankton, and benthic fauna or in a larger degree by the gills and skin and in the process they bioaccumulate. The region of accumulation of heavy metals within fish varies with route of uptake, heavy metals, and species of fish concerned. Their potential use as biomonitors is therefore significant in the assessment of bioaccumulation and biomagnification of contaminants within the ecosystem. Concentrations of heavy metals in the organs of fish are determined primarily by the level of pollution of the water and food. Under certain conditions, chemical elements accumulated in the sediments of water bodies can migrate back into the water meaning that silt can become a secondary source of heavy metal pollution [2].

The effects of heavy metals have been shown in a small fishing village near Minamata Bay in Japan (1953-1960) where a plastic factory had been discharging mercury wastes into Minamata Bay, 700 people died, 22 babies were poisoned prenatally, and 9,000 were left with degrees of paralysis and brain damage after they had eaten fish, shell fish and cephalopod which were intoxicated by methyl mercury [22]. Also in Minamata, archived umbilical cord bloods from 151 placentas (saved by women due to Japanese tradition) were correlated with the methyl mercury exposures and a degree of neurological damage diagnosed in offspring [16]. Similar accident happened in Niagata in 1970 where people had eaten sea fish with high concentration of methyl mercury. Almost at the same time, increased concentrations of heavy metals and metalloids were noticed in fresh water fish in the open waters of Sweden and Canada

[3]. Toxic substances may knock down immune reproductive, nervous, and endocrine systems in animals and these effects can be at organ, tissue, and cell nerves [15]. Toxic metals can affect man through inhalation, ingestion, in skin contact and along food chain resulting to neurotoxic, haemotoxic, nephrotoxic conditions on the respiratory and reproductive systems [11].

In Imo state, Nigeria, Alinnor and Obiji [5], performed a study to examine heavy metals (Pb, Fe, Cd, Mn, Hg, Cu, and Zn) composition in fish samples from Nworie River and in frozen fish samples purchased from Ekeonunwa market. They pointed out that untreated waste products discharged into Nworie River contaminated the biota in the aquatic system with the heavy metals. Also they found that frozen fish samples purchased from Ekeonunwa market were contaminated with heavy metals.

Knowledge of the changing concentration and distribution of heavy metals in the environment is a priority for good environmental management programmes all over the world [8, 10]. The aim of this study was to determine the concentrations of heavy metals of some fish species collected from natural source(s) and fish ponds as a possible source of pollution indicator and to determine if the heavy metals present exceed the permissible limits.

2. Materials and Methods

2.1 Study Locations

2.1.1 Source A (Otamiri River)

Otamiri River (Fig. 1) is one of the main rivers in Imo state, Nigeria. The river runs south from Egbu past Owerri and through Nekede, Ihiagwa, Eziobodo, Olokwu Umuisi, Mgbirichi, and Umuagwo to Ozuzu in Etche, Rivers State, from where it flows to the Atlantic Ocean. The length of the river from its source to its confluence at Emeabiam with the Uramiriukwa River is 30 km. The Otamiri watershed covers about 10,000 km² with annual rainfall of 2,250-2,500 mm. Otamiri

River is polluted from the effluents of wastewater treatment plants, domestic and industrial effluents.

2.1.2 Source B (Nworie River)

The Nworie river ((Fig. 1; joined to the Otamiri river at Nekede in Owerri) is about 9.2 km in length. The Nworie river is subject to intensive human and industrial activities, and is used as a source of drinking water by the poor when the public water system fails. Waste management in Owerri is inefficient and contributes to the pollution of the river.

2.1.3 Source C (Fish Hatchery)

Fish hatchery from the Fish Laboratory, Department of Fisheries and Aquaculture Technology, Federal University of Technology, Owerri, is located at Latitude 5°27'50.23" N and Longitude 7°02'49.33" E Owerri West, Imo State (Fig. 1). This fish farm uses pelleted feed and ground water for cultivation of fishes.

2.1.4 Source D (Philip's Fish Pond)

Philip's fish pond is a private fish farm located at Control along World Bank road in Owerri, Imo state (Fig. 1). It employed the use of ground water and sea water for cultivation of fresh water and marine species respectively. Philip's fish pond also uses artificial pelleted feed and tap water for cultivation of fish.

