EVALUATION AND RISK ASSESSMENT OF TRACE METAL IN *Solanum aethiopicum* GROWN AROUND MECHANIC WORKSHOPS IN UMUAHIA ABIA STATE, NIGERIA.

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ABSTRACT

The careless dumping of waste from automobile workshops has significantly increased the concentration of trace metals in the surrounding environment. This study investigated the health risk assessment associated with *Solanum aethiopicum* fruit consumption. Soil and *Solanum aethiopicum,* plant from Umuahia automobile workshop were analyzed for As, Cd, Cr, Cu, Fe, Hg, Li, Ni, Pb and Zn. This was done using Inductively Coupled Plasma Optical Emission Spectrophotometer (ICP-OES), while Hg was analysed using a Cold Vapour Atomic Fluorescence Spectrophotometer (CV-AFS) after acid digestion. The average concentration of As, Cd, Cu, Zn, Fe, Pb, Ni, Hg, Li and Cr in the fruit were 7.16±0.03, 1.68±0.16, 5.03±0.03, 19.45±0.32, 76.21±0.73, 6.23±0.45, 3.87±0.17, 0.0003±0.0001, 0.003±0.001 and 15.35±0.22 mg/kg, respectively. The HRI obtained for Cd was the highest 1.821 while the THQ was 1.82135. Fruit had trace metal concentrations higher than the USEPA, WHO, and FAO's approved permitted standards. Cd, Cr and Pb were determined to be the primary contributing factor linked to the development of health hazards and carcinogenic risk based on the results of the risk assessment. It is therefore appropriate to educate the public on the potential risks associated with consuming garden eggs from Umuahia automobile workshop.

Keywords: automobile workshop; trace metals; risk assessments; *Solanum aethiopicum;* carcinogenic risks

INTRODUCTION

Fruits and vegetables have always been a significant component of human and animal diets throughout history [1]. Fruits and generally speaking, plants provide both nutritional and therapeutic uses as food sources. The fruiting plant *Solanum aethiopicum,* sometimes known as garden egg, belongs to the *Solanaceae* family of plants. It has fruits that vary in shape and colour, and it can reach a height of roughly 2.5 metres. Asia and tropical Africa are its main habitats [2]. This plant has been considered an underutilised crop, presumably due to the lack of scientific research and awareness about it, among other reasons [3].

The garden egg is rich in protein, water, ash, minerals, vitamins, carbs, fat, crude fibre, and other compounds that are important for promoting health and supplementing nutrients [4].

The majority of the fruits have low dry matter

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content and a high moisture content [5]. The fruits of *S. aethiopicum* L. also contain a number of essential mineral elements, such as calcium, magnesium, potassium, sodium, manganese, iron, copper, zinc, and phosphorus [4].

Additionally, they can be used to treat a number of illnesses, including skin infections, swollen joint aches, constipation, allergic rhinitis, asthma, and nasal catarrh [6]. Fruits are a vital part of a healthy diet for individuals of all ages since they are an excellent source of vitamins, fibre, and minerals. The aubergine is a staple of Sub-Saharan African traditional cuisine. At visits, weddings, and other social events, the fruits are distributed as a token of friendship. They are thought to represent fruits and blessings. The characteristics of African aubergine species vary significantly from one another. These include variations in fruit colour and form, plant branching, petiole length, leaf blade breadth, and corolla diameter.

