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Quality of Reclaimed Water and Reared Catfish Carp in Aquaculture Ponds Receiving Treated Municipal Wastewater: Implications to Human Health

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ABSTRACT

Re-use of treated wastewater for aquaculture and irrigation offers a possibility for water conservation and sustainable food production, however, the issue of human health is crucial. We assessed quality of water and catfish carp (*Clarias gariepinus*) in a fishpond receiving treated effluents from a municipal wastewater treatment plant in Kilimanjaro, Tanzania for physico-chemical water quality parameters, bacteria, nitrogen and heavy metals. Concentrations were compared to WHO standards to assess potential health risks. The water quality parameters conformed to WHO standards. Concentrations of measured toxic metals in water and fish exceeded WHO standards. These results indicate that the reared catfish are not suitable for human consumption.

Introduction

Fish perform all their bodily functions, including breathing, feeding, excreting and reproducing, in the water where they live and grow [1]. The biological, physical and chemical qualities of the water are therefore of critical importance for ensuring sustainability of aquaculture. To a greater extent, the quality of pond water determines the success or failure of an aquaculture operation [1]. Thus the balance and standards of water quality in terms of temperature; amount of acidity and alkalinity (pH); dissolved gases such as O_2, CO_2 and NH_3; total hardness; turbidity; biological oxygen demand (BOD); faecal coliforms; nutrients and some chemical species such as heavy metals are important in operation and maintenance of fish ponds [2].

In some locations of Tanzania, as is in other countries, treated wastewater from wastewater treatment plants are re-used in aquaculture and agriculture [3] as a means of disposal for the water. Wastewater treatment is the process of removing contaminants from municipal runoff and domestic wastewater to produce solid waste or sludge for discharge and a stream of treated outlet suitable for discharging back into the environment in a stream, river, ocean bay, lagoon, wetland or for re-used in activities such as fish ponds, irrigation of rice paddy farms, golf courses, green ways, gardens as well as parks [4, 5]. There are several methods of wastewater treatment, some conventional and some non-conventional. Waste Stabilization Ponds (WSP) is one of the non-conventional methods of wastewater treatment used in Tanzania [3, 6, 7]. WSPs utilize algae, bacteria and solar radiation as the natural processes in breaking down of solids and conditioning the treated wastewater.

Treated wastewater from WSP can be used to make aquaculture ponds, where fish and other aquatic organisms are reared for the purpose of supplementing food and hence fighting malnutrition and providing employment, while at the same time conserving water [8]. However, there are some concerns on the impact of the reclaimed water on both the reared species and the users. Treated wastewater re-use in aquaculture is now receiving more scientific attention, especially because of the associated concerns over public health. Reasonably good quality water from the WSP outlets contains some nutrients, which is an added advantage for application in aquaculture, agriculture and forestation. Fish reared in aquaculture ponds can utilize fresh water with an additional feeds, or re-use treated wastewater with or without added food as the fish can use the organic matter as their food source. However, even if cultured species are able to grow and thrive in a pond, low levels of pollutants may cause the aquaculture products to be contaminated and lead to a possibility of bio-accumulation in the species and therefore risk to human health. Assessment of quality of water as well as that of the produced species should therefore be carried out to safeguard the health of users and to minimize potential undesirable effects on the environment such as eutrophication.

For several decades, communities in Moshi District, Kilimanjaro Region in northern Tanzania have been building ponds for collecting water for their livestock and for irrigation purposes. Currently, the constructed ponds are serving a variety of more purposes, including fish production, fire protection, wildlife habitat, hydro-electric power energy generation, recreation, erosion control and landscape improvement. Typical ponds with surface areas of a quarter of an acre to several acres can be managed for good fish production and recreation.

The Moshi Urban Water and Sanitation Authority (MUWSA) started a fish pond in 2004. The pond, which has dimensions of 18 M length, 11.5 M width and of 1.0 M depth, uses treated wastewater from the Municipal outlets.

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In the treatment process, raw wastewater is passed through a central sewerage system to a wastewater treatment system located at the Mabogini area in the Municipality. The systems consist of nine Waste Stabilization Ponds (WSPs), two small sludge ponds which receive the wastewater brought by the trucks from locations that are not directly connected to the central sewerage system in the Municipality.