2.2 Preparation of Sample

A total of 12 fish samples were used for analysis with three being collected from each site at arbitrary points. The samples were washed with distilled water and oven-dried at 70 °C for 72 hours using Searchtech DHG electrothermal oven. The oven-dried samples were pulverized using electric blenders and sieved to a uniform particle size of 1.18 mm and labelled appropriately. And 10 g of each of the ground fish samples were weighed, transferred into a 250 mL conical

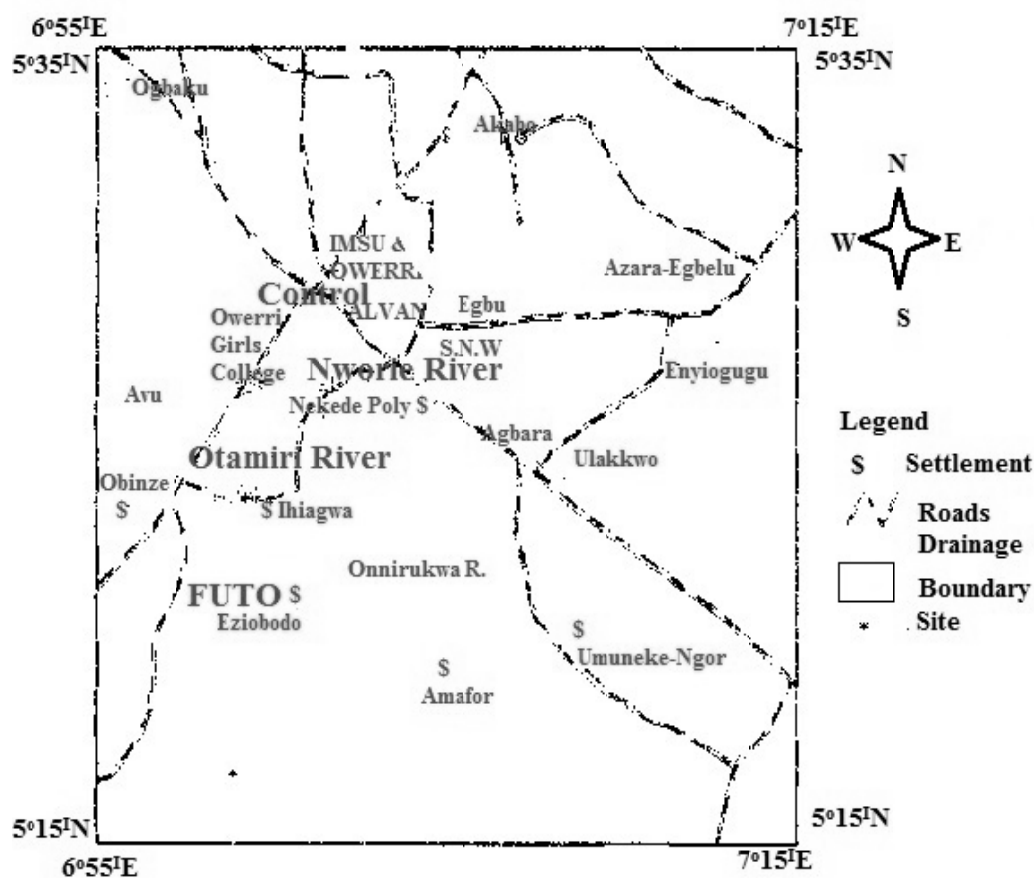


Fig. 1 Map of study areas.

flask and 100 mL of aqua regia was added and set aside to dissolve for 1 hour. The conical flasks and their contents were placed on a hot plate at temperature of 120-160 °C in a fume cupboard for 3 hours until a clear solution of about 2-5 mL was obtained. The content in the flask was allowed to cool and then transferred into a 25 mL volumetric flask by filtration and made up to the mark with deionized water. The reagent blanks were prepared accordingly to determine the purity of the reagents.

2.3 Preparation of Standards

Standards of Hg, Pb, Cd, Cr, Zn, Fe, and Ni solutions of different concentrations were prepared from each of the heavy metal solution of 1,000 ppm stock solution of the analyte, a sub-stock of 100 ppm was prepared using $C_1V_1 = C_2V_2$, then five different standards were obtained from the sub-stock solution of 100 ppm. The set of standard solutions and the titrates of the digested samples were analyzed by FS 240 Varian atomic absorption spectrophotometer (AAS) SpectrAA. Hg, Pb, Cd, Cr, Zn, Fe, and Ni cathode lamps were used for the analysis of the respective heavy metal ions in the standards and the filtrate of the samples.