Pollution from the disposal of wasted lubricants is one of Nigeria's biggest environmental issues; it happens significantly more frequently than contamination from crude oil [7]. Many more car workshops are dispersed across the cities of Southeast Nigeria, where auto workers dump or spill lubricating fluids, waste motor oils, and other petroleum-based solvents on any available surface [8]. The way spent engine oil spreads and damages the surrounding towns' agricultural land and waterways has been exacerbated by these erratic patterns. Spent lubricant, often known as waste engine oil, is usually collected and drained during maintenance on automobile and generator engines [9]. Trace metal (TM) contents disrupt the structure and function of the soil, lowering crop quality and productivity and having a negative effect on human health through the food chain. Natural TMs are elements of the crust of the Earth that are present in soils. Nonetheless, a significant enrichment of TMs in agricultural soils is associated with human activities such mining, domestic and commercial wastewater, automobile exhaust, chemical fertilisers, wasted lubricant, and pesticides [10]. Although these heavy metals are necessary in tiny quantities for certain critical biological functions and signals, excessive concentrations of them can be hazardous. Certain heavy metals, which pose a threat to humankind, include lead (Pb), chromium (Cr), arsenic (As), copper (Cu), cadmium (Cd), and Mercury (Hg). These metals have also been linked to cancer, neurotoxicity, hepatotoxicity, neonatal mortality, and renal toxicity [11]. This makes it important to assess the risks to human health that this fruits pose when cultivated near auto shops, commonly referred to as mechanic villages. There are research studies on mineral composition of *Solanum aethiopicum*, and soil analysis around mechanic workshops in Nigeria [12-14]. However, to the best of our knowledge, no studies have been conducted on determination of metal (loid) levels in garden egg grown around mechanic workshops in umuahia Abia State, Nigeria. Therefore, it is necessary to perform a comprehensive study for assessing levels and human health risks of TMs in the garden eggs.

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Although these *Solanum aethiopicum* are highly popular in South-eastern Nigeria, little is known about the factors that contribute to the bioaccumulation of trace metals, particularly mercury (Hg) and lithium (Li), and the potential health risks in the *Solanum aethiopicum* sample. This eventually led to an evaluation of ten trace metals in the leaves of this fruit grown egg grown around mechanic workshops in umuahia Abia State, Nigeria. A significant information gap may result in poor policy decisions and unnecessary consumer exposure. Therefore, we designed our research to investigate metal concentrations and their possible harm to consumers of *Solanum aethiopicum* in umuahia mechanic to fill the previously indicated knowledge gap. Therefore, measuring the amounts of As, Cd, Cu, Zn, Fe, Pb, Ni, Hg, Li and Cr in *Solanum aethiopicum* specie as the primary goal of the study. The values detected were utilized to compute the risk assessment parameters (estimated daily intake, impact on provisional tolerable weekly intake, target hazard quotient, hazard index, and cancer risk) to tackle the problem of consumption safety. The relationships between the elements were also examined.

MATERIALS AND METHODS

Sample Collection and Preparation

A total of 80 freshly sampled samples of *Solanum aethiopicum* were harvested around (2 to 4 ft. distant) mechanic workshops in Umuahia Abia State, Nigeria in the months of November, 2023, using standard sampling methods to assess TMs [15], additionally, and the sampling locations were nearer to busy highways. The fruits were chosen for sampling at varied times and frequencies based on their accessibility around mechanic workshops in Umuahia. For every garden egg sample, a composite of at least 5 samples (1 kg/sample) was prepared from each sampling location. The Taxonomy Section of the Forestry Department at Michael Okpara University of Agriculture in Umudike, Nigeria, recognized and verified the samples. Control sample was collected 500 m away from the workshop cluster. After being collected, the samples were thoroughly washed under running tap water to get rid of any dust and air deposition. After disposing of the inedible parts, they went through two additional washing in distilled water and were then chopped into small pieces. Following that, the samples were homogenised, dried, and crushed using a clean mortar and pestle. After that, samples were stored for additional examination at -20 ^{o}C in sealed polythene bags. Soil samples from each point were collected in triplicate at the sub-surface level at 10 -20 cm depths using a soil auger and transported to the laboratory in a sterile polyethylene bag. The soil samples were thoroughly mixed to obtain a representative sample, air dried, crushed and sieved with 2 mm mesh before wet digestion.