The WSPs in this establishment are categorized into an anaerobic pond, two facultative ponds and a series of six maturation ponds of which the second maturation pond is connected to the Horizontal Sub-Surface Flow Constructed Wetland (HSSFCW). The HSSFCW is then connected to the MUWSA fish pond and a paddy farm. The HSSFCW and the fish pond drain their treated wastewater for re-use into some rice and maize farms and then ultimately discharged into the Njoro River. Monitoring of flow rates and physico-chemical parameters at the inlet and outlet as well as cleaning the fish pond are conducted once per week.

Few studies have focused on the integrated wastewater re-use with fish farming in the developing world [9]. In Tanzania, there is no documented study that specifically investigated the quality of water and fish in fishponds that use treated wastewater, nor the quality of the produced fishes in such ponds. In this study, we first quantified levels of some key physico-chemical, chemical and biological water quality parameters due to their importance on pond fish production as well as on the quality of the reared species. We then quantified concentrations of a range of toxic heavy metals in the produced catfish carp in the MUWSA fish pond in Moshi Municipality. The main objective is to assess the suitability of the fish for human consumption.

Materials and Methods

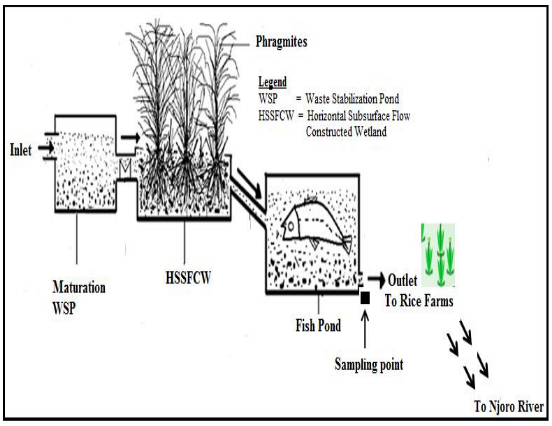
Description of the Study Area

The Moshi Municipality Council is located in Kilimanjaro Region, northern Tanzania, at the foot of Mount Kilimanjaro, between Latitude 3°20´ and 3°25´ South and 37°20´ and 37°25´ East. The Municipal wastewater treatment plant is located at Mabogini area, about 5 Km southern part of the Municipal Council. The climate of the area has a monthly mean air temperature of between 22 °C and 35 °C. The mean annual rainfall is about 1200 mm and the mean elevation altitude is 765 m above sea level. Activities carried out by local residents at Moshi Municipality are mainly farming, livestock keeping and small scale entrepreneurship. The population served by the Moshi Municipal wastewater treatment plant is estimated to be about 600,000 people.

The Moshi Municipal Integrated Wastewater Treatment Plant (IWTP) operates to stabilize wastewater of domestic, industrial and institutional nature. The industries include the Coffee curing, Rafiki and Mazao curings. Other industries like Kibo paper and Moshi leather have their own waste stabilization ponds and constructed wetlands. The institutions joined to the central sewerage system include Kilimanjaro Christian Medical Centre (KCMC), Mawenzi Kilimanjaro Regional hospital, hotels, Moshi Municipal dispensaries, schools, mosques and churches. Treated wastewater used for aquaculture farming in the fish pond comes from the WSPs outlet which was initially passed through the HSSFCW. The water is then released for irrigation of the paddy farms.

Sample Collection

Water samples from the fish pond were collected at the outlet of the pond at the point where water is released for irrigation to the rice farms and then to Njoro River, as indicated in Sketch 1.



Sketch 1. Moshi Municipal Integrated Wastewater Treatment System showing the sampling point at the fishpond

Plate 1. MUWSA fish pond

Plate 2. Rice farm and indigenous trees irrigated with treated wastewater from the fishpond outlet

Grab water samples were collected with white polyethylene bottles which were carefully cleaned with de-ionized water and rinsed three times with the sampled water on site immediately before collection. Samples were collected three times a week in two distinct seasons of the area. The wet season sampling was done from March to June while the dry season sampling was from July to October 2011. Water flow rate, temperature, pH and Dissolved Oxygen (DO) were measured and recorded *"in-situ"* using potable monitors, HACH DR 2500 (2001), while Total Suspended Solids, Turbidity, BOD_5, NH_3-N, TKN, Org-N, NO_2-N, NO_3-N, Chl"a", N-Fish and F-Coliforms were measured in water quality laboratory using the method described by APHA [10]. The catfish carp (*Clarias gariepinus*) species were caught randomly from the pond, stored in cold boxes and transported to the Department of Zoology, University of Dar es Salaam for further processing.

