Heavy metal levels and human health risk implications associated with fish consumption from the Lower Omo River (Lotic) and Omo Delta Lake(Lentic), Ethiopia

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Abstract

This study ~~was~~ is the first to ~~investigate~~ determine the levels of heavy metals in commercially important fish species~~-~~, namely ~~(~~*Latesniloticus* and *Oreochromis niloticus*~~)~~ and the ~~likely~~ potential human health risks associated with their consumption. A total of ~~One~~ 120~~hundred and twenty~~ fish samples ~~(60 from each water) body~~ were collected from the lower Omo river and Omo Delta, with 60 samples from each water source~~by fishermen~~. The fish tissue samples (liver and muscle) were analyzed using a~~A~~ flame atomic absorption spectrometer ~~to detect~~for ~~was used for the analysis of~~ nine heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn)~~in the fishtissue samples (liver and muscle)~~. The human health risk assessment tools used were the target hazard quotient (THQ), the hazard index (HI), and the target cancer risk (TCR). The mean levels of heavy metals detected in the liver and muscle of L. *niloticus* from the lower Omo River generally occurred in the order ~~of~~ Fe > Zn > Pb > Cu > Mn > Cr > Co > Ni and Pb > Cu > Mn > Co > Ni, respectively.~~Whereas Meanwhile, t~~The mean levels of metals in the muscle and liver tissues of *O. niloticus* were in the order ~~of~~ Fe > Pb > Zn > Mn > Cu > Cr > Co > Ni and Pb > Zn > Mn > Fe > Cu~~.~~> Co > Ni, respectively. Similarly, the mean levels of heavy metals detected in the liver and muscle of *L. niloticus* from Omo delta occurred in the order ~~of~~ Fe > Zn > Pb > Cu > Mn > Cr > Co > Ni and Fe > Pb > Zn > Mn > Cu > Co > Cr > Ni, respectively. ~~While t~~The mean levels in the muscle and liver tissues of *O. niloticus* from the Omo delta were in the order ~~of~~ Fe > Pb > Zn > Mn > Cu > Cr > Co > Ni and Pb > Fe > Zn > Mn > Co > Cu > Ni, respectively. The study revealed that the THQ values were below 1, indicating that consumption of *L. niloticus* and *O. niloticus* from the studied sites does not pose a potential non carcinogenic health risk. Although the TCR values for Pb in this study were within the tolerable range, it~~'~~s mean concentration in the muscle and liver tissues of both fish species from the two water bodies exceeded the permissible limit established by FAO/WHO. ~~The mean concentrations of Pb in the tissues of *L. niloticus*andO.*niloticus*from the two water bodies was above the FAO/WHO permissible limits. There is no potential non carcinogenic health risk due to the consumption of studied fish species as the THQ value is less than~~

~~1.The Pb level in muscle and liver tissues of both fish species was above FAO/WHO permissible limit~~.This ~~results~~ is a warning sign~~al~~ for early intervention, and it emphasizes the need~~-~~ ~~call~~ for regular monitoring of ~~the~~ freshwater fish. Therefore, it is imperative to ~~Consequently,~~ investigate~~ing~~ the pollution levels and human health risks of heavy metals in fish tissues from lower Omo River and Omo delta ~~is imperative~~ for ~~both~~ environmental and public health concerns.

Keywords: Heavy metals, Human health risk, Omo Delta, Omo River

Introduction

Aquatic products including fish are becoming ~~more~~ increasingly popular ~~for human consumption since they are a great~~ as a source of protein, omega-3 fatty acids, vitamins, selenium, and calcium for human consumption (Kalantzi et al., 2016). ~~As part of a balanced diet,~~ T~~t~~he American Heart Association ~~advises~~ recommends consuming two servings of fish per week as part of a balanced diet (Neff et al., 2014). However, it is worth noting ~~at~~that a~~A~~quatic products, due to their high fat and protein content, ~~have favorable health impacts, but they~~ may also contain contaminants~~.~~, which can have negative effects on human health ~~due to since they containtheir high amounts of fat and protein contain, which can have negative effects on human health~~ (Usydus et al., 2009). *Oreochromis niloticus (O. niloticus)* and *Lates niloticus (L. niloticus)* are the most commercially important fish species in Ethiopia. *L. niloticus* sampled from lower Omo River and Omo Delta has a standard length of 45 cm and total length of 180 cm. It has terminal mouth with villi form teeth; dorsal fin long, deeply notched into anterior and posterior regions. Whereas *O. niloticus* sampled from lower Omo River and Omo Delta has a total length of 33 cm which ~~-~~has a mouth terminal with bicuspid teeth on the outer jaws; dark vertical bands on flank; scales between pelvic and pectoral fins distinctly smaller than those on the rest of the body; dark body; blackish opercular spot (Wakjira and Getahun 2016).

Various natural and ~~anthropogenic~~ human caused factors, such as ~~the~~ sewage discharge ~~of~~ from homes or industrial~~ sewage~~, storm runoff, leaching from landfills/dumpsites, and atmospheric deposits, can cause heavy metals to accumulatein aquatic environments (Rahman et al., 2016). Heavy metals are ~~noticeable~~ significant ~~contaminants~~ pollutants ~~of~~ in freshwater ecosystems~~logy~~ and food supplies (Manal et al., 2014) and can pose sever~~serious~~ risks to both humans and aquatic life (Solomon et al., 2016).The risk of consuming ~~danger of eating~~ heavy metals from contaminated food is increasing in developing ~~nations~~ countries ~~such as~~like Ethiopia (Berehanu et al., 2016, Samuel et al., 2020).~~Humans may consume~~ fish muscles that have accumulated heavy metals can be consumed by humans (Lubna et al., 2015, Gure et al., 2019), which ~~could~~ can pose health risks to various vital organs ~~including~~ such as the kidney (Manal et al., 2014), liver , and brain (Safiur et al., 2012),lung , and heart (Mir et al., 2021),and reproductive system at the cellular, tissue, and organ levels (Javed and Usmani,2011).~~The presence of~~ E~~e~~xcessive heavy metals in fish tissues ~~has the potential to~~can negatively impact early development, growth, behavior, and reproduction, ~~as well as~~and damage ~~to~~ the neurological systems of fish species (Taslima et al., 2021). Thus,~~As a result,~~ the accumulation of heavy metals in human diets, including fish, ~~has emerged as~~is an urgent ~~worldwide danger~~global treat that ~~demands~~ requires attention, ~~particularly~~ especially in developing ~~nations such as~~countries like Ethiopia.

In recent years, ~~the lower Omo River (Lotic) and the Omo delta (Lentic) have experiencedanthropogenic~~ human activities such as agriculture~~al~~, industrial, and economic development have affected the lower Omo River(Lotic) and the Omo delta (Lentic) (USEPA, 2010, Wakjira and Getahun, 2017). These activities have threatened the quality of the ~~Lotic and the Lentic~~ water bodies (Ojwang et al., 2010, Avery, 2012),~~which may be related to~~have been linked to the presence of heavy metals in fish tissues. In addition ~~to urbanization along the shoreline, lower Omo River (Lotic) and Omo delta (Lentic) are subject to~~ extensive agricultural processing, manufacturing, and agrochemical-based irrigation projects lower Omo River (Lotic) and the Omo delta (Lentic) are subjected to pollution from urbanization and shoreline (Avery, 2012). ~~Additionally, other~~ S~~s~~tudies have also shown that fish tissues from Lake Turkana, which is located close to the Omo ~~delta~~delta, contain ~~(the subject of the presentstudy), have~~higher levels of heavy metals (Magu et al., 2016, Christof et al., 2017).