Samples analysis for Trace metals

After being collected, the samples were sliced, cleaned, and allowed to air dry. An agate

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homogenizer was used to homogenise the dried samples, which were then placed in previously cleaned HDPE vials for further examination. For all aqueous solutions, deionized water (18.2 MΩ cm-1) from a Milli-Q system (Human Power I Plus, Korea) was utilised. From Merck in Darmstadt, Germany, the best mineral acids and oxidants (HNO_3 and H_2O_2) were utilised. Following a 12-hour soak in a 10% nitric acid solution, deionized water was used to rinse all of the plastic and glassware. The MERS-8, Australia microwave closed system was employed for digesting. Samples weighing 0.25 g were subjected to a 7-minute microwave digestion process including 9 ml of HNO_3 (60%) and 1 ml of H_2O_2 (30%). The samples were then diluted to a volume of 50 ml using deionized water. The blank digest was made using the same procedure. Under the digestion settings, the temperature was increased to 190 ^oC in 12 minutes and held there for 5 minutes using microwave technology. This process was done once more [16]. Every example solution was understandable. Materials of analytical grades were employed in the research. The elements As, Cd, Cr, Cu, Fe, Li, Ni, Pb and Zn. were analysed using an Inductively Coupled Plasma Optical Emission Spectrophotometer (ICP-OES) from PerkinElmer's 7700 and 8500 DV series, while Hg was analysed using a Cold Vapour Atomic Fluorescence Spectrophotometer (CV-AFS) model PE-1100 (Nippon Instruments Corporation, Takatsuki, Japan). Each sample was prepared in triplicates, and as indicated in Table 1, quality control (QC) for the assessment process was conducted using the Oriental Basma Tobacco Leaves (INCT-OBTL-5), a Certified Reference Material (CRM) supplied by the Institute of Nuclear Chemistry and Technology in Poland. Milligrammes per kilogramme dry weight are used to express the element contents found in the garden eggs samples. The analytical method's precision and accuracy evaluations are displayed in Table 2.

Table 1: Recoveries of certified reference material INCT-OBTL-5

Metals	Certified value (mg/kg)	Obtained value (mg/kg)	Recovery (%)
As	668 ± 0.0028	664±0.034	98
Cd	2.64 ± 0.14	2.67±0.21	101
Cr	*6.30	6.34±0.12	103
Cu	10.1±0.4	10.3± 0.8	102
Fe	*0.149	0.151±0.05	106
Hg	0.021 ± 0.001	0.023±0.002	98
Li	19.3	19.7	101
Ni	8.50	8.46	101
Pb	2.01±0.31	2.04±0.38	105
Zn	52.4±1.08	52.7±2.00	101

* Is information values in the INCT-OBTL-5 (the rest are certified values)

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The precision and accuracy of the analytical approach

To evaluate the precision and accuracy of the analytical approach, the multi-element trace assessment of Oriental Basma Tobacco Leaves (INCT-OBTL-5), Certified Reference Material (CRM) was provided by the Institute of Nuclear Chemistry and Technology in Poland. The accuracy was verified by calculating the standard deviation of CRM sample (INCT-OBTL-5), and the recoveries were found to vary from 98% to 106%, as shown in Table 1. Ten reagent blanks were examined for heavy metal content to determine the analytical method's limit of detection (LOD). The method detection limit (MDL) was calculated using Student's t value x SD, and the limit of quantification (LOQ) was established using triple tests. In this study, LODs as shown in Table 2. The amount of each element found in the samples are is given in mg/kg dry weight.

Table 2: IDL, MDL, LOD and LOQ for the method of analysis of the for *Solanum aethiopicum*

Element	IDL[a] (mg/L)	MDL (mg/l)	LOD *Solanum aethiopicum* (mg/L)	LOQ for *Solanum aethiopicum* (mg/L)
As	0.002	0.011	0.004	0.026
Cd	0.004	0.018	0.006	0.014
Cr	0.002	0.014	0.004	0.031
Cu	0.010	0.014	0.005	0.040
Fe	0.022	0.018	0.006	0.024
Hg	0.001	0.001	0.001	0.016
Li	0.002	0.014	0.001	0.031
Ni	0.004	0.018	0.006	0.024
Pb	0.001	0.021	0.003	0.016
Zn	0.010	0.021	0.005	0.050

[a]Instrumental detection limit.