Analysis of Fish Samples

The fish samples were weighed and measured, before being dissected and incubated at 70 ºC to dry for two days. The dried fish muscle tissue samples were cut into small pieces with scissors and ground in a kitchen blender with titanium blades until a smooth mass was obtained. The representative samples of about 50 mg were weighed by a Spring Sartorius BL600 Top Weighing Scale (2005) in a wind seal room. Samples were then placed in test tubes, added with 2 ml concentrated nitric acid (HNO_3) and left overnight for digestion. On the following day, 1 ml perchloric acid ($HClO_4$) was added in each test tube and this was covered and left overnight again. On the third day, distilled water was added to 25 ml volume and then analyzed by Graphite Atomic Absorption Spectrophotometer (Graphite AAS) for concentration levels of five heavy metals, Cd, Cr, Cu, Hg and Pb.

Results and Discussions

Water Quality Parameters in the Fishpond

Levels of the physico-chemical water quality parameters measured at the outlet to the fish pond are summarized in Table1.

Table 1. Results of the physico-chemical water quality parameters measured at the fish pond

Parameter	Dry Season (n = 45)		Rainy Season (n = 45)	
	Max	Mean ± SD	Max	Mean ± SD
Temperature(ºC)	28.6	26.0 ± 2.6	25.3	24.0 ± 1.3
pH	8.5	7.5 ± 1.0	6.7	6.5 ± 2.7
DO (mg/l)	6.7	5.5 ± 1.2	7.3	5.9 ± 1.4
BOD_5 (mg/l)	60.0	54.5 ± 5.5	84.0	59.7 ± 24.3
TSS (mg/l)	1.94	1.48 ± 0.46	2.13	1.91 ± 0.22
Turbidity(NTU)	29.6	25.8 ± 3.8	38.9	34.2 ± 4.7
Org–N (mg/l)	5.5	4.5 ± 0.96	15.6	14.8 ± 3.2
NH_3–N (mg/l)	3.61	3.13 ± 0.50	3.05	2.64 ± 0.41
NO_2^-–N (mg/l)	0.09	0.05 ± 0.04	0.06	0.06 ± 0.05
NO_3^-–N (mg/l)	2.1	1.57 ± 0.45	2.5	1.98 ± 1.46
TKN (mg/l)	8.1	6.5 ± 1.6	19.9	16.6 ±3.3
FC (100/ml)	6.7 x 10^3	4.7 ± 2.0 x 10^3	8.4 x 10^3	7.0 ± 1.36 x 10^3
Chl “a” (mg/l)	547	417 ± 130	225	168 ± 57

Key

Org–N = Organic nitrogen
TKN = Total Kjeldahl Nitrogen
FC = Faecal Coliforms
Chl “a” = Chlorophyll “a”

The data in Table 1 show that temperature ranges were normal for the area during both seasons. The average temperature in the area ranges between 20 ºC and 30 ºC [11]. Generally, the measured temperatures were lower during the rainy season, reflecting the climatic condition of the area, which is cooler during the rainy season months [12]. Studies have indicated that since fish are cold-blooded creatures, their metabolism and hence their growth rate is directly affected by temperature. Recommended temperature range is 26 to 32 ºC, extremely low temperatures have been found to cause death [13]. Another implication of temperature on aquaculture is its effects on the available DO in the ecosystem. High temperatures may cause lower solubility of oxygen. This is supported by different studies that have established the fact that warm water holds less oxygen than cold water. For example, in a similar study conducted in Dar es Salaam city, Tanzania it was revealed that warm water with 32 ºC was able to hold only 7.4 mg/l DO, while cold water at 7 ºC held up to 11.9 mg/l DO at saturation point [14].

