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# Human Risk Assessment of Consuming Farm Raised Fish in Uyo, Nigeria

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Author IED designed the study, wrote the protocol and the first draft of the manuscript. Author NUM managed the literature searches and the experimental process. Author NUM identified the species of fish. Both authors read and approved the final manuscript.*

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## ABSTRACT

**Background:** Fish farms are usually established in other to achieve self sufficiency in fish production, and to also supplement capture fishery production. This study was carried out to ascertain the risks or otherwise of consuming farm raised fish in Uyo, Akwa Ibom State.
**Methods:** The fish species collected from these farms was *Clarias gariepinus*. The fish feeds (multifeed and coppen) as well as the water samples from the ponds were also analysed. All samples were collected from two commercial fish farms located at different areas in Uyo. These samples were digested and analyzed for the level of six trace metals namely lead (Pb), nickel (Ni), cadmium (Cd), chromium (Cr), cobalt (Co) and zinc (Zn) using atomic absorption spectrophotometer. Target hazard quotient as well as hazard index were calculated for the analysed trace metals. Physicochemical properties of the water samples collected were analysed using standard methods.
**Results:** In general, the highest concentrations of trace metals were present in the feeds except zinc while the lowest concentrations were observed in all the water samples. From the results, it was observed that lead, cadmium and chromium exceeded the maximum permissible limits set by WHO and other international regulatory agencies in water while cobalt and chromium was above permissible limits in fish and feed. From the results, it was revealed that the target hazard quotients

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(THQ) for individual trace metals and hazard index (HI) values based on Ni, Pb, Cd, Cr and Zn were all less than 1. The physical parameters of the water samples obtained from the ponds indicated that all the parameters were within permissible limits except for pH and conductivity.
**Conclusion:** From the results obtained from the target hazard quotients and hazard index calculations, the study established that health risk associated with the intake of these metals via consumption of these fishes was insignificant. However, continuous monitoring of farm raised fishes as well as the feeds given to these fishes is necessary in other to reduce or completely avoid contamination by trace metals.

*Keywords: Target hazard quotients; physicochemical parameters; ponds; fish farms; fish feeds; standard methods.*

## 1. INTRODUCTION

Fish is a very important part of a healthy diet; they are the major sources of healthy long-chain omega-3 fats, high in protein, rich in other nutrients such as vitamin D and selenium, and low in saturated fat. The consumption of fat in fish is of importance because they contribute to the reduction of cardiovascular diseases [1,2] and lead to improvement in learning ability [3]. They also lower blood pressure and heart rates, improve blood vessel function, at higher doses, lower triglycerides and may ease inflammation [4]. Fish is produced from capture and cultured (aquaculture) fisheries operations. Fish farms are usually established in other to achieve self sufficiency in fish production, and to also supplement capture fishery production. According to [5], fish farming otherwise known as fisheries provide food for consumption, employment and financial income, and a food source when other sources are out season. Nevertheless, human beings as well as aquatic organisms are at risk due to an increase of trace metal concentration in the marine environment [6,7,8]. Irrespective of the sources of fish, it has been established that fish are good bio-accumulators of organic and inorganic pollutants, especially trace metals [9]. Trace metals gain access into the aquatic system from natural and anthropogenic sources and get distributed in the water body, suspended solids and benthic sediments during the course of their transportation [10]. Trace metals in fish represent a potential risk, not only to the fish themselves but also to piscivorous birds, mammals and even humans [11]. Metals may enter fish either directly through the digestive tract due to consumption of contaminated water and food, or non-dietary routes across permeable membranes such as gills [12]. Cultured fishes may absorb dissolved elements and trace metals from its feeding diets, pesticides, antibiotics and the surrounding water leading to their accumulation in various tissues in significant amounts thereby exhibiting toxicological effects at target organs [13]. Water quality variables and chemical elements are important determinants of metal availability and toxicity. It is also dependent on the availability of the metal in the ionized form [14]. Water quality is usually influenced by factors such as hardness, pH, dissolved oxygen, temperature, salinity, interactions with trace metal salts and other particles such as suspended solid [15]. One of the measures taken to encourage fish farming is the production of fish feeds. Synthetic fish feeds are usually in the form of granules or pellets which provide the nutrition in a stable and concentrated form, enabling the fish to feed efficiently and grow to their full potential. The feeds are combined with other ingredients such as vegetable, proteins, cereal grains, vitamins and minerals [16]. However, some researchers speculate that all fish feeds contain measurable levels of some contaminants. Thus, one of the primary concerns regarding contaminants in fish feed is the possible human health impacts [17]. Considering the importance of fish, the contamination of its feeds will greatly affect both the fish and the vulnerable population that depends on it as sources of proteins and as a staple food.