To the best of our knowledge, no study has been reported on the level of heavy metals in fish tissues and associated human health risks in the lower Omo River (Lotic) and the Omo delta (Lentic). However, some studies have been performed on the concentrationsof elements in fish tissue from Lake Turkana ~~in~~ on the Kenyan side (Magu et al., 2016, Christof et al., 2017), which is the point where ~~where~~ the southernmost tip of the Omo River extends into it. ~~Thus~~Therefore, it is crucial to determine~~ing~~ the concentrations of heavy metals in fish tissues from the lower Omo

River (Lotic) and the Omo delta (Lentic) ~~is crucial for both~~ environmental and public health issues. ~~Therefore, the present~~The ~~study~~current study aimed to evaluate ~~assess~~the human health ~~risks~~ risks associated with heavy metals present ~~of heavy metals~~ in commonly consumed fish spices (*L. niloticus* and *O. niloticus*) collected from the lower Omo River (Lotic) and the Omo delta (Lentic). The sample were tested for the presence of ~~The concentrations of~~ nine heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn)~~,were measured in the samples, and the noncarcinogenic~~ and carcinogenic health risks to adults and children associated with consuming fish were calculated.

Materials and Methods

Description of the study area

The Omo River (Lotic) basin (**Figure 1**) located in southern ~~is one of~~ Ethiopia, is one of the countries' ~~'s~~ most important river systems , ~~and has a drainage~~covering an area of approximately 79,000 km^2 (CSA, 2017). It starts ~~off in the southwestern Ethiopian highlands~~ at an altitude of 2,200 m above sea level (a.s.l) and flows through the Eastern Arm of the Great Rift Valley of East Africa before finally ending ~~in its lower portion (Omo delta), and finally endsup~~ in Lake Turkana at an altitude of 365 m (a.s.l.) (Wakjira and Getahun, 2017).

The Omo delta (Lentic), ~~is~~ situated in the Eastern Arm of the Great Rift Valley ~~of East Africa(Avery, 2012)~~, ~~and~~ is approximately 50 kilometers from Omorate Town in the downstream direction. It forms a ~~The Omo delta is situated in the Eastern Arm of the Great Rift Valley of East Africa(Avery, 2012)which lies across the Ethiopia-Kenya border in southern Ethiopia lowlands forming~~ Bird's F~~f~~oot D~~d~~elta with an area of 98 km^2 (Wakjira and Getahun, 2017) and lies across the Ethiopia-Kenya border in southern Ethiopia lowlands. ~~It~~ The Omo Delta starts at an altitude of ~~off in the southwestern Ethiopian highlands at~~ 2,200 meters above sea level (a.s.l) and flows in its lower portion (Omo Delta) at an altitude that ends Lake Turkana~~of~~(Wakjira and Getahun, 2017).~~It~~ The Omo Delta ~~isnearly~~ is almost 820km South of Addis Ababa, the ~~(~~c~~C~~apital ~~city)and~~city, and 508km from the regional city of ~~(~~Hawassa~~)~~.

Fish sample collection and storage

Thirty ~~fish~~ samples of ~~from~~fish from each ~~species~~ species, namely ~~(~~*L. niloticus* and *O. niloticus*~~)~~ were ~~taken~~ collected from the Omo Delta Lake and the River water, respectively. The s~~S~~ampling~~ecollection~~ and storage ~~were~~ of these samples strictly followed ~~carried out in accordance with~~ APHA and EMERGE procedures(Rosseland et al., 2001, APHA, 2017). The f~~F~~ish samples were ~~taken~~ collected from fishermen who used plastic nets to trap fresh~~collected fresh traps of~~*L.*

Niloticus and *O. niloticus* from the sampling sites located at [4°48'13.67"N36°2'0.37"E, 4°48'10.80"N36°2'9.16"E, 4°48'4.20"N 36° 2'8.98"E, 4°47'52.59"N 36° 2'4.80"E, 4°47'38.38"N 36° 2'16.96"E] in ~~of~~ the River water ~~using plastic nets~~. The fish samples were washed with deionized water just before dissecting the tissues. The fish were then dissected in the field using plastic blades to obtain liver and muscle tissue. After removal, each liver and muscle tissue samples was carefully covered with aluminum foil and sealed simultaneously in polyethylene bags. The tissues were then separately labeled based on species and tissue type. The wrap samples were cautiously placed in an icebox, and immediately transported to the Arbaminch Minch University of Chemistry Laboratory ~~immediately~~ after dissection and wrapping in an ~~icebox and~~ icebox. The samples were then preserved in a freezer at -20 °C until analysis. The Field experiments were approved by research council of Hawassa University (Approval number bio/499/13).

Sample preparation and digestion

The fish tissue samples were prepared ~~following~~ according to the guideline of the ~~USEPA guidelines~~United State Environmental Protection Agency (USEPA, 2010).~~Accordingly, fish~~The ~~tissues (~~muscle and liver tissues were separately oven dried ~~separately~~ at 60° until they reached constant weight ~~was obtained~~. ~~To make powder,~~ T~~t~~he dried tissues were then crushed ~~using~~ in to a powdered ~~mortar~~using mortar and pestle. The powdered tissue samples weighing ~~(~~0.5g~~)~~each were ~~separatedand~~ready for digestion. Ash digestion was carried out by taking 0.5 grams of muscle and liver tissue, which was ~~subsequently~~ subjected to ~~transferred toa furnace at~~ a temperature of 550°C for 4 hours. After each sample was entirely turned ~~completely~~ in to ash, it was removed and cooled in desiccators. The ash samples were mixed with 10 ml of 20% HNO_3 in 50 ml beakers, placed on a hot plate, and ~~then~~ heated slowly at 120 °C for 30 minutes. After digestion and cooling, dilution and filtration were ~~carried~~ done ~~out~~ using distilled water and filter paper (Whatman No. 42) ~~respectively~~. Digestion was performed ~~using~~ following ~~the protocol~~ analytical method protocol for atomic absorption spectrometry(Perkin, 1996).

Sample analysis

The analysis was ~~carried out~~conducted ~~in~~ accordance ~~with the~~to APHA guidelines~~(APHA~~, 2017~~)~~.~~The heavy metal contents of~~ T~~t~~he fish tissues samples were ~~analysed~~ tested for heavy metal content ~~via~~ using flame atomic absorption spectrometer (FAAS, novAA400p).Calibration curves were prepared using a~~A~~nalytical grade standards of each target heavy metal~~ were used to constructthe calibration curves~~.