Estimated Daily Intake Of The Heavy Metals

The Estimated Daily Intake (EDI) of heavy metals in garden egg in Umuahia auto workshop was calculated in accordance with USEPA, [17] as shown in equation 3.

$$EDI = \frac{(C \times FIR)}{BW} \quad \ldots\ldots\ldots\ldots 3$$

(BW = average body weight which is set as 60.7 kg for adults; C = concentration of the metal in the samples (mg/kg); FIR is the average daily consumption of the vegetable in Nigeria (g/person/day), which was estimated to be 65 g/day [17]. EDI values were expressed as (mg/kg BW/day) for the heavy metals and were compared with each metal’s reference oral dose (RfD) [18].

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Health Risk Index

Health risk index (HRI) was calculated by dividing the EDI with the corresponding reference oral dose for each of heavy metal. This is shown in equation 4.

$$HRI = \frac{EDI}{RfD} \ldots\ldots\ldots\ldots\ldots\ldots 4$$

Where RfD = oral reference doses for As, Cu, Fe, Cr, Zn, Cd, Ni, Li, Hg, and Pb are 1.0, 0.04, 0.70, 0.003, 0.3, 0.001, 0.001, 0.02, 1.00 and 0.0035 mg/kg/day respectively [18].

Non-carcinogenic Risk Assessment

Non-carcinogenic risk assessment methods established by United States Environmental Protection Agency [19] are based on target hazard quotient (THQ) and hazard index (HI). The THQ is a ratio of determined dose of a pollutant to a reference dose level as demonstrated in equation 5.

$$THQ = \frac{ED \times C \times FIR \times EF \times 10^{-3}}{RfD \times BW \times AT} \ldots\ldots\ldots\ldots\ldots 5$$

(THQ = target hazard quotient; C = heavy metal concentration in the foodstuff; FIR = food ingestion rate 65 (g/day); ED = exposure duration (average lifetime which is 55 years for Nigeria [20]; EF = exposure frequency (365 days/year); RfD = oral reference doses for the metals; AT = average exposure time (365 days/ year × exposure years, assumed as 55 years); BW = average adult body weight (60.7 kg).

If the THQ is less than 1.0, the exposed population is unlikely to experience adverse health effects [20],

Hazard index (HI) was then generated to evaluate the non-carcinogenic risk potential of the combined metals. HI was calculated as the sum of HQs as shown in equation 6.

HI = (THQ_i + THQ_{ii} + THQ_{iii} …THQ_n) i.e. ΣHQ_s……………………6

Where i, ii, iii etc., represent each metal.

If the value of HI is greater than 1.0, there is a potential for adverse health effects on the exposed population and mitigation measures are required [21].

Carcinogenic Risk Assessment

The equation used for estimating the target carcinogenic risk factor (lifetime cancer risk) is shown in equation 7.

$$TCR = \frac{E_F \times ED \times FIR \times C \times CSF_O \times 10^{-3}}{BW \times AT} \ldots\ldots\ldots\ldots\ldots 7$$

TCR is the target carcinogenic risk over a lifetime, E_F is exposure frequency (365 days/year), AT is the averaging time for carcinogens (365 days/year × ED), and CSFo is the oral carcinogenic slope factor from the Integrated Risk Information System database which was 0.0085, 0.38 and 0.5 mg/kg/day for Pb, Cd and Cr respectively [22]. The cumulative target carcinogenic risk (CTCR) was calculated using equation 8.

$$CTCR = \sum TCRi \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 8$$

Statistical Analysis

Utilizing information from each sample, descriptive statistics were calculated. One-way analysis of variance (ANOVA) was used to

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evaluate the differences in parameter concentrations across samples, with a significance level of ($p<0.05$). Version 16 of the statistical software for social sciences, or SPSS® (SPSS Inc., USA). The Global Positioning System, also known as GPS, was used to locate the sampling regions. Values below the MDL and abnormally low were referred to as "zero.