The aim of this study was to determine the presence and concentration of contaminants in farmed fish commonly consumed in Uyo, since fish is an important component of the human diet in this area, as well as fish feed commonly used in most fish farms in Uyo metropolis.

## 2. MATERIALS AND METHODS

### 2.1 Study Sites

The samples analyzed were obtained from two different fish farms namely Farm A and Farm B in Uyo local government area of Akwa Ibom State.

## 2.2 Collection and Preservation of Fish Samples

Live and mature samples of *Clarias gariepinus* were purchased from the two fish farms under study. Fish samples purchased were washed with distilled water to remove adhering particles and were stored separately in properly labelled coolers and transferred to the laboratory where they were kept in a refrigerator prior to analysis.

## 2.3 Collection of Water Samples

Water samples from each of the ponds were collected at the depth of about 20 cm from four different points within each pond to form a composite sample. Two separate samples were collected in each pond in properly labelled 2 litre pre-cleaned polyethylene containers prior to analysis. The water samples for trace metal analysis were preserved with concentrated nitric acid, while the other portion not acidified was kept for physico-chemical analysis.

## 2.4 Collection of Fish Feeds

In Farm A, multifeed was given to the fish; while coppen feed was given to the fishes in Farm B. Approximately 50–100 g of each feed was collected from the different farms for analysis. These feeds were grounded with a sterile mortar and pestle into fine particles, which were then stored in different polyethene bags that were properly labelled pending analysis.

## 2.5 Sample Preparation/Digestion

Whole fish samples were used for analysis since these fishes are most often eaten whole. Fish samples were cut into smaller portions with a clean knife. The tissues were oven-dried at 70℃ for 24 hours to a constant weight. The dried sample was then milled with a grinder, stored in dried labelled plastic containers and then stored in desiccators until digestion. Digestion of the samples was carried out based on the standard methods of [18] as follows: 2 g of the ground fish samples from the different farms were put in a clean and pre-weighed crucible. These samples were then ashed in a furnace at 750℃ for 2 hours until white ash was formed. The ashed samples were then leached with 5 ml of 6M HCl and the volume made up to 20 $cm^3$ with distilled water. The same digestion procedure was repeated for feed samples except that it was not washed and dried as the fish samples. All digested samples were analysed in triplicate.

## 2.6 Analysis of Water Samples

### 2.6.1 Trace metal analysis

Water samples for trace metal analysis were pre-treated with nitric acid ($HNO_3$) as outlined by [18]. Trace metal contaminants in the water samples, fish and feeds were determined using Atomic Absorption Spectrophotometer (AAS).

## 2.7 Determination of Physical Parameters of Water

Temperature and pH were determined in-situ, using a mercury-in-glass thermometer and pH meter (Hach model) respectively. Dissolved oxygen (DO) and biochemical oxygen demand (BOD) were determined by Winkler's methods [18]. A multipurpose conductimeter was used to measure the conductivity and salinity, while total dissolved solids (TDS) and total suspended solids (TSS) were determined in the laboratory.

## 2.8 Human Health Risk Assessment

The prospective non-carcinogenic human health risk of consuming the selected fish species, *Clarias gariepinus* contaminated with trace metals was assessed according to the method by [19]. This was done by calculating Target Hazard Quotient (THQ) for each metal in fish from each farm. The hazard quotient is the ratio of single substance exposure level over a specified time period to a reference dose (or concentration) for that substance derived from a similar exposure period. The hazard index (HI), which is the sum of THQs for all contaminants, was also estimated for the fish samples from the different farms. Per capita consumption of fish for Nigeria is estimated by FAO to be 11.2 kg per annum and thus the daily per capita was estimated to be 0.0306 kg per day.