The pH ranges during both seasons were within the standards set by the World Health Organization (WHO) [15] and the Tanzanian Standards for Effluents (TSE) [16] of pH 6.5 to 8.5. Generally, pH values were lower during the rainy season. The pH decrease during the wet season could be accounted for by the low algae photosynthetic activities, decay of organic matter and nitrification resulting in less use of CO_2 which in turn decreases pH as was reported in other studies [13]. The significance of pH in fishpond water is its effect on the solubility and chemical forms of various compounds which can be toxic to fish [2]. Furthermore, low pH (< 4) may cause acidic death, while high pH (> 11) may cause alkaline death to the fish [13].

Concentrations of Dissolved Oxygen (DO) in the fish pond shown in Table 1 were generally within the acceptable range, except for a few cases where they decreased slightly due to excretions and the decay of micro-detritus which utilize some oxygen. Rainy season samples had higher concentrations of DO than the dry season samples. This is expected due to the relationship between DO and temperature. Low levels of DO (> 5 mg/l) may reduce feed intake, cause slow growth and is stressful for fish to survive. Depletion of DO in water also encourages microbial reduction of nitrates to nitrites that increases denitrification process and intensifies removal of nitrogen as well as reducing sulphates to sulphides. Dissolved Oxygen levels higher than recommended value has been shown to cause gas bubble trauma to the fish [17]. When compared to other studies, DO levels reported in this study are a bit higher than those reported in Dar es Salaam of 6.44 mg/l from a fish pond connected downstream a HSSFCW and 6.62 mg/l from a fish pond connected downstream a WSP [14]. A similar study reported DO concentration of 5.4 mg/l and 13.0 mg/l in a fish pond in a low cost integrated wastewater treatment system in Zanzibar, Tanzania [18].

The mean concentrations of BOD_5 at the fish pond were 54.5 ± 5.48 mg/l and 59.7 ± 24.29 in the dry season and the rainy season samples respectively, as shown in Table 1. These values are higher than the WHO and the TSE, which set permissible limits at 30 mg/l BOD_5 [15, 16]. The typical range of BOD_5 in raw domestic wastewater is 100 to 300 mg/L, while treated wastewater is expected to have about 20 mg/L or less [13]. Domestic wastewater is also attributed to high levels of phosphate and organic load thus causing higher levels of BOD.The rainy season in this study experienced higher BOD_5 levels probably due to increased sources of oxygen-consuming waste from stormwater runoff from streets during rainfalls.

Results of BOD_5 levels in this study were comparable to those found in Dar es Salaam with concentration levels of 61.15 mg/l and 70 mg/l from fish ponds connected downstream a HSSFCW and downstream of a WSP, respectively [14]. A similar study in Dar es Salaam city, in the country reported an average BOD_5 concentration of 101.45 mg/l from a WSP outlet, which was well above the results of this study [19].

Table 1 also shows that mean concentrations of TSS were 1.48 ± 0.46 mg/l during dry season and 1.91 ± 0.22 mg/l during the rainy season. These concentrations are within the WHO and TSE permissible limits [15, 16]. Similar findings were reported by in Malawi [20]. The relatively higher level of TSS during the rainy season is probably due to the same reason given for BOD_5.

Mean concentrations of turbidity at the fish pond were 25.8 ± 3.77 NTU during the dry season and 34.2 ± 4.69 during the wet season as shown in Table 1, which were within the

WHO permissible limit of 300 NTU in an outlet of treated wastewater [15]. In a similar study reported a mean turbidity of 44.35 ± 5.42 NTU when a fish pond was connected downstream a HSSFCW and 210 ± 3.61 NTU when the fish pond was connected to the WSP that were well above the results of this study [14]. Turbidity and TSS are measures of the level of suspended solids in water, which may be mineral or organic particulates. Among the effects of high levels of turbidity and TSS is to reduce light penetration in the water column which may reduce photosynthesis by submerged aquatic plants and asphyxiate other biota. Turbidity may be caused by inadequate filtration or re-suspension of sediments, or sloughing of bio-film, or death and decay of biomass [21].