Human health risk assessment

Noncarcinogenic risks

The study aimed to determine the potential health risks posed by consuming heavy metals found in fish muscle. This was done by calculating ~~Using the~~ target hazard quotient (THQ) and hazard index, which help to determine the likely hood of non-carcinogenic health hazards in humans.~~it was determined whether consuming heavy metals from fish muscles would likely pose noncarcinogenic health concerns to humans.~~ The THQ result ~~signifies~~ assess the risk posed by a single heavy metals ,while HI results calculate the cumulative risk from all heavy metals found in fish muscle.~~health risk for a single heavy metal whilethe HI result signifies cumulative risk in fish muscle.~~ Values of THQ and HI ~~values~~< 1 indicate that the ~~health~~ risk of ~~effects~~health effects ~~are unlikely to occuron exposed individuals~~is low, ~~. However, when the THQ and HIvalues~~while values ~~are>~~greater than 1.0 suggest that ~~, this implies that~~ potential noncarcinogenic health hazards are likely to occur~~on exposed~~ individuals who consumed fish muscle. The greater the THQ value is, the greater the possibility of risk to the exposed individuals(USEPA, 2011).The noncarcinogenic risk was assessed for both adults and children who ingested fish muscle from the lower Omo River and Omo Delta ,one to seven days per week. The THQ and HI were estimated using EPA guidelines(USEPA, 2011, USEPA, 2019) using equations 1 and 2 below

$$\mathrm{THQ} = \frac{(EF\times \mathrm{ED}\times \mathrm{IR}\times \mathrm{Cm})}{(\mathrm{RfD}\times \mathrm{WAB}\times \mathrm{AT})} 10^{-3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \mathrm{Eq(1)}$$

$$HI = \sum \mathrm{THQ} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathrm{Eq(2)}$$

Where: THQ is a non-carcinogenic health risk; the average life expectancy in Ethiopia is 65 years for adults and 6 years for children. ED is the exposure duration (USEPA, 2005, WHO, 2015); EF is the exposure frequency which is 365 days/year for people who eat fish muscle 7 times a week and 52 days/year for those who eat once a week (FAO, 2014), and IR is the average fish ingestion rate of an individual in a day (g/day/person) which is 30g for adults and 15g for children in Ethiopia (USDA, 2000, USEPA, 2005).The RfD is the oral reference dose which is the daily ingestion of a contaminant that is unlikely to cause health effects during a life time as defined by the USEPA (2003) in mg kg^{-1}/day which is 0.001for Cd, 0.003 (Cr) , and 0.03; 0.040 (Cu), 0.7, 0.020 (Ni), 0.14 (Mn), 0.0035 (Pb) and 0.30 (Zn); BW is the average body weight equivalent to 60 kg for adults and 21kg for children in Ethiopians (WHO, 2012); AT is the average exposure time for non-carcinogens which is 365 days/year x ED; Cm is the average concentration of heavy metals in fish muscles (mg/kg dry weight);WAB is the average body weight .

Carcinogenic risk (TCR)

The target carcinogenic risks (TCR) test estimates an individual’s possibility of developing ‘cancer over a lifetime while exposed to a potential carcinogen and the acceptable risk levels for carcinogens range from 10^{-4} to 10^{-6} ‘(USEPA, 1989).The TCR was estimated using equation 3 below.

$$\mathrm{TCR} = \frac{(EF\times \mathrm{ED}\times \mathrm{Cm}\times \mathrm{IR}\times \mathrm{CSFO})\times 10-3}{(\mathrm{WB}\times \mathrm{AT})} \text{ ……Eq(3)}$$

where: TCR is the target cancer risk; CPSO is an oral carcinogenic slope factor in mg/kg/day with values include1.7 mg kg^{-1}/day for Ni, and 0.5 (Cr), 0.001(Cd) and 0.0085 for Pb(USEPA, 2010). The other parameters are presented in Equations 1 and 2.

Data Quality

The precision of the method and validation of the results were checked via a recovery test (APHA, 2017).The fish samples were spiked with a known concentrations of heavy metals and the spiked samples were digested in triplicate using the same method used for the original samples. The percent recovery was then calculated using equation 4.

$$\mathrm{Recovery} = \frac{(Spiked\ result - Unspiked\ result)}{(\mathrm{Amount\ added})}\times 100\% \quad \text{…..Eq(4)}$$

All recovery values were within the acceptable range (80% -120%) for heavy metal analysis (Harvey, 2000)and are summarized in **Fig 2 below**

Data analysis

The data were analysed using IBM SPSS 21 statistical software. The results of testing normality and homogeneity of variance for data from water bodies were determined using a Kolmogorov-Smirnov and Levene’s tests, respectively, and the data confirm that the water ~~bodies~~bodies’ data has not compromised the assumptions. There for we used nonparametric (Mann-Whitney's U-test) were used to determine the variations in the levels of heavy metals between fish tissues and species.

Additionally, to correlate the effect of one metal concentration on the concentration of the other metal in the water bodies samples, the Pearson correlation matrices using correlation coefficient (r) for the samples were used. The results were compared with the values in the literature and FAO/WHO standard limits.

Results

Levels of heavy metals in ~~*the*~~ *O. niloticus in* the *Omo River and Omo Delta*

Table 1 ~~lists~~ shows the average levels of metals found in *O. niloticus* muscle and liver tissues from the Omo River and Omo Delta. Manganese (Mn) was found in the Omo River at mean concentrations of 0.356 mg kg^{-1} in the liver and 0.379 mg kg^{-1} in the muscle of *O. niloticus*. However, in *O.niloticus* the concentrations of Mn were 0.387 mg kg^{-1}and 0.384 mg kg^{-1} in the liver and muscle respectively. The mean levels of elements in the liver and muscle tissues of *O. niloticus* from the Omo River were in the following order: Fe>Pb> Zn >Mn> Cu > Cr > Co > Ni and Pb> Zn >Mn> Fe > Cu.> Co > Ni. However in the Omo Delta, the mean concentrations of detected elements in the liver and muscle tissues of *O. niloticus* were in the following order: Fe >Pb> Zn >Mn> Cu > Cr > Co > Ni and Pb> Fe > Zn >Mn> Co > Cu > Ni respectively. *O. niloticus* muscle in the liver samples from the Omo river and the Omo Delta both contained no detcetd amount of cadmium. Additionally the order of the detcetd elements in the liver of *O. niloticus* inhabiting both water bodies followed a similar pattern.

The concentrations of Zinc in the muscle tissue of *O. niloticus* ~~was~~ were 0.424 mg kg^{-1} and 0.394 mgkg^{-1}in Omo River and Omo Delta ~~respectively(~~respectively (**Table 1**). The level of liver tissue in *O. niloticus* in the present study was (0.556 mg kg^{-1}) in the Omo Delta and (0.477 mg kg^{-1}) in the Omo River. Copper (Cu) levels in *O. niloticus* muscle tissues ranged from 0.129 mg kg^{-1} to 0.071mg kg^{-1}, with the Omo River exhibiting greater levels. The mean concentrations of Cu in the liver tissues of *O. niloticus* were 0.189 mg kg^{-1} and 0.291mg kg^{-1} in the Omo River and Omo delta respectively.

The average Cr content in *O.niloticus* tissue is displayed in Table 1.The average Cr concentration in *O. niloticus* livers from the Omo River was 0.145mg kg^{-1}, which was less than the average Cr concentration in the Omo delta, which was 0.154 mg kg^{-1}. Cr was not detected in the muscle tissues of *O.niloticus* in the Omo River and Omo delta.