The average daily exposure to each metal for the Nigerian population was therefore calculated using the equation below:

$$THQ = \frac{EF \times ED \times FIR \times C}{RfD \times BW \times At} \times 10^{-3}$$

Intake (mg/ kg/ day) = ($C$ x $IR$ x $FI$ x $EF$ x $ED$) / ($BW$ x $AT$)

Where

- T*HQ* = Hazard quotient (unit less);
- *C* = contaminant concentration in fish (mg/kg);
- FIR = ingestion rate (kg/d);
- *EF* = exposure frequency (d /y);
- *ED* = exposure duration (y);
- *BW* = the body weight (kg);
- *AT* = the averaging time (period over which exposure is averaged in days).

To evaluate the potential risk to human health through more than one trace metal, the hazard index (HI) has been developed [20]. The hazard index is the sum of the hazard quotients as described in the following equation:

$$HI = \Sigma(HQ1, HQ2 \ldots HQn)$$

The average body weight and exposure duration were estimated to be 70 kg and 70 years respectively, while IR, FI and EF were estimated to be 0.0306 kg/d, 100% and 365 d/y respectively. The averaging time (period over which exposure is averaged in days) was also estimated to be 25550 days (365 days x 70 years).

### 2.9 Transfer Factor (TF)

The transfer factor in fish tissues from the aquatic ecosystem and feed which include water and feed was calculated according to [21] and [22] as follows:

$$TF = \frac{\text{Metal concentration in tissue of fish}}{\text{Metal concentration in water or feed}}$$

## 3. RESULTS

A summary of the results obtained in this study are presented in Tables 1-4.

**Table 1. The results of the concentration of trace metals (Pb, Cd, Cr, Co, Zn and Ni) in fish, feed and water samples from farms A and B**

| Sample Id | Pb | Cd | Cr | Co | Zn | Ni |
|---|---|---|---|---|---|---|
| Farm A W(mg/l) | 0.424±0.008 | 0.009±0.003 | 0.287±0.001 | 0.135±0.003 | 0.917±0.004 | 0.027±0.0002 |
| Farm B W(mg/l) | 0.451±0.002 | 0.021±0.004 | 0.244±0.003 | 0.159±0.015 | 0.658±0.002 | 0.015±0.001 |
| Farm A FI(mg/kg) | 1.040±0.003 | <0.01±0.001 | 0.91±0.003 | 0.51±0.002 | 33.55±0.004 | <0.01±0.001 |
| Farm B FI(mg/kg) | 0.94±0.002 | 0.09±0.001 | 0.45±0.003 | 0.34±0.001 | 27.2±0.006 | <0.01±0.001 |
| Farm A FED(mg/kg) | 6.21±0.005 | 0.55±0.002 | 3.76±0.004 | 7.42±0.002 | 20.77±0.004 | 0.44±0.003 |
| Farm B FED(mg/kg) | 9.86±0.002 | 0.37±0.002 | 2.35±0.003 | 8.95±0.001 | 14.92±0.079 | 0.65±0.003 |

*W = water, FI = fish, FED = feed*

**Table 2. Results of physicochemical properties of water samples**

| Parameters | Farm A | Farm B |
|---|---|---|
| Temperature ℃ | 25.90±0.005 | 26.7±0.004 |
| pH | 6.05±0.003 | 5.93±0.006 |
| Conductivity µ/Scm | 700.00±1.022 | 220±0.012 |
| Salinity % | 0.04±0.001 | 0.001±0.000 |
| TDS mg/l | 390.00±0.024 | 114.00±1.005 |
| BOD mg/l | 5.16±0.018 | 4.98±0.003 |
| TSS mg/l | 425.00±0.005 | 235.00±1.250 |
| DO mg/l | 9.12 ±0.003 | 8.6±0.008 |

**Table 3. Calculated transfer factor**

| | Pb | Cd | Cr | Co | Zn | Ni |
|---|---|---|---|---|---|---|
| Farm A(water/muscle) | **2.45** | **1.11** | **3.17** | **3.77** | **36.58** | 0.37 |
| Farm A(feed/muscle) | 0.17 | 0.018 | 0.24 | 0.06 | **1.61** | 0.02 |
| Farm B(water/muscle) | **2.08** | **4.28** | **1.84** | **2.13** | **41.33** | 0.66 |
| Farm B (feed/muscle) | 0.09 | 0.24 | 0.19 | 0.03 | **1.82** | 0.015 |