2.4 Analysis of Sample

The samples were thoroughly mixed by shaking, and 100 mL of each sample was transferred into a beaker of 250 mL volume. The samples were aspirated into the oxidizing air acetylene flame. When

the aqueous sample was aspirated, the sensitivity for 1% absorption was observed. The limits of detection of the equipment for the different heavy metals analyzed were 0.001.

2.5 Statistical Analysis

The values obtained for the various heavy metals in the fishes were represented in bar charts. Further statistical analyses were carried out using *t*-test and Analysis of Variance (ANOVA). The *t*-test and ANOVA were performed using software via Statistical Packages for Social Sciences (SPSS) and Microsoft Excel.

3. Results

The mean concentration of heavy metals in the fish samples obtained from the study sites is illustrated in Table 1. Results showed that there were no significant differences between the heavy metals levels of fishes from rivers and fish ponds. Chromium levels in all the sample locations were below the limit of detection of the machine (0.001).

Mercury levels of tilapia fishes from Otamiri River and FUTO pond were below the detection limit of 0.001. The highest mercury level in the fish samples from Philip's pond was found in the tilapia fish (1.4 ppm). In cat fish, the distribution pattern for the mercury levels was as follows: Philip's pond < FUTO pond < Nworie river < Otamiri river. The fish samples from Otamiri River had the highest mercury level (3.7 ppm), while the Philip's pond (1.4 ppm) had the least

Table 1 Heavy metal levels of fishes.

Metal	Otamiri River		Nworie River		FUTO pond		Philip's pond	
	Tilapia	Catfish	Tilapia	Catfish	Tilapia	Catfish	Tilapia	Catfish
Mercury ppm	ND	3.70	0.10	1.70	ND	1.60	1.40	1.40
Cadmium ppm	0.24	0.27	0.25	8.33	0.17	0.16	0.13	0.14
Iron ppm	22.97	11.22	30.80	7.54	0.78	4.09	22.18	13.21
Nickel ppm	0.05	0.06	0.09	0.10	0.10	0.02	0.18	0.04
Zinc ppm	10.03	10.05	9.89	10.00	10.02	9.84	9.95	9.99
Lead ppm	0.80	0.48	0.56	0.50	0.25	0.17	0.25	0.45
Chromium ppm	ND	ND	ND	ND	ND	ND	ND	ND

ND = not detected.

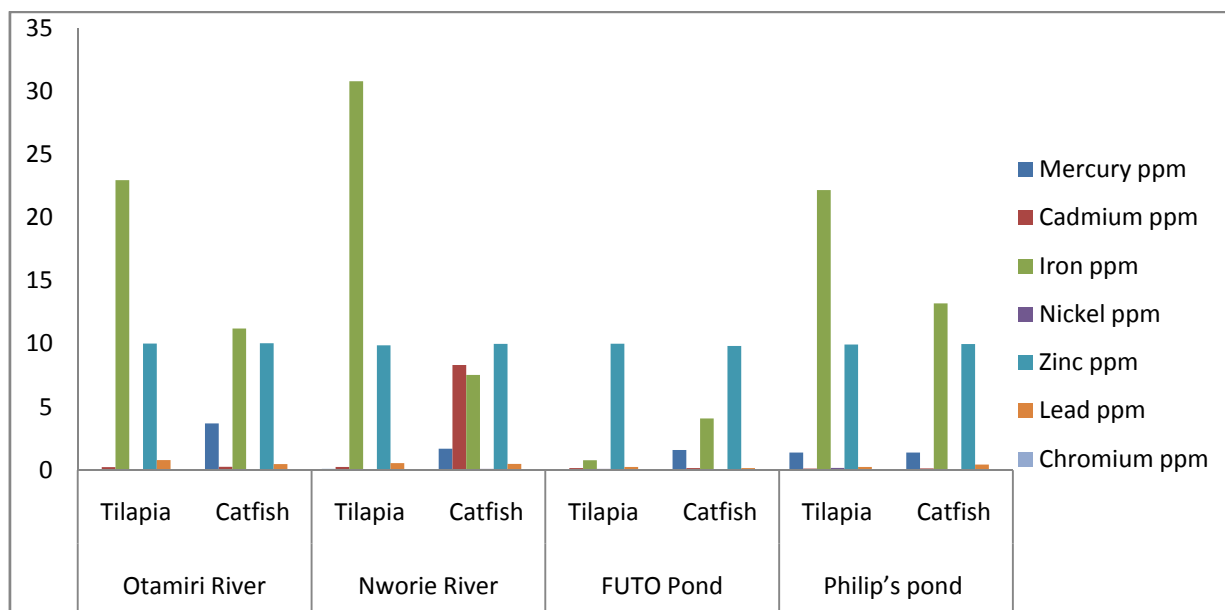


Fig. 2 Heavy metals concentrations in the different sample locations.