O. niloticus muscle and liver samples from the Omo River and the Omo delta both contained no detected amount of cadmium. The lead (Pb) level of muscle tissues ranged from 0.790 mg kg^{-1} to 0.597 mg kg^{-1} with greater value occurring in the sample from the Omo River. The analysis showed that except for iron and cobalt the mean levels of all detected heavy metals were not significantly different (p.value >0.05) in the mean concentration in the muscle tissue of *O. niloticus* between the Omo River and Omo delta (**Table 1**).

The Omo River and Omo Delta had mean iron concentrations of 0.268 mg kg^{-1} and 0.411 mg kg^{-1}, respectively, in the muscle tissues of *O. niloticus*. The findings of the present study showed that the Fe concentration in the liver of *O. niloticus* was 1.100 mg kg-*1* in the Omo River and 1.74 mg kg^{-1} in the Omo Delta. The average iron concentration in *O. niloticus* muscle samples from the Omo River and Omo Delta was significantly different (p value < 0.01).

The concentration of nickel in the muscle of *O. niloticus* is shown in Table 1. The Omo River and Omo Delta had mean nickel concentrations in the muscle of *O. niloticus* was 0.010 mg kg^{-1} and 0.013 mg kg^{-1}, respectively. However, the current findings indicate that the mean Ni concentration in the liver of O. *niloticus* in the Omo River and Omo Delta are 0.014mg kg^{-1} and 0.018 mg kg^{-1}, respectively. The Cobalt concentrations in *O. niloticus* muscle tissue varied from 0.054mg kg^{-1} to 0.080mg kg^{-1} in the Omo River and Omo delta. There was statistically significant site (Omo River and Omo Delta) dependent (p value < 0.01) variation in the mean Co concentration in the muscle tissues of *O. niloticus.*

Correlation between heavy metals in the fish muscles from lower Omo River and Omo delta is presented in Table 2. The analysis was done to evaluate the correlations among heavy metals in the fish tissues of *O. niloticus* and *L. niloticus*. The results of Pearson's correlation coefficients of the present study in the muscle of *O. niloticus* from lower Omo River revealed that there were significant (p< 0.01, P< 0.05) correlations between heavy metals; Cr and Fe (r=0.753), and Cr and Ni (r=(0.702), Fe and Ni (r=0.65), Co and Fe (r=0.482),and Fe and Zn (r=-0.23). A significant correlation in muscle of *O. niloticus* from Omo Delta was also observed between heavy metals; Cr and Fe (r=0.705), Cr and Ni (r=0.683), Cr and Pb (r=0.533), Pb and Fe (r=0.480), Pb and Cu (r=0.450), Co and Cu (r=-0.381) (**Table 2**).

Levels of heavy metals in *L. niloticus* in the Omo River and Omo Delta

The levels of Manganese in the muscle tissue of *L. niloticus* were 0.383mg kg^{-1} and 0.385mgkg^{-1}in the Omo River and Omo Delta respectively (**Table 3**).The maximum mean concentrationof heavy metals detected in the liver of *L. niloticus* was Fe (2.918 ± 1.47 mg kg^{-1})) and the minimum mean concentration was Ni (0.011±0.003mg kg^{-1}).The Mean levels of the metals in the liver and muscle of *L. niloticus* generally occurred in the order of Fe > Zn >Pb> Cu >Mn> Cr > Co > Ni and Pb> Cu >Mn> Cr > Co >Ni respectively.

The ~~concentration of Zinc in the muscle tissue of *L. niloticus*were~~concentrations of Zinc in the muscle tissue of L. niloticus were 0.642 mg kg^{-1} and0.428 mg kg^{-1}in Omo River and Omo Delta respectively. The Copper (Cu) concentration in *L. niloticus* muscle tissues from the Omo River and Omo delta varied between 0.157 mg kg^{-1} and 0.13 mg kg^{-1}, respectively. However, the mean copper concentration in liver tissues of *L. niloticus* ranged from 0.481 mg kg^{-1} to 0.407 mg kg^{-1} in the Omo River and Omo delta, respectively.

The Chromium (Cr) level ranged from being below detection limit to 0.154 mg kg^{-1}. Greater level of Cr was observed in the liver tissues of *L. niloticus* muscle tissue exhibited significant site (Omo River and Omo Delta) dependent variation in the mean Co concentration (p value< 0.02). The Lead (Pb) level in *L. niloticus* muscle tissues varied between 0.793 mg kg^{-1} and 0.890mg kg^{-1} in the Omo River and Omo delta respectively. As presented in Table 3,the mean Pb concentration in *L. niloticus* muscle tissue significantly differed by site (p value < 0.01) (Omo river and Omo delta). The mean concentration of Fe in the muscle tissue of *L. niloticus* ~~were~~ was 0.509 mg kg^{-1} and 0.94 mgkg^{-1} in the Omo River and Omo Delta respectively. In the Omo River and Omo Delta, the mean Fe levels in *L. niloticus* muscle tissue differed significantly (p value <0.01) (**Table 3**). The Mean nickel (Ni) concentration ranged from 0.011mg kg^{-1} to 0.019 kg^{-1} in the Omo River and Omo Delta respectively. Similarly, the mean nickel concentrationin*L. niloticus* muscle tissue significantly differed (p value <0.01) depending on location (Omo River and Omo Delta).

The results of Pearson's correlation coefficients in the muscle of *L.niloticus* from Omo Delta revealed that there were significant correlation between Cr and Ni (r= 0.623), Cr and Fe (r = 0.622), Cr and Mn (r= 0.604), Pb and Cu (r= 0.526), Ni and Mn (r= 0.519), Pb and Cr (r=0.494).There was also significant correlation in *L. niloticus* in the same water body between metals Cr and Fe (r= 0.671), Co and Fe (r = 0.545), Pb and Co (r =0.517), Pb and Fe (r =529), Pb and Ni (r =-0.454), and Cr and Zn (r = -0.3810)(Table 4).

The difference in mean level of heavy metals between fish tissues and fish species from Omo Delta are presented in Table 5.The mean level of heavy metals between liver and muscle of *L .niloticus* from Omo Delta were significantly different for Zn, Cr, Pb, Fe, and Co. Similar difference was observed in *O.niloticus* for all detected heavy metals except for Zn and Co. Fish species based difference was observed between liver of *O.niloticus and L.niloticus* for Pb, Ni, and Co. Similarly, significant difference was observed –between mean level of Muscle of *O.niloticus* and *L. niloticus* for Pb, Fe, and Ni. Likewise, the differences in mean level of heavy metals among the fish's tissues and species from lower Omo River are also presented in (Table 5),

Human health risk of heavy metals through consumption of fish from the Omo River

The non-carcinogenic health risks associated with the nine heavy metals in children and adults who consumed muscle from *L. niloticus* and *O. niloticus* from the Lower Omo River were assessed using THQ and HI indices. The index results (THQ and HI) obtained by eating the muscle of fish within one to seven times a week are presented in Table 6.The THQs in the muscle of *L. niloticus* and O. *niloticus* decreased in the order Pb> Cu >Mn> Co > Zn > Fe > Ni and ‘Pb> Cu >Mn> Co > Ni >Zn > Fe respectively (Figure 3 and Figure4).