**Table 4. Estimated Target Hazard Quotient (THQ) and Hazard Index (HI) for Pb, Cd, Cr, Zn, and Ni, for fish obtained from farms A and B**

| Metals | Farm A | Farm B |
|---|---|---|
| | THQ | THQ |
| Pb | $1.1\times 10^{-4}$ | $1.0\times 10^{-4}$ |
| Cd | $1.1\times 10^{-6}$ | $9.8\times 10^{-6}$ |
| Cr | $9.9\times 10^{-5}$ | $4.9\times 10^{-5}$ |
| Zn | $3.6\times 10^{-3}$ | $2.9\times 10^{-3}$ |
| Ni | $1.1\times 10^{-6}$ | $1.1\times 10^{-6}$ |
| Total (HI) | $3.8\times 10^{-3}$ | $3.1\times 10^{-3}$ |

## 4. DISCUSSION

### 4.1 Lead (Pb)

The data presented in Table 1 shows that water, feed and fish samples obtained from these farms were contaminated with trace metals. Lead was identified in appreciable amount in water samples with mean concentrations 0.424±0.008 mg/l and 0.451±0.002 mg/l for farms A and B respectively. On comparing the concentrations with the permissible limit of 0.01 mg/l lead in water as stipulated by [23], the results obtained showed that the mean concentration of lead in the water samples obtained from the ponds in farms A and B far exceeded the guidelines value. This may be attributed to some non-point sources such as run-off from agricultural lands, roads and parking lots within the study area. This result is at variance with 0.004 mg/l reported by [24] for water samples obtained from Tono Irrigation Reservoir in Navrongo, Ghana. [25] reported mean concentrations of 0.207, 0.183, 0.198, 0.189 and 0.66 mg/l in different locations along Nkisa river, Nigeria. [26] equally reported Pb concentration of mean values 0.009 and 0.005 mg/l for Ominla and Oluwa Rivers, respectively.

The mean concentration of lead in the feed was 6.21±0.005 mg/kg and 9.86±0.002 mg/kg for farms A and B respectively. [16] revealed that the level of lead in Multi feed and coppen feed obtained in Markudi, Nigeria was 348 µg/kg and 375.00 µg/kg respectively. Trace metals found commonly in fish feed are contributed by the raw ingredients and by a mineral pack added by the manufacturer [17]. Association of feed control official maximum tolerable level for lead is 30 ppm. From the results obtained in this study, the level of lead did not exceed this permissible limit. This implies that the level of lead in the feed may not affect animal performance and should not produce hazardous residues in human food derived from the animal.

The mean Pb level in fish obtained from farms A and B were 1.040±0.003 and 0.94±0.002 mg/kg respectively. These results differ from the concentrations (mg/kg) of Pb recorded for *Hydrocynus forskahlii* (3.51), *Clarias auguillaris* (3.43), *Scomber japonicus* (4.61) and *Scomber scombrus* (4.78), as reported by [27]. [28] Reported mean concentrations of lead in wild and farmed catfish, *Clarias gariepinus* from River Kaduna and Fadama fish pond as 0.70 mg/kg in juvenile river catfish, 0.19 mg/kg for matured river catfish, and 0.13 mg/kg for farmed juvenile catfish and 0.15 mg/kg for matured farmed catfish. [25] working on the trace metal distribution in fish, sediment and water samples from Nkisa river, Nigeria reported that the level of Pb in fish species *Protopterus annectes, Gymnarchus niloticus* and *Clarias gariepinus* were of mean values 0.98, 0.76 and 0.87 mg/kg, respectively. The Food Act 1998 specifies a tolerable level of lead of 2.0 ppm (mg/kg) in fish. Furthermore, [23] set the threshold level for lead at 2.0 mg/kg. From the results obtained in this study, the concentration of lead did not exceed the maximum limits set by the Food Act and WHO.