Data in Table 1 show that the measured organic nitrogen (Org–N) levels at the fish pond had mean values of 4.5 ± 0.96 mg/l during the dry season and 14.8 ± 3.19 mg/l during the rainy season. The dry season concentrations were within the WHO and the TSE permissible limits of (5 mg/l) [15, 16], while the rainy season concentrations differed significantly with the dry season values and exceeded the limits. This increase is probably due to rainfall run-offs that increased nitrification in the system. The Org-N concentration trends were similar to those of TKN.

Concentrations of NH_3–N which were up to 3.61 mg/l during the dry season and up to 3.05 mg/l during the wet season were significantly higher than the WHO permissible limits of 0.2 mg/l for re-use in fishing and irrigation [15]. NH_3–N levels were generally higher during the dry season because the high temperature and pH during the dry season may lead to an increase in the un-ionized NH_3 concentration in the system. The main source of NH_3 in fish ponds is fish excretion. High concentrations of NH_3–N in a fish pond may cause depletion of DO for the fish respiration, thereby leading to suffocation and death [21]. Variation of NH_3-N concentration is influenced by variation of Org-N mineralization and loading in the effluent.

The highest concentrations of NO_2^-–N were 0.09 mg/l and 0.06 mg/l at the outlet to the fish pond during the dry and the wet seasons respectively, as shown in Table 1. These values were within the WHO and the TSE limit of 1.0 mg/l [15, 16]. The concentration levels imply that there was a nitrification process of NO_2^-–N to NO_3^-–N along the system. The results of this study agree with those reported in a rural community of the Eastern Cape Province of South Africa which measured NO_2^-–N concentrations range of 0.09 - 1.3 mg/l in final outlets of a treated wastewater treatment, although climatic conditions and other factors are different [22].

Table 1 indicates that the mean concentrations NO_3^-–N were 1.57± 0.45 mg/l during the dry season and 1.98 ± 1.46 mg/l during the wet season. The levels were lower than the WHO and the TSE standards [15, 16]. Nitrates may undergo denitrification to inorganic atmospheric nitrogen N_2 or nitric acid (N_2O) and Nitrous Oxide (NO) and hence increase nitrogen removal rate from the system.

The TKN levels at the fish pond were up to 8.1 mg/l during the dry season and up to 19.9 mg/l during the wet season. The permissible limit is 15 mg/l [15]. There is no proven deleterious effect for aquaculture and agriculture in reuse of such an outlet since TKN might range from 10-20 mg/l [16]. A similar study found TKN of up to 33.79 mg/l in another location in Tanzania where a fish pond was connected downstream an HSSFCW [14].

Levels of FC measured in this study were up to $6.71 x10^3$ FC/100 ml during the dry season and $8.4 x10^3$ FC/100 ml during the rainy season. WHO set a guideline of $1x10^3$ faecal coliforms per 100 ml for fishpond water to protect against the risk of bacterial invasion on and in the fish [15]. Concentrations measured in this study therefore exceed the WHO limit. Faecal coliforms bacteria are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. Although generally not harmful themselves, they indicate possible presence of disease-causing micro-organisms that also live in human and animal digestive systems. Their presence in concentrations above allowable limits in treated wastewater used for fish rearing suggests that eating the fish might be a health risk [23]. Furthermore, according to the WHO [15], invasion of fish muscle by bacteria is very likely to occur when fish are grown in ponds containing faecal coliforms exceeding the acceptable limit. Faecal coliforms and other pathogens can be removed from wastewater by combined processes of sedimentation, photolysis, filtration, autolysis or natural die-off or due to ultra-violet rays from the sun [24].

Studies have shown that bacterial levels in water vary significantly with rainfall [14]. In agreement to this, the wet season samples exhibited significant higher levels of FC than the dry season. A some studies found high FC numbers in the outlet of a wetland in the wet season that were attributed to high flows, which could have reduced the hydraulic retention time of the wastewater [25]. High flows increase the velocity of the wastewater flow during the wet season which may affect the biological and chemical degradation of organic matter. A similar study established that dry season samples had higher temperatures and lower levels of FC compared to the wet season samples, suggesting that higher water temperatures were an important factor in reducing the survival of total coliform and other bacteria in water [26].