The HI values due to the consumption of *L. niloticus* muscle were 0.558 (for adults) and 1.01(for children). Similarly, the HI values for *O. niloticus* were 0.555 (for adults) and 0.1 (for children).The maximum THQ and HI values were observed for Pb whereas the minimum was observed in Ni (**Table 6**).

In all the evaluated samples, the THQs for heavy metals in fish muscle ingested by adults and children were less than one. However, the Hazard Index (HI) of the detected heavy metals for children was greater than one. The mean contribution of the THQ value to HI showed that Pb, Cu, and Mn contributed about 97% to HI through muscle of fish tissues. Pb while single-handedly contributed about 90% to HI via the muscle tissues of both fish species.

The likely target cancer risk was due to the ingestion of Pb and Ni through muscle of *L. niloticus* and *O. niloticus*for 1 to 7 days a week are presented in Table 7. The target cancer risk (TCR) values in the muscle of both *L. niloticus* and*O. niloticus* were in the order of Ni>Pb (**Table 7**).

Human health risk of heavy metals through the consumption of fish from the Omo Delta

Using the THQ and HI, the noncarcinogenic risks of the heavy metals identified in the muscle of *L. niloticus* and *O. niloticus* from the Omo delta were evaluated in adults (**Table 8**) and children (**Table 9**). Tables 8 and 9 for adults and children, respectively, show the index findings (THQ and HI) from eating fish muscle one to seven times a week. The THQs values in the muscle of *L. niloticus* and O. *niloticus* were in the order Pb> Cr > Cu >Mn> Co > Zn >Fe> Ni and Pb>Mn> Co > Cu > Zn > Ni> Fe respectively. The index (HI) values due to consumption of *L. niloticus* muscle were 0.668 (for adults) and 0.433 (for children). Similarly, the HI values in *O. niloticus* were 0.942 (for adults) and 0.441 (for children).The maximum THQs values were observed for Pb in both *L. niloticus* and *O. niloticus* whereas, the minimum was observed for Fe in muscle of *O.niloticus* and Ni in *L. niloticus.*

The probable target cancer risk due to the ingestion of Cr, Pb, and Ni through the muscle of *L. niloticus* and *O. niloticus* for 1to 7 days a week is presented in Table 10. The target cancer risk (TCR) values in the muscle of both *L. niloticus*and*O. niloticus* were in an order of Ni>Cr>Pb(**Table 10**).The THQ for heavy metals in fish muscle consumed by adults and children was less than one in every sample that was examined, and the Hazard Index (HI) of the identified heavy metals was also less than one.

Discussion

The lead (Pb) level in muscle tissues ranged from 0.597mg kg^{-1}to0.890 mg kg^{-1} with higher in the Omo Delta sample. This may be due to the water nature ~~in~~ of the Omo River and the Omo delta. These results are different from those of Gure et al. (2019), Felly et al. (2020), and Fredrick et al. (2021) who reported mean concentrations of lead at 8.39 mg kg^{-1}, 9.99 mg kg^{-1}, and 5.8 mg kg^{-1}, respectively. The Pb levels in muscle tissues at both the Omo river and Omo delta sites were greater than the previously reported(Magu et al., 2016; Samuel et al., 2020). Heavy agricultural runoff comprising pesticides, agrochemicals, and fertilizers, as well as petrol from fishing boats that contain lead, may be the source of the highest Pb concentration. However, the Pb content in the liver tissue of *O. niloticus* in the present study was lower than that reported by Dugasa and Endale (2018) Pb(1.63 mg kg^{-1})and Pb (6.02 mg kg^{-1}) by Gure et al.(2019).The mean Pb levels in the muscle tissue of *O. niloticus* between the Omo River and Omo Delta were above the FAO/WHO recommended limits in the human diet (FAO/WHO, 2014).These findings showed that muscle tissue from the Omo River and Omo delta is not safe for human consumption due to Pb toxicity.

The lead (Pb) levels in *L. niloticus* muscle tissues varied between 0.793 mg kg^{-1} and 0.89 mg kg^{-1} in the Omo River and OmoDelta respectively. The results of the current study were higher than those of the prior studies on the Pb concentrations of 0.131 ± 0.048 mg kg^{-1} and 0.181 ± 0.664 mg kg^{-1}, respectively, in the River Nile (Aswan) and Nasser Lake, as reported by (Al-Hossainy et al., 2017). Similarly, our finding was higher than the previous study by (Machiwa, 2005) who reported Pb concentration in the range of < 0.01–0.08mg kg^{-1} in Lake Victoria, Tanzania. Additionally, the Pb levels of *L. niloticus* muscle tissues of this finding was higher than earlier report by (Magu et al., 2014; Lubna et al., 2015; Samuel et al., 2020) but lower than those reports by (Felly et al., 2020; Fredrick et al., 2021). Additionally, the Pb levels in the muscle of *L. niloticus* in the present study was higher than the previous report by (Magu et al., 2016), but lower than those reports by (Felly et al., 2020; Fredrick et al., 2021). It's possible that heavy rains carried the wastes down, contributing to the greater metal level in *L. niloticus* (Dural et al., 2007; Saei-Dehkordi and Fallah, 2011). The highest values of Pb could be due to intensive anthropogenic activities like use of agrochemicals, Car washing, gas/fuel station, solid wastes, and effluents from factories. The mean Pb levels in *L. niloticus* muscle tissues were above the FAO/WHO recommended limits in the human diet (FAO/WHO, 1989).

In the muscle of *O. niloticus*, manganese (Mn) was detected in the Omo River at mean concentration of 0.379 mg kg^{-1}. In contrast, the muscle of *O. niloticus* contained 0.384 mg kg^{-1} of Mn in OmoDelta. Rather than the water naturally becoming more enriched with Mn, anthropogenic activities are typically responsible for Mn concentrations in natural waters above 0.2 mg/l (Nagpal, 2001). Salinity, water hardness, pH, and the presence of other contaminants are some of the variables that affect manganese toxicity in aquatic environments.

The results of this study showed that the concentration of Mn in *O. niloticus* muscle (0.379 mg kg-1) was lower than the Mn (1.972 mg kg^{-1}) levels in muscle tissues (*O. niloticus*) reported by Ermias et al. (2015) in Lake Hawassa, Ethiopia, and the Mn (0.77 mg kg^{-1}) concentration reported by Emmanuel et al. (2021) in the Volta River Basin of Ghana. However, these value are comparable to those found in the muscle of *O. niloticus* species from Lake Hawassa as reported by Abayneh et al. (2003) Mn (0.55mg kg^{-1}).The observed value is below the permitted human food intake level established by FAO/WHO in 1989.

Zinc levels in *O. niloticus* muscle tissue were 0.424 mg kg^{-1} in the Omo River and 0.394 mgkg^{-1}in the Omo Delta, respectively. The Zn level in muscle tissues of *O. niloticus* from Omo River (0.424 mg kg^{-1}) of the current findings was comparable with those reported by Zenebe (2011) in Ethiopia (0.26 mg kg^{-1}) but, less than Magu et al. (2014) from freshwater fish in Kenya (0.647 mg kg^{-1}) and 19.36 mg kg^{-1} reported by Lubna et al. (2015) from the Langat River in Malaysia. The present investigation found that the concentration of Zn in *O. niloticus* muscle from the Omo Delta was lower than that in the muscle of the same species as reported by Abayne et al. (2003), Ermias et al. (2015), and Samuel et al. 2020 (4.76 mg kg^{-1}, 21.11 mg kg^{-1}, and 19.36 mg kg^{-1}, respectively). According to FAO/WHO (1989), the mean zinc concentration in the muscle of *O. niloticus* from the Omo River and Omo Delta was lower than the MPL in the human diet. These findings suggest that, in terms of zinc toxicity, *O. niloticus* from the Omo River and Omo Delta may be safe for ingestion by humans.