### 4.2 Cadmium (Cd)

The results obtained revealed that the water samples obtained from Farms A and B had 0.009±0.003 mg/l and 0.021±0.004 mg/l respectively as concentration of cadmium. The WHO acceptable concentration for Cd in drinking water is 0.003 mg/l. The result of the analysis indicates that water samples from Farms A and B were contaminated with Cd when compared to WHO standard. The results obtained differed from the range of 1.5 – 4.4 mg/l reported by [28] for water samples obtained from River Kaduna and Fadama fish pond. The contamination of the pond water with cadmium may be as a result of corrosion of some galvanised plumbing and water main pipe materials that supplies water to the ponds.

Table 1 show that the mean concentration of cadmium in the fish samples from Farms A and B were < 0.01 ± 0.001 and 0.09 ± 0.001 mg/kg respectively. The results in this study differed from the mean concentration of cadmium, 0.02 and 0.03 mg/kg recorded for muscles of *Clarias gariepinus* and *Orechromus niloticus* respectively, which were obtained from Kubanni

River, northern Nigeria by [29]. The results showed that the fish samples from both farms did not exceed the maximum permissible limits of 2 µg/g for cadmium in fish as specified by WHO.

Also, the concentration of cadmium in fish feed from both farms was below the permissible limit as stipulated by WHO.

### 4.3 Chromium (Cr)

Chromium, particularly Cr (III) plays an important role in the body function (metabolic functions, cofactor of insulin etc.) in trace amount but it turns to be toxic when it exceeds the tolerance limit. However, the chief health problems associated with chromium compound are related to chromium (VI). The breathing of dust or mists containing chromium (VI) compounds leads to ulceration and eventual perforation of cartilaginous portions of the nasal septum [25]. From the results obtained in this study, it was observed that the concentration of chromium in the water, fish and feed samples obtained from both farms were above the permissible limits set by WHO. It should be noted that chromium has several oxidation states, primarily as metallic trivalent, which is found in most foods and nutrient supplements [30]. The source of chromium in this research may have originated primarily from the feeds.

### 4.4 Cobalt (Co)

The concentrations of Co in all the study samples are shown in Table 1. The highest concentration of Co (8.95 ± 0.001 mg/kg) was found in feed obtained from Farm B, while the lowest (0.135 ± 0.003 mg/kg) was found in water sample from Farm A. According to [31], Co is required in the form of cobalt-containing vitamin B, which enhances formation of red blood cells. However if cobalt is ingested in large quantities, it may result in pernicious anaemia [32]. From the result, the concentration of Co in the samples analyzed were still within the permissible limit of 1 mg/kg as specified by WHO/FAO except in feeds obtained from both farms.

### 4.5 Zinc (Zn)

Zinc plays an important role in the enzyme system, in the synthesis of the ribonucleic acid, which points to its role in the development of germ and somatic cells [33]. It has been reported that zinc concentration has effect on the hepatic distribution of other trace metals in fish. Studies have shown that excessive concentration of Zinc leads to retardation of growth and may bring about metabolic and pathological changes in various organs in fish [34]. The values obtained for zinc in water, fish and feeds samples from both farms were within the limit stipulated by WHO, indicating that these ponds were not contaminated with zinc.

### 4.6 Nickel (Ni)

Studies have revealed that an uptake of large quantities of nickel may result in respiratory failure, birth defects, asthma, chronic bronchitis and heart disorders. This can also cause various kinds of cancer on different sites within the bodies of animals [35]. From the results obtained in the present study, the concentration of nickel ranged from <0.01 to 0.65 mg/kg. On comparing these concentrations with the maximum permissible limit of nickel (0.5 to 1.0 mg/kg) as stipulated by WHO, it was observed that the concentrations were within the permissible limits, implying that the samples obtained from both farms were not contaminated with nickel.

### 4.7 Physicochemical Properties of Water

The quality of water in terms of physicochemical and biological characteristics in the fish ponds offers the most favourable conditions for the existence of fish as well as other biota which constitute essential components of the food chain [36].

Metal accumulation is affected by some of the same parameters that affect toxicity (water chemistry and particulate matter). As such it is potentially one of the most valuable tools for identifying and quantifying the impact of metals in aquatic environments [37,38,39,40].

Temperature affects the rate of metabolism, feeding pattern, breeding and rate of enzymatic activities in fish [28]. From the results obtained, the temperature of water samples obtained from both farms was lower than 30 – 35°C set by [23].