Data in Table 1 show that during the dry season, Chl “a” levels in the fish pond were up to 547 mg/l, while the wet season levels were up to 225 mg/l. Chl“a” is an important algae growth indicator as high chlorophyll conditions are typically associated with high nitrogen nutrient removal from the ecosystem. Low Chl “a” levels in the pond during the wet season indicate that algae are utilized as food for the zooplanktons in the system.

Concentration of Heavy Metals in Treated Wastewater

Mean concentrations of heavy metals measured in treated wastewater collected from the MUWSA fishponds are summarized in Table 2.

Table 2. Concentrations of heavy metals in treated wastewater at the outlet from the fish pond

Element	Mean concentrations (mg/l) ± SD (n = 15)
Cd	0.12± 0.54
Cr	0.01 ± 0.03
Cu	3.10 ± 0.18
Pb	4.22 ± 3.47
Hg	ND

ND = not detected

Data in Table 2 indicate that apart from Hg which was not detected, Cd, Cr, Cu and Pb were measured in various concentrations. Different organs such as WHO have set concentration limits for metals in reclaimed wastewater used for aquaculture. Examples of used limits are Cd < 0.01 mg/l; Cr < 0.10 mg/l; Cu < 0.20 mg/l, Pb < 0.5 mg/l [27]. These limits were exceeded in four out of the five investigated metals.

Studies have shown that municipal wastewater contain a variety of organic and inorganic substances from domestic and industrial sources, including a number of toxic metals that may be found in significant quantities as a result of contributions from various sources such as industry, residential users and urban runoffs [28, 29]. It has also been revealed that Pb and Cd are among the most commonly encountered toxic heavy metals in wastewater [30]. In agreement to this, concentration of Pb was the highest in this study.

While many heavy metals are removed during the treatment of wastewater some trace concentrations may still be found on the treated effluent depending on the efficiency of the treatment process [31]. Because of their high solubility in the aquatic environments, heavy metals may be absorbed by the reared species. Potential impacts of toxic metals in reclaimed water for fishpond re-use such as the ones found in this study, include bio-accumulation in the reared species and possible adverse effects on their growth, toxicity to the species, and subsequent ingestion by humans who use the species for food. Regular contact with reclaimed water contaminated with toxic metals can also have potential health risks to the pond workers [32].

According to the WHO, preventing chemical pollutants from entering sewers is the best way of preventing chemical pollutants in wastewaters [27], however, this was deemed difficult to achieve where there are many small-scale industries and where industrial zones are not isolated to provide their own wastewater treatment plants [33], such as in this study area.

Concentrations of Nitrogen and Heavy Metals in Fish Muscles

Concentrations of nitrogen in fish ranged from 0.16% to 0. 24%. The WHO standard of animal tissue nitrogen is 4% to 10% [15]. The results of N-Fish from this study therefore indicated that the nitrogen content in the fish tissues may not have effects on human health.

The concentration levels of heavy metals in muscles of common carp fish (*Claries gariepinus*) sampled from the fish pond are summarized in Table 3.

Table 3. Concentrations of Heavy Metals in Muscles of Carp Fish Samples Collected from the Fishpond

Element	Concentration in fish muscles (mg/kg)	
	Dry season	Rain Season
Cd	1.65 ± 0.04	1.29 ± 0.05
Cr	7.36 ± 0.15	0.43 ± 0.02
Cu	5.46 ± 0.12	2.37 ± 0.06
Pb	28.30 ± 0.56	21.66 ± 0.47
Hg	1.27 ± 0.02	1.08 ± 0.04

Data in Table 3 shows that concentrations of Cd in fish muscles were up to 1.65 mg/kg, which far exceeds the WHO permissible limit of Cd in fish tissues of 0.1 mg/kg [15]. This is an alarming observation. Cadmium enters the environment from industrial discharge, metal plating, old used batteries, landfill leachate, leaching from rocks, soils, disposed domestic, industrial and mine wastewater [34]. Studies have established that sources of Cd in the environment included galvanized metals, smelting, photographic materials, oil paints, plastics, sewage sludge and atmospheric deposition. Excess Cd in water and crops may cause liver, kidney, testicular tissue and red blood cells damage, anaemia and toxicity to aquatic biota [35]. Studies have shown that exposure to Cd in levels exceeding permissible limits such as the ones found in this study may have a range of health effects.