The concentration of zinc in muscle tissue of *L. niloticus* ~~were~~ was 0.642 mg kg^{-1} and 0.428 mg kg^{-1} in the Omo River and Omo Delta respectively. The level of Zn in muscle of *L. niloticus* in this finding was also higher than the earlier study by zenebe (2011). Similarly, our finding was higher than that of a previous study (Machiwa, 2005),in which the Pb concentration was reported to be in the range < 0.01–0.0189 mg kg^{-1}in Lake Victoria, Tanzania.

Copper (Cu) levels in *O. niloticus* muscle tissues ranged from 0.129 mg kg^{-1} to 0.071 mg kg^{-1}, with the Omo River exhibiting greater levels. The levels are below the maximum permitted limit in the human diet established by the FAO/WHO (1989). The mean copper level of *O. niloticus* muscle tissues in this investigation was higher than the copper amount reported in prior studies by Zenebe (2011) Cu 0.03 mg kg^{-1}. This may be attributed to agricultural runoff, which may carry higher values of these metals and arise from anthropogenic activities such as the use of chemical fertilizers and pesticides in agriculture land. However, the finding of ~~the~~ our study was lower than that of the previous studies, which included Cu (0.419 mg kg^{-1}) (Magu et al., 2014), Cu (13.833 mg kg^{-1}) (Ermias et al., 2015), and Cu (4.64 mg kg^{-1}) (Gure et al., 2019). According to FAO/WHO(1989), *O. niloticus* from the Omo River and Omo Delta had mean Cu concentrations in their muscles that were below the MPL for humans' diets. These findings demonstrated that *O. niloticus* from the Omo River and Omo Delta may be safe for consumptionby humans because of Cu toxicity.

The copper (Cu) level in *L. niloticus* muscle tissues varied between 0.157 mg kg^{-1} and 0.130 mg kg^{-1} in the Omo River and Omo delta respectively. The levels are below the FAO/WHO (1989) maximum permissible limit in the human diet. The mean Cu levels of muscle tissues in O. niloticus of this study were~~as~~ higher than the earlier report by Zenebe (2011). Similarly, the present finding were higher than those of the prior studies on the Cu concentrations in the range 0.001–0.097mg kg^{-1} (Machiwa, 2005) in Lake Victoria, Tanzania. The mean muscle content of Cu in *L. niloticus* of the current study was lower than the previous study reports by (Jhon, 2007; Felly et al., 2020) but lower than the study report by Magu et al (2016).

The current findings showed that the mean Cu concentration in *O. niloticus* liver tissues was 0.407 mg kg^{-1} in the Omo Delta and (0.481 mg kg^{-1}) in the Omo ~~River~~River. These values are ~~, which were~~higher than the ~~values reported~~ findings reported by Dugasa and Endale (2018) which were at ~~for Cu(~~0.029 mg kg^{-1}~~)~~. However, ~~these~~ the results are~~were~~ lower than those of a~~prior~~ previous study that reported a concentration of Cu at ~~(~~8.28mg kg^{-1}~~)~~ (Gure et al., 2019).

According to the findings of the current investigation, *O. niloticus* tissue had a lower Cr concentration than that reported by Lubna et al. (2015); Cr = 1.48 mg kg^{-1}; and Gure et al. (2019); Cr = 10.3 mg kg^{-1}. However, the levels of Cr in the liver tissue of *O. niloticus* was 0.126 mg kg^{-1} in the Omo River and 0.151 mg kg^{-1}in the Omo River, which was lower than the Cr (8.28mg kg^{-1}) levels reported in a report by Gure et al. (2019) from the Gibe River in Ethiopia.

The chromium (Cr) levels ranged from being below the detection limit to 0.154 mg kg^{-1}. Higher level of Cr was observed in the liver tissues of *L. niloticus.* The muscle content of Cr in *L. niloticus* of this result (0.039 mg kg^{-1}) was lower than that in previous studies (Samuel et al., 2020; Emmanuel et al., 2021).However, the levels of Cr in the liver tissue of *L. niloticus*in the current study was higher than the study reported by Dugasa and Endale (2018) and lower than that in the study byGure et al. (2019) from Ethiopia.

The study found that the muscle tissues of *O. niloticus*~~The~~ from the Omo River and Omo Delta had mean iron concentrations of 0.268 mg kg^{-1} and 0.411 mg kg^{-1}, respectively~~, in the muscle~~

~~tissues of *O. niloticus*~~. These levels were lower than those reported by other studies ,such as ~~The results of the present investigation revealed that the muscle tissue of *O. niloticus* had less Fe than that reported by~~ Abayneh et al. (2003) and Samuel et al. (2020), who reported 5.49 mg kg^{-1} and 11.34 mg kg^{-1}, respectively. Similarly, the current study~~findings~~ showed~~that *O. niloticus* have lower Fe levels in their muscle tissues than those found in research~~lower levels of Iron in *O. niloticus* muscle tissues than those found in other research ~~by~~ (Abayneh et al., 2003; Dugasa and Endale, 2018; Emmanuel et al., 2021).Additionally the levels of Iron in muscle tissue were within the alloable limit set by ~~The tissue levels of Fe are below the~~ FAO/ WHO (2011),indicating that they are safe for human consumption. ~~allowable limit~~. Regarding the liver tisuues, the study found that ~~These findings suggestthat, in terms of Fe toxicity, the muscle tissues of *O. niloticus* from the Omo River and Omo Delta may be safe for ingestion by humans. The current study's findings showed that the~~ Fe concentration in the liver of *O. niloticus* was 1.100 mg kg^{-1} in the Omo River and 1.74 mg kg^{-1} in the Omo delta, which was greater than the earlier Fe (0.809mg kg^{-1}) reported by Dugasa and Endale (2018).

The mean concentration of Fe in the muscle tissue of *L. niloticus* ~~were~~ was 0.509 mg kg^{-1} and 0.94 mgkg^{-1}in the Omo River and Omo Delta respectively. The tissue levels of Fe in this study were below the FAO/ WHO (2011) allowable limit. These concentrations are within the FAO/WHO (1989) recommended permissible human diet intake levels. The Ni levelsof muscle tissues in *L. niloticus* in the present finding were comparable to those in previous reports (Zenebe, 2011; Magu et al. (2016); Samuel et al., 2020) and lower than the studies recorded by (Emmanuel et al., 2021).