RESULTS AND DISCUSSION

Human activity in nature and their desire to raise their standard of living have been linked to increases in the amounts of trace metals in both soil and food [23]. The primary issue at hand pertains to the potential hazards that vehicle mechanics and repair shops may present. Trace metals are primarily found in waste produced by these workshops and service systems, which is improperly dumped into the ground. The analysis of trace metals in soil and *Solanum aethiopicum* (garden egg) and soil sample are summarized in table 3-4. The presence of metal-containing wastes in mechanic workshops that eventually find their way into the soil may be the cause of the rise in the metal content of soil from these workshops, which is consistent with findings from [24-25].

Arsenic in soil throughout the world result from a concentration of natural and man's activities. The highest concentration of Arsenic is recorded at S2 8.64±0.03mg/kg (garden egg) and lowest is record at control 0.73±0.13mg/kg. The concentration of Arsenic from the result obtained is greater than the WHO standard in soil sample (WHO= 5.0mg/L) [19] the higher concentration of this metal could be as result of natural deposit. Nickel (Ni) concentration, as shown in Table 3 and 4, in the soils investigated shows a distribution mean of soil and garden egg 4.90 mg/kg and 3.56 mg/L for ohiya Phase 11 (S2) while the mean values of 0.82 mg/kg obtained for the respective control sites. The results are lower than values of 11.5 mg/kg in [26] and 17.38 - 16.52 mg/kg recorded by [27]. Like the other metals, the distribution of Ni in this location could be attributed to the disposal of spent automobile batteries from the nearby auto-battery chargers and various paint wastes which have contributed to the contamination of the soil samples [28]. However, in all cases, the concentrations of Ni obtained were below the maximum allowable limits for heavy metals in soils and water according to World Health Organization (WHO), which suggests that, for now, there is little anthropogenic contribution which indicates low significant difference at $P \leq 0.05$ among the Ni concentrations. Zinc (Zn) concentration, as shown in Table 2 and 3, the sample around auto-mechanic had highest range of 32.53±0.07mg/kg in soil while the values of garden egg were recorded to be 27.53±0.03mg/kg in S2. The control value at garden egg was also found to be low at 6.54 mg/L compared to that of soil, 9.54 mg/kg. There was significant difference at $P \leq 0.05$ among the concentrations of Zn which showed that the anthropogenic activities had imparted greatly on the soils. These high values especially at the auto-mechanic area suggest that,

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there is anthropogenic contribution. Since no industry exists in the vicinities of these areas, the elevation of Zn levels could be from the auto-mechanic workshops as Zn is noted to be a part of several additives to lubricating soils [29]. However, the concentrations of Zn in this study are high compared with many other studies [29-31], although it is comparable to that of soils in Cameroon, South East Korea and that of Yauri, North-West Nigeria [32]. Presence of zinc in the soil of garden egg area could be attributed to corrosion of metal parts of the vehicles. Zinc is also a component of crude oil and machine exhaust [33]. The Zn concentrations obtained are above the maximum allowable limits according to World Health Organization (WHO). Cadmium (Cd) concentration, as shown in Table 2 and 3, the soils are low but has the highest value at S2 of 3.02 mg/kg and almost in the same range of values except at control. It was reported by some researchers that cadmium is regarded as one of the most toxic heavy metals even at low concentration as obtained in this study. The concentrations obtained at both sites are still relatively within the acceptable limits of World Health Organization (WHO) standard. The Cd concentration at the control site is consistent with that of [34] who investigated heavy metals in soils of auto-mechanic shops and refuse dump sites in some parts of Makurdi, Central Nigeria, as well and reported a range of 0.6 - 3.5 mg/kg. The results are also in the same range reported by [29] and [35]. The mean Cd levels especially in the auto-mechanic area confirm that the auto-mechanic workshop environment is generally Cd enriched. The main source of environmental Cd pollution is the ferrous-steel industry [36]; the accumulation of Cd in the areas studied is likely to come from lubricating oils, vehicle wheels and metal alloys used for hardening of engine parts [37], The Cd concentrations showed no significant difference at $P \leq 0.05$ but it is cleared that the anthropogenic activities had imparted on the soils.