The pH of the water is important because it affects the solubility and availability of nutrients, and how they can be utilized by aquatic organisms [41]. The values of pH obtained from water samples from both farms indicated that the pH of water sample from Farm A was within the maximum permissible limit of 6.5 – 8.5 set by WHO, and was also within the pH range of 6.5

and 9 for diverse fish production [42]. However, that of Farm B was slightly acidic (5.93). According to [28], low pH may be attributed to the fact that ammonia, a by-product of fish excretion is present in its ionized form.

Electrical conductivity is a measure of water capability to transmit electric current and also it is a tool to assess the purity of water. It is directly related to the concentrations of ionized substances in the water and its nutrient status. From the findings in this study, it was observed that electrical conductivity of the water sample obtained from Farm A exceeded the permissible limit of 250 µ/Scm set by [23], while that of Farm B was below the set limit. The high conductivity of pond water obtained in Farm A may be attributed to the fact that in most cases, water used for aquaculture is usually treated by farmers [28].

Total dissolved solids (TDS) indicate the total amount of inorganic chemicals in solution [43]. A maximum value of 400 mg/ l of total dissolved solids is permissible for diverse fish population [42]. It has been reported by [44] that farmers use artificial animal feeds to augment pond nutrients which has been reported to increase total dissolved solids. Also, excessive organic manure may lead to increase in TDS. From the results, the total dissolved solids in water samples from both farms were below permissible limits, demonstrating that these ponds are favourable for aquatic biodiversity.

Biochemical oxygen demand (BOD) is the measure of extent of organic pollutants in the water body. The current WHO recommendation for cleanliness of a stream has used $BOD_5$ as a measure on the basis that 0 mg/l is considered very clean; 2 mg/l is clean, 3 mg/l fairly clean, 5 mg/l doubtful and 10 mg/l bad [45]. [46] reported that biochemical oxygen demand range of $\geq 2 \leq 4$ does not show pollution while levels beyond 5 mg/l are indicative of serious pollution. From the results, it was observed that BOD of the water samples obtained from both farms was in the range of $\leq 4 \leq 5$, indicating moderate pollution.

The total suspended solids are made up of carbonates, bicarbonates, chlorides, phosphates and nitrates of metals such as calcium, magnesium sodium, potassium, magnesium as well as other particles [47]. The permissible limit for TSS in drinking water is 500 mg/l. From the results obtained in this study, the values for TSS from both farms were within the permissible limit.

Dissolved Oxygen is one of the important and critical characteristics of water quality assessment. Adequate dissolved oxygen is necessary for good water quality, survival of aquatic organism and decomposition of waste by microorganism [48]. These values indicated that ponds in both farms had an appreciable level of dissolved oxygen capable of supporting aquatic life [49].

### 4.8 Human Health Risk Assessment

Hazard ratios and hazard indices calculated for five metals (Pb, Cd, Cr, Zn and Ni) in samples from both farms were all below 1, indicative of a non-carcinogenic effect on human health for all the five metals. This means that the exposure of these metals to the human population from the consumption of farm – raised *Clarias gariepinus* will not result in any considerable health risks that may be associated with the metals.

The accumulation of metals in fish depends on an equilibrium between absorption and depuration rates [50,51], and thus may reflect localized bioavailability of these substances. It also has to do with the concentration of the trace metal in the surrounding water as well as the feeding habits of the fish species [52]. A transfer factor of 1 and above indicates that the metal is biomagnified. The results in this study showed that the transfer factors of all elements in fish with respect to water from both farms were greater than 1 except for Ni. This means that the fish may have undergone bioaccumulation of these elements from these ponds. This could be a further confirmation of a previous postulate that it is the dissolved forms of the trace metals that are effectively available to fish for bioaccumulation [53]. In the case of feed to fish, it was observed that the calculated transfer factor for all the elements were less than 1, except for zinc. This may be attributed to the fact that mineral supplements are usually added to feeds so as to fulfil required limits.

## 5. CONCLUSION

The quality of fishes raised in different farms in Uyo metropolis was assessed. Although the target hazard quotients and hazard indices recorded for the fish species were below 1, indicating that the consumption of these fish may not result in any considerable health risk however, this study revealed that lead, cadmium and chromium exceeded their permissible limits stipulated by various international agencies. This may threaten their continued survival, leading to the reduction in l quantity and commercial accessibility.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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