The results of this investigation showed that the mean concentrations of nickel in *O. niloticus* muscle in the Omo River and Omo Delta were 0.010 mg kg^{-1} and 0.013 mg kg^{-1}, respectively. These concentrations are within the FAO/WHO (1989) recommended permissible human diet intake levels, which cannot impose immediate adverse health effects. The Ni levelsof muscle tissues from *O. niloticus* and *L. niloticus* in the present finding were comparable to those in previous reports (Zenebe, 2011; Samuel et al., 2020) and lower than those in studies (Magu et al., 2016; Emmanuel et al., 2021). The Cobalt levels *O.niloticus* muscle tissues varied from 0.054mg kg^{-1} to 0.082 mg kg^{-1} in the Omo River and Omo delta respectively. The mean muscle level of Cobalt~~o~~ in *O. niloticus* was comparable with the previous report by Samuel et al. (2020) .However;

the mean Co level in the current finding was lower than that in the study recorded of the muscle and liver tissue of *O. niloticus* by Gureet al. (2019).The Cd concentrations in the muscle and liver tissues of both fish species were below the detection limit for the Omo River and Omo Delta Lake.

A T-test ~~At-test~~ ($p<0.05$) was conducted to compare the mean levels of heavy metals in the muscle and liver tissues of *L. niloticus* and *N. niloticus*. The results showed that ~~revealed that~~ there were significant differences in the mean levels of all heavy metals except for Mn, Cu, and Ni in ~~the muscle and liver tissues of~~ *L. niloticus* and Zn and Co in~~. Similarly, significant differences in the mean levels of heavy metals were detected between the muscle and liver tissues of~~ *O. niloticus*~~, with the exception of Zn, and Co~~. Due to their non-biodegradable and persistence nature in the environment, heavy metals cause toxicity in fish by producing oxygen reactive species through oxidizing radical production. Higher level of heavy metals in liver tissue in the present study may adversely affect fish physiology such as hemato-biochemical properties, immunological parameters especially hormones and enzymes, histopathology of different major organs (Shahjahan et al., 2022).

There were also species dependent significant differences in the mean levels of Pb, Ni, and Co in the liver tissues of *L. niloticus* and *O. niloticus*. Likewise, the mean contents of Pb, Fe, and Ni in muscle tissues of both species were significantly different ($P<0.05$). Numerous researchers examined the possibility that variations in the accumulation of heavy metals across different species of fish could be linked to their habitat and eating preferences, such as whether they are omnivores, herbivores, or carnivores (Yılmaz et al., 2005; Kamal et al., 2023).Variations in the mean concentrations of heavy metals between *L. niloticus* and *O. niloticus* in the current study may be attributed to variations in feeding habits and habitat use (Elias et al., 2014; Samuel et al., 2020). Biological factors including age and growing rates of fish species could also be ~~attribute~~attributing to differences in heavy metal concentrations between *L. niloticus* and *O. niloticus* (Yılmaz et al., 2005; Ahmad et al., 2015) of the present study.

The differences in the mean levels of heavy metals between the fish tissues (liver and muscle) in this finding could be due to the ability of various metals to bind with carboxylate oxygen, the amino functional groups, and nitrogen in metal-binding proteins (Uysal et al., 2009; Gure et al., 2019; Pramita et al., 2021).The variations between tissue levels of metals could also be ascribed due to differences in the physiological role of each tissue in which muscle generally accumulates lower levels of heavy metals (Ahmad et al., 2015;Olawusi et al., 2019). Many studies also confirmed that there was variation in heavy metal levels among fish tissues and species (Samuel et al., 2020; Gure et al., 2019), which was also observed in the current finding.

In general, *L. niloticus* showed a greater burden of heavy metals than ~~did~~ *O. niloticus*. This could be due to differences in the behavior and feeding habits of the two species. Thus, the relatively high level of metals in the *L. niloticus* tissues in the present study could be attributedto their feeding habits as they are bottom-dwelling carnivores that feed on zooplankton, shrimp, clams, snails, insects and other fish species ,unlike to *O. niloticus* which feeds on algae and other vegetables (Magu et al., 2016; Elias et al., 2005). Carnivores are more likely to accumulate heavy metals than other fish ~~are~~ (Ahmad et al., 2015). Also this finding has potential ecological implication particularly relating with the level of heavy metals in liver tissues of both fish species from the water bodies. The finding of the study revealed that liver tissue gad higher burden of heavy metals (Pradip et al., 2019).These can cause a variety of fish population morphology such as decrease of hatching rate, feeding behavior, reproductive system which in turn adversely affect aquatic bodies and aquatic ecosystems that has a significant influence on the food chain and freshwater ecology.

A strong significant positive correlation was observed between heavy metals Cr and Fe (r=0.703) in the muscle of *O. niloticus* from both lower Omo River and Omo Delta (r= 0.705). The heavy metals; Fe and Ni (r=0.65), and Co and Fe (r=0.482 had moderate positive correlation whereas Fe and Zn (r=-0.23), and Cu and Zn (r=-0.19) weak negative correlation in the *O. niloticus* from lower Omo River. The strong positive correlation existed among the heavy metals could be due to the similar sources of pollution and similarities in behavior of heavy metals in the water bodies. The negative correlation existed among the heavy metals may due to the difference in source of pollution.

The THQs for heavy metals in fish muscle consumed by adults and children in all of the samples from the Omo River that were analysed were less than one, indicating that people are unlikely to face significant health concerns as a result of ingesting a single heavy metal through consumption of the fish muscles. The Hazard Index (HI) of the discovered heavy metals was also less than one, indicating that, at the time of the study, there was no significant risk to human health from consuming *L. niloticus* and *O. niloticus* muscle tissues from the Lower Omo River source. The mean contribution of the THQ value to HI showed that Pb, Cu, and Mn contributed approximately 97% the HI through the muscle of fish tissues. Pb alone was responsible for 90% of the HI through the muscular tissues of the two fish species. Therefore, in regard to non-carcinogenic dangers, more attention should be given to the Pb level in the muscle of both fish species. Regarding the noncarcinogenic risks, Emanuel et al. (2021) reported that the THQ value for Mn (0.00325) was greater in their study conducted in the Volta Basin River, Ghana, than in the current findings for Mn (0.011). However, these authors reported lower THQs values for Ni (0.000108), Zn (9.2×10^{-5}), and Fe (2.14×10^{-8}) than the present study via intake of *O. niloticus* muscle by children. Similarly, Samuel et al (2020) from their study in Ethiopia from Boicha stream (Hawassa) reported higher THQ values for Fe (0.01), Co (0.001), Ni (0.002), Cu (0.02), and Zn (0.039) than the present findings. However, they reported a lower THQ value for Pb (0.026) than was found in the present study (0.5368) for *O. niloticus* by an adult while consuming one to seven days a week.

For fish sampled from the Omo river, the target cancer risk (TCR) values in the muscle of both *L. niloticus* and *O. niloticus* were in the order of Ni > Pb. The TCRs values for Pb and Ni in this study were within the tolerable range of (10^{-6} to 10^{-4}) (USEPA, 2012) for all levels of exposure. The highest TCRs were observed for nickel in *L. niloticus* and *O. niloticus* muscle consumed by children for Ni was 6.72×10^{-5} and 6.24×10^{-5} respectively. Similarly, the highest TCR value due to *L. niloticus* and *O. niloticus* by adults for Ni was 4.51×10^{-5} and 4.08×10^{-5} respectively. This demonstrated that, for all exposure levels, there was no risk to the health of *L. niloticus* and *O. niloticus* from ingesting Pb and Ni through muscle. It was also observed that children had a higher probability of developing risk when exposed to heavy metal pollution. Emmanuel et al. (2021) from their study in Volta Basin River, Ghana, reported lower target Cancer Risk (TCR) for Ni in children (5.5×10^{-8}) than the present study. Similarly, Samuel et al (2020) from their study in Ethiopia from Boicha stream (Hawassa) reported higher target Cancer Risk (TCR) for Ni in adult (5.51×10^{-5}) than the present study (4.08×10^{-5}). However, they reported a lower TCR for Pb (7.65×10^{-8}) than was found in the present study (1.58×10^{-5}) via intake of *O. niloticus* muscle by adults.