Copper (Cu) concentration, as shown in Table 2 and 3, obtained at the soil around auto-mechanic area were slightly higher than those at the fruits except at the control site. There is mild range of distribution of Cu in the sites with mean values of 6.73 mg/kg for soil, and 5.73 mg/kg for fruit. According to World Health Organization (WHO), the concentrations of Cu obtained do not exceed the maximum permissible limits for heavy metals in soils and fruits. Likewise, when compared to the values obtained by some researchers; (100 mg/kg) in Australia, Canada, Poland, Great Britain, Japan (125 mg/kg), and Germany (50 mg/kg) [38]. The concentration of Cu could be ascribed to automobile wastes containing electrical and electronic parts, such as copper wires, electrodes and copper pipes and alloys from corroding vehicle scraps which have littered the vicinity of auto-mechanic workshops for a long time, with metals released from the corrosion gradually leaching into the soil [32]. The presence of Cu in the soils and fruits could also be attributed to the wearing or abrasion of the milling machine parts of valve and emission of

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these metals through the exhaust of the machine [39]. There is slight significant difference at $P \leq 0.05$ among the concentrations of Cu in the soils however the anthropogenic activities had contributed to the release of this heavy metal into the soil. Lithium Li concentration in the fruit overshot the permissible concentration limit in the fruit which is 0.01 mg/kg. It had 4.21±1.73 mg/kg as its value and has no known safe level within the human system. This high concentration of Li in the fruit could be attributed to excess fuel combustion by vehicles being serviced in the workshop and the fact that the roots of Garden eggs may have spread to the auto electrical servicing workshop soil since the *Solanum aethiopicum* are growing just within the area (2 to 4 ft. distant). The high concentration of Li in car batteries that need to be serviced eventually contaminates the soil. Li has several negative impacts. This could perhaps be attributed to the workshop's age, location, waste disposal practices, and elemental analysis method.

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Table 3: Trace metal concentrations in Garden eggs grown around mechanic workshops in Umuahia Abia State, Nigeria. (mg/kg)

Sites	Pb	As	Cr	Fe	Zn	Li	Hg	Cu	Ni	Cd
S1	6.06±0.03	4.06±0.01	23.00±0.01	96.74±0.16	23.64±0.07	0.004±0.002	0.005±0.001	5.33 ± 0.023	2.07±0.01	2.23±0.04
S2	8.64±0.03	5.01±0.03	28.00±0.02	93.05±0.08	27.53±0.03	0.005±0.001	0.007±0.001	6.73 ± 0.004	3.56±0.02	2.76±0.03
S3	6.01±0.03	7.16±0.03	13.02±0.03	76.49±0.12	19.45±0.05	0.003±0.002	0.005±0.001	3.80 ± 5.073	2.61±0.06	1.68±0.16
S4	5.08±0.05	7.04±0.01	15.06±0.13	105.85±0.31	17.48±0.02	0.003±0.002	0.004±0.001	2.94 ± 0.093	2.45±0.02	1.18±0.03
Control	0.73±0.13	1.02±0.07	3.05±0.03	26.05±0.34	6.54±0.03	BDL	BDL	1.035 ± 0.003	0.32±0.08	0.08±0.04
NESREA STANDARDS	160	NS	100	NS	420	NS	Ns	100	70	3
WHO	0.3	0.02	0.85	425.5	5.0	Ns	0.02	0.20	0.20	0.10

S1= ohiya Phase 1 , S2= ohiya Phase 11, S3= Aba road, S4= umuagu junction. . BDL= Below detective limit; NS (Not Specified).