(1.4 ppm) (Fig. 2). Cat fish was found to accumulate more mercury than tilapia fish.

Cadmium recorded the highest concentration in tilapia fish from Nworie River with (0.25 ppm), while Philip's pond had the lowest concentration (0.13 ppm). The distribution pattern of Cd levels in both cat fish and tilapia was as follows: Philip's pond < FUTO pond < Otamiri River < Nworie River. Nworie River had the highest Cd concentration of 8.33 ppm, while Philip's pond had the least (0.14 ppm). Cadmium was found to be highest in catfish from Nworie River (8.33 ppm) and least in tilapia fish from Philip's fish pond (0.13 ppm) (Fig. 2).

Tilapia fish from Nworie River had the highest concentration of Fe (30.8 ppm), while FUTO pond had the least (0.78 ppm). The distribution pattern for the Fe concentration in tilapia fish was thus: FUTO pond < Philip's pond < Otamiri River < Nworie River. In cat-fish, the concentration of Fe was highest in Philip's pond (13.2 ppm) and least in FUTO pond (4.09 ppm). The distribution pattern of the Fe concentration in cat fish was as follows: FUTO pond < Nworie River < Otamiri River < Philip's pond. Iron concentration was found to be highest in tilapia fish from Nworie River (30.8 ppm) and least in tilapia fish

from FUTO fish pond (0.78 ppm) (Fig. 2).

Tilapia fish from Philip's pond had the highest Ni level (0.18 ppm) and the least in Otamiri River (0.05 ppm). The distribution pattern of Ni in tilapia fish was as follows: Otamiri River < Nworie River < FUTO pond < Philip's pond. In cat-fish, Nworie River had the highest concentration (0.1 ppm) and the least in FUTO pond (0.02 ppm). The distribution pattern of Ni in cat fish was: FUTO pond < Philip's pond < Otamiri River < Nworie River. Nickel was found to be highest in tilapia fish from Philip's fish pond (0.18 ppm) and least in catfish from FUTO fish pond (0.02 ppm) (Fig. 2).

The lowest Zn concentration was found in tilapia fishes from Nworie River (9.89 ppm), while Otamiri River recorded the highest concentration (10.03 ppm). The distribution pattern of the Zn concentration was: Nworie River < Philip's pond < FUTO pond < Otamiri river. In cat-fish, the concentration of Zn was highest in Otamiri River (10.05 ppm) and lowest in FUTO pond (9.84 ppm). The distribution pattern of the Zn concentration in cat fish was as follows: Otamiri river < FUTO pond < Philip's pond < Nworie river. Zinc was found to be highest in cat fish from Otamiri River (10.05 ppm) and lowest in catfish from

FUTO pond (9.84 ppm) (Fig. 2).

Lead recorded the highest concentration in the tilapia fish from Otamiri River with 0.80 ppm, while Philip's pond and FUTO pond had the lowest concentration of 0.25 ppm. The distribution pattern was Philip's pond < FUTO pond < Nworie river < Otamiri river. In cat-fish, the distribution pattern for the lead concentration is as follows: FUTO pond < Philip's pond < Otamiri River < Nworie River. Nworie River had the highest lead concentration of 0.50 ppm, while FUTO pond had the least concentration (0.17 ppm). Lead was found to be highest in tilapia fish from Otamiri River (0.80 ppm) and least in catfish from FUTO fish pond (0.17 ppm) (Fig. 2).

4. Discussion

The fishes accumulated mercury, cadmium and iron concentrations that were above the maximum permissible limits for fish consumption proposed by FAO [14], USFDA [29] and WHO [31]. This high level of Hg, Cd and Fe can be attributed to the discharge of untreated waste products into the river. Nworie river is surrounded by institutions (Federal Medical Center Owerri, Alvan Ikoku College of Education and Holy Ghost College) and Otamiri River is linked with Nworie river and also has institutions that find their way into the river through run offs. The ponds received heavy metal contamination through infiltration from underground water and tap water that were used for the cultivation of fish.