The THQs for heavy metals in fish muscle consumed by adults and children was less than one in all of the Omo Delta samples that were analysed, indicating that people are unlikely ~~that~~ to face significant health hazards as a result of consuming fish muscles that contain heavy metals. The Hazard Index (HI) of the discovered heavy metals was also less than one, indicating that, at the time of the study, there was no significant risk to human health from consuming *L. niloticus*and *O. niloticus* muscle tissues from the Lower Omo River source. As seen from the risk assessment data, more emphasis should be given to the carcinogenic risk of Pb in the muscles of both fish species. Emanuel et al. (2021), from their study in the Volta Basin River, Ghana, recorded a lower THQ value for Mn (0.00325) than the present findings for Mn (0.0062) from *O. niloticus*. They also reported lower THQ values for Ni 1.08×10^{-4}), Zn (9.2×10^{-5}), and Fe (2.14×10^{-8}) than the present study via intake of *O. niloticus* muscle by adults and children. However, compared to the current results, Samuel et al. (2020) found that the THQ values for Fe (0.01), Co (0.001), Ni (0.002), Cu (0.02), and Zn (0.039) were greater in their study conducted in Ethiopia near Lake Hawassa. They did, however, disclose a lower THQ value for Pb (0.026) in muscle *O. niloticus* by an adult while consuming one to seven days a week than the current finding (0.384).

The target cancer risk (TCR) values in the muscles of both *L. niloticus* and *O. niloticus* were in the order of Ni>Cr>Pb in the Omo Delta. The TCR values for Pb and Ni in this study were within the tolerable range of (10^{-6} to 10^{-4}) (USEPA, 2012) for all levels of exposure. The highest TCRswereobserved due to the consumption of *L. niloticus* and *O. niloticus* muscle was by children for Ni 1.11×10^{-4} and 7.58×10^{-5} respectively. Similarly, the highest TCR value due to *L. niloticus* and *O. niloticus* by adults for Ni was 7.75×10^{-5} and5.3×10^{-5} respectively. This showed that, at all exposure levels, there was no risk of cancer from consuming Cr, Pb, or Ni through the muscle ofL. *niloticus* and *O. niloticus*. It was also observed that children had a higher probability of developing risk when exposed to heavy metal pollution. Emmanuel et al. (2021) from their study in Volta Basin River, Ghana, reported a lower target Cancer Risk (TCR) for Ni in children (5.5×10-8) than the present study (1.11×10^{-4}). Samuel et al (2020) from their study in Ethiopia from Lake Hawassa reported higher target Cancer Risk (TCR) for Ni in adult (5.51×10^{-5}) than the present study (5.3×10^{-5}). However, they reported a lower TCR for Pb (7.65×10^{-8}) than the present study (1.22×10^{-5}) via the intake of *O. niloticus* muscle by adults

Conclusions

This study had the objective of measuring the levels of heavy metals ~~e~~ present in the liver and muscle tissues of two commercially significant fish species namely *L. niloticus* and *O. niloticus* found ~~study determined the heavy metal levelsin liver and muscle tissues of the most widely distributed and economically important fish species (*L. niloticus* and *O. niloticus*) as well as the possible risks to human health from the~~ in the Omo River Basin and Omo Delta located in ~~,~~ southern Ethiopia. ~~This study was the first of its kind done and~~ T~~t~~he finds~~ing~~ of the study provided the first baseline information on the level of nine heavy metals in these fish species ~~*L. niloticus* and *O. niloticus*~~from Ethiopian low land freshwater. The levels of a~~A~~ll ~~the levels of~~ heavy metals ~~under~~ evaluated~~tion~~, ~~with the~~ except~~ion~~ of Pb, were within the permissible limits established by the FAO/WHO (1989) for the Omo River. Similarly t~~T~~he levels of all heavy metals under investigation, ~~with the~~ except~~ionof~~ Pb and Cr, were within the permissible limits established by (FAO/WHO, 1989) in the Omo delta. The liver and muscle tissues of *L. niloticus* were found to have h~~H~~igher accumulations of heavy metals ~~were generally observed in the liver and muscle tissue of *L. niloticus* than in~~ those of *O. niloticus*, ~~and generally,~~with the liver accumulating ~~ed~~ more heavy metals than muscle tissues. Overall, the study suggested that there are possible risks to human health from heavy metals contamination in these fish species.

The level of heavy metal pollution ~~found~~ in fish tissue is a cause for concern.~~serves as a signal for quick action~~.While the~~The results of~~ health risk assessments did not ~~indicated that there was no potential damage~~indicate any immediate danger to human health, ~~from exposure to the investigated heavy metals. However~~, the mean ~~Pb~~ levels of Pb detectedin the both liver and muscle tissue of ~~both fish~~two fish ~~species were higher than the FAO/WHO (1989) allowed level, suggesting that freshwater fish~~ from the Omo River and Omo Delta exceeded the allowed level set by FAO/WHO(1989).These suggested that ~~should be~~ regular~~ly~~ monitoring of freshwater fish in this area is necessary.~~ed~~. Furthermore~~Similarly~~, the TCR resulting from Ni exposure ~~via~~ through the consumption of *L. niloticus* and *O. niloticus* muscle is ~~frightening~~ alarming, ~~and~~ as it may increase the risk of cancer ~~in the future, particularly~~ in young people who engage in ~~due to the numerous~~ vigorous and prolonged developmental activities ~~being carried out~~. Therefore, it is imperative to ~~monitor~~monitor~~ing~~ heavy metal levels in the tissues of *L. niloticus* and *O. niloticus*~~is vital and~~, policy makers are advised to take appropriate action at this alarming level to ~~protect~~

safeguard freshwater fish and people from the threat of heavy metal pollution from the lower reaches of the river and Omo Delta.

Authors' contributions

AA: The primary investigator of the study was responsible for the study's conception, design, writing of the proposal, datacollectionprocess, final analysis, and article production. Participating in the study design, GTY, SSS and YSB reviewed and critiqued the entire paper, paying particular attention to the procedure and analysis sections. The final manuscript was read and approved by all the authors.

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Availability of Data and Materials

"The dataset is made available on the manuscript."

Ethical Approval:

Letters of support from the Department of Biology Hawassa University were also obtained. Ethical clearance and approval were obtained from the Hawassa University Institutional Review Board (IRB) and approval number Bio/499/13. "All methods were performed in accordance with the relevant guidelines and regulations".

Consent for publication

"Not applicable "

Conflicts of interest

The authors declare that they have no financial and non-financial competing interests

Declaration

"All the authors have read understood, and have complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors"

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