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Table 4: Trace metal concentrations of soil around mechanic workshops in Umuahia Abia State, Nigeria. (mg/kg)

Sites	Pb	As	Cr	Fe	Zn	Li	Hg	Cu	Ni	Cd
S1	8.06±0.05	4.56±0.02	24.02±0.06	98.74±0.18	25.64±0.06	0.005±0.002	0.007±0.001	5.47 ± 0.043	3.45±0.04	2.56±0.04
S2	9.64±0.04	5.51±0.03	29.00±0.08	96.05±0.10	32.53±0.07	0.006±0.001	0.009±0.001	5.73 ± 0.034	4.90±0.02	3.02±0.03
S3	7.64±0.04	7.86±0.03	17.02±0.03	79.49±0.11	21.45±0.05	0.004±0.002	0.006±0.001	3.30 ± 5.083	3.09±0.06	2.28±0.16
S4	6.88±0.06	8.04±0.02	19.06±0.13	110.85±0.21	19.48±0.04	0.004±0.002	0.006±0.001	3.94 ± 0.056	2.85±0.02	2.15±0.06
Control	1.97±0.16	2.94±0.06	5.95±0.02	20.05±0.04	9.54±0.03	BDL	BDL	1.635 ± 0.005	0.82±0.02	1.08±0.04

S1= ohiya Phase 1 , S2= ohiya Phase 11, S3= Aba road, S4= umuagu junction. . BDL= Below detective limit

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The result of the analysis of lead concentration showed that the highest value is recorded in S2 0.006 mg/kg and the lowest is in 0.004 mg/kg. Lead was not detected at control sample. Just like other metal analyzed, the concentration of the metal was above the recommended limit while in some location the metal is with the maximum allowable limit [43]. The value obtained in this study was lower than 19.62mg/L reported by [30] for auto-mechanic workshop area in Owerri, south-East Nigeria. However, the level are in line with throe reported by [28] in South-South Nigeria and throe in industrial area in North-west Nigeria, but above that reported by [40] in central Nigeria. Virtually all the level of lead obtained in this study are below the acceptable limit for soil in several countries. It in reported that lead has the composition of heavy metal in waste oils [41]. Chromium is one of those heavy metal the environment concentration of which is steadily increasing due to industrial growth, especially the development of metal, chemical and tanning industrial [43]. The highest concentration of chromium is recorded in S2 29.00 mg/kg soil and lowest is in S3 17.02mg/kg while the control soil had a value 5.95 mg/kg which were high than the fruits as shown in ta. Result obtained in the lowest investigation showed that the concentration of chromium in some of the location is above the maximum allowable limit of WHO [43]. The non-biodegradability of chromium is responsible for it, persistence in the environment, once mixed in soil it undergone transformation into various mobile before ending into the environmental sink [44]. The amount of iron (Fe) in the soil and in the garden egg are shown in table 2 and 3, are higher than those found in the four varieties of garden egg as reported by [45]. This implies higher bioactivity prediction for these varieties as compared to *S. macrocarpon* (round and oval shapes), *S. aethiopicum* and *S. gilo* varieties reported [13, 45]. The results obtained in this study show that the mechanic activities contribute significantly to heavy metals pollution in the soils. This is similar to earlier reports by other studies [47-49]. The levels of mercury found in the fruit samples varied with the collection site of the sample and the mercury content in the soil at the collection sites. Hg concentrations in soil around auto mobile workshops ranged from 0.006 to 0.009 mg/kg and that of the garden egg range from 0.004 to 0.006 mg/kg while the control was below detective limit. This wide range was close to the reported results that Hg concentrations vary widely from 0.010 mg/kg to 1.000 mg/kg in rural and remote areas, and from 0.100 mg/kg to >10.000 mg/kg in urban, industrial, and mineralized/mined lands [49,50]. The wide range of Hg concentrations denoted that Hg concentrations in separate studies were spread out over a large range of values in Chinese agricultural soil. The different soil Hg occurrence in different auto mobile workshops might be due to the components of physical parents and the human activities related to Hg emissions. The reported mean mercury contents in tested samples were low and did not pose a health risk.