The high levels of mercury (> 1.40 ppm) recorded in this study may be due to industries, institutions, breweries and automobiles that discharge waste products into the river. Cat fish accumulated more mercury concentrations and can be deduced that this species of fish is prone to mercury contamination. Hence, people who constantly catch/take fish from the study sites may be accumulating mercury in their body through consumption therefore at a health risk. Mercury is not essential in the body even in trace

amounts. They are toxic to the body and their presence affects the nervous system, which includes depression and lack of concentration [19].

Cd is not an essential element for humans, animals and plant. In Saudi Arabia, Abdel-Baki et al. [1] found the concentration of Cd to be 0.0075 ppm, which was lower than concentrations of the present study (< 1 ppm). The WHO/FAO has determined a maximum tolerable weekly intake of 7 µg Cd/kg of body weight [29] while the EU maximum residue limit (MRL) permitted in fish is 0.1-0.3 µg/g for Cd [17]. The result of this study falls within the range of MRL, except cat fish from Nworie River with concentrations of 8.327 ppm. The high accumulation of Cd in cat fish obtained from Nworie river indicates the level of house hold wastes and industrial wastes that are continually discharged into the river. Also, it can be attributed to the extent of receiving pollution occurring at the time of sample collection. It is reported that, intoxication with Cd in pregnant women has been related to reduced pregnancy length and newborn weight and recently, to disorders of the endocrine and/or immune system in children [26] and results to bone defects in man.

Iron is an essential part of haemoglobin; the red colouring agent of the blood that transports oxygen through our bodies. Fe recorded concentrations higher than 4 ppm with highest concentration of 30.8 ppm. Tilapia fish accumulated more Fe concentrations than the cat fish. Increased level of iron may cause conjunctivitis, choroiditis, and retinitis if it contacts and remains in the tissues.

Ni, Pb and Zinc were below the maximum permissible limits for human consumption. High levels of Ni can cause respiratory problems, liver damage, skin irritation, and decreased body weight [20, 28]. Excess amount of Zn can cause system dysfunctions that result in impairment of growth and reproduction while Pb exposure leads to neurobehavioural development [9, 21].

Chromium is not known to accumulate in the

bodies of fish and was not detected in the fish samples from the study sites. However, high concentrations of chromium, due to the disposal of metal products in surface waters, can damage the gills of fish that swim near the point of disposal leading to mortality and decline in fish production.

Tilapia fish from Nworie River recorded heavy metal concentration of Zn (9.892 ppm), Ni (0.086 ppm) and Pb (0.56 ppm) and did not exceed the maximum permissible levels (MPL). This corresponds with the findings of Shareef [27] who also found the following values in tilapia fish as Zn (7.522 ppm), Ni (0.892 ppm), Pb (0.115 ppm).

The assessment of cat fish by Ezemonye and Egbroge [13] in Warri River, recorded the concentration of Cd level to be 0.190 ppm which was a close range with all the values as recorded for Cd (0.266 ppm, 0.157 ppm, 0.125 ppm) in cat fishes from Otamiri River, FUTO fish pond and Philip's fish pond respectively except for cat fish from Nworie River which had 8.327 ppm of Cd. In River Niger and River Benue, Eneji et al. [12] obtained the following results: Zn (18.1 ppm), Pb (3.58 ppm), Fe (68.7 ppm) and Cr (92.9 ppm) and Zn (17.8 ppm), Pb (2.73 ppm), Fe (113 ppm) and Cr (88.5 ppm) respectively. These concentrations were higher than the ones recorded in the present study (Zn (< 10.5 ppm); Pb (< 1 ppm); Fe (< 31 ppm) and Cr; ND). This proves River Niger and River Benue to be highly polluted with heavy metals more than the Otamiri and Nworie Rivers. The reason for high level of pollution could be attributed to geographical location and higher exposure to different pollution sources.

5. Conclusion

The study indicates that effluents are constantly being discharged into Nworie and Otamiri rivers by human activities not considering the health risks of the aquatic ecosystem and biota. Also, the heavy metals contamination of the farmed fish can be attributed to be as a result of the constituents of the pelleted feed,

seepages as well as the ground water used for cultivation of fishes. These toxicants will be transferred to man through the consumption of fish and poses health hazards because of their cumulative effect in the body. The accumulation of heavy metals in the fishes obtained from the sample locations is an important warning signal for fish health and human consumption. The present study has shown that precautionary measures need to be taken in order to prevent future heavy metals pollution and ensure the safety of the environment and aquatic life.

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