The results of Cr levels in fish muscles from this study revealed high concentrations in fish (7.36 mg/kg dry weight) which far exceeded the WHO limit of 1.0 mg/kg [15], which again is an alarming observation. Similar studies in other locations report relatively low levels of Cr in fish muscles when compared to this study, for example, in Nigeria a study reported Cr concentration of 0.04 mg/kg from dry weight in fish muscle [36] whereas in East Calcutta wetlands, India a study reported a level of 2.7 mg/kg dry weight in fish samples [37]. Chromium enters the wastewater from fossil-fuel combustion, cement-plant emissions, old mining operations runoff, used metal plating and waste incineration. Most of these sources are also reported in the study location. Exposure to Cr at high concentrations may cause liver, kidney and respiratory damage, internal haemorrhaging, dermatitis and skin ulcers [37].

With regard to Cu, data in Table 3 show that its concentrations in muscles of carp fish collected from the fish pond were up to 5.46 mg/kg. This concentration although a bit higher than the standard, it is still tolerable. Generally, bioaccumulation and biomagnifications of the metal in the environment, may lead to its uptake in the food chain and become toxic and pose health hazards to humans consuming the fish.

This study found extremely high concentration of Pb in fish samples collected from the fish pond (up to 28.30 mg/kg) indicating a need for taking serious caution. The limit recommended by WHO for Pb in fish tissues is 0.1 mg/kg [15]. Concentration of Pb in treated wastewater samples collected at the outlet from the fish pond (Table 2) was also relatively high.

A similar study by in Iran recorded a level of 0.085 to 1.515 mg/kg in the Indo-pacific king mackerel fish tissues and 0.076 to 0.835 mg/kg in the Tigertooth croaker fish tissues, which were well below the levels established in this study [38]. A similar study in Nigeria Delta reported a level of less than 0.01 mg/kg of Pb in fish tissue, which was well below this study, with no risk of effects on human health [36].

Lead enters the environment from plumbing, leaded gasoline, coal mining and industrial sources that through run-off may enter into the fish pond. Documented health effects of Pb include effect to red blood cells chemistry that may result in increased miscarriages and stillbirths as well as delays normal physical and mental development in babies and young children. In children Pb is said to have the potential of lowering attention span, hearing and learning capacities, leading to loss of up to 2 IQ. The Pb levels of 10 – 20 μg/ml in blood may also cause anaemia, gastrointestinal distress, encephalopathy, brain damage and early death [39].

Concentration of Hg was in tissues of fish collected from the fish pond were up to 1.27 mg/kg. This level exceeded the WHO and TBS limit of 0.01 mg/kg in fish tissues [15]. Documented sources of Hg in the environment include industrial waste, mining, pesticides, smelting, fossil-fuel combustion, coal, electrical equipment such as old used batteries, lamps and switches which through run-off may enter into the fish pond.

Conclusions and Recommendations

Analyses of water and fish samples from a fishpond using reclaimed municipal wastewater in Kilimanjaro Tanzania showed that levels for various physico-chemical water quality parameters are within the accepted WHO guidelines. It was further observed that bacteria levels and nitrogen concentrations were also within safe limits. However, concentrations of the toxic metals Cd, Cr, Cu, and Pb were above the recommended limits in both water and fish muscle samples. The data presented in this study have highlighted that metal contaminants were probably not adequately removed in the wastewater treatment process and that their concentrations in the reclaimed water may have potentially enhanced metal accumulation in the reared catfish species. These results indicate the necessity of improving the quality of the treated effluent prior to its discharge into the fishpond. This can be achieved by conventional treatment processes such as chemical precipitation, ion exchange, and electrochemical removal. The fishpond should be regularly polished prior to discharging the treated effluent. The high concentrations of some of the toxic metals such as Pb suggests that attention should be paid to protect pond workers and populations living close to the pond from unprotected contact with the pond water. The implications of this level of toxic metal concentration are that the reared catfish in the pond are not suitable for human consumption. The study suggests a need for assessing the quality of rice in the fields irrigated by the discharged treated waste as well as quality of the final outlet that is discharged to the River Njoro. There is also a need for investigating organic contaminants and other types of contaminants of emerging concerns in the reclaimed water and fish.

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