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Health Risks Assessment of the Trace Metals

The target hazard quotient (THQ), target carcinogenic risk (TCR), hazard index (HI), estimated daily intake (EDI), health risk index (HRI), and target hazard quotient (THQ) factors were calculated to examine the possible health risks connected with long-term consumption of these trace metal-contaminated *Solanum aethiopicum*. Table 5 presents the EDI results for studied trace metals in the adult population. The estimated intakes tend to be lower than the PMTDI values except for Cr in S1 and S2. The United States Environmental Protection Agency [20] reported that each trace metal's reference oral dose (RfD) was less than the EDI values for all the trace metals evaluated in *Solanum aethiopicum* from all the study areas except for Cr and Pb in S1 and S2.

Table 5: Estimated daily intake (EDI) of metals in *Solanum aethiopicum* (mg/kg BW/day)

Trace Metals	S1	S2	S3	S4	Control	RfD (mg/kg/ day)	PMTDI
As	0.00685	0.0000720	0.0105	0.00343	0.000350	1.0	0.2
Cd	0.0321	0.0821	0.0571	0.00142	0.000432	0.001	0.005
Co	0.000014	0.000003	0.000021	0.000011	0.00136	0.03	0.023
Cr	1.072	1.042	0.0035	0.0250	0.000250	0.003	0.3
Cu	0.00150	0.00150	0.00157	0.00164	0.000999	0.04	0.5
Fe	0.192	0.0912	0.191	0.0375	0.0345	0.70	11
Hg	0.0002	0.0003	0.0004	0.0003	0.0003	0.02	0.2
Li	0000004	0.000006	0.000003	0.000004	0.000005	1.00	0.02
Pb	0.0393	0.0864	0.00236	0.00129	0.000357	0.0035	0.005
Zn	0.000118	0.000054	0.000129	0.000110	0.000321	0.3	1.00

EDI = Estimated Daily Intake (mg/kg BW/day); S1= ohiya Phase 1, S2= ohiya Phase 11, S3= Aba road, S4= umuagu junction.

PMTDI from the FAO/WHO Expert Committee on Food Additives [52]. A reference dose is an estimation of a daily exposure to the general population (including the sensitive subpopulation) that is probably not going to result in a significant lifetime risk of negative consequences [54]. This suggests that the adult population residing in those areas are susceptible to the harmful consequences of these metals.

The HRI for *Solanum aethiopicumas* presented in Table 6. Ranges as follows; Al (0.0000720-0.00685), Cd (0.142-0.821), Co (0.000367-0.0452), Cr (0.0117-0.0833), Cu (0.0241-0.0411), Fe (0.0493-0.274), Pb (0.0369-0.714),

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and Zn (0.000180-0.00107). The HRI values for *Solanum aethiopicum* in this study are much lesser than 1 except for Cd and Cr in S2. Generally, HRI less than 1 means that the exposed population is safe of metals health risk while HRI greater than 1 means the opposite. Therefore, the exposed population around the study area is not at any risk of trace metal poisoning except for Cd, Cr and Pb in S1 and S2. A previous study by Adedokun *et al*. [53] reported HRI values far greater than 1 for Cd, Pb, Zn, Ni and Cu in some leafy vegetables obtained from four markets in Lagos metropolis and concluded that the population was at greater risk of those Trace metals.

Table 6: Health risk index (HRI) of metals in the *Solanum aethiopicum*

Trace Metals	S1	S2	S3	S4	Control
As	0.0685	0.0720	0.0105	0.0343	0.0350
Cd	0.321	1.821	0.571	0.142	0.432
Co	0.0467	0.0100	0.0700	0.0367	0.0452
Cr	1.0240	1.0473	0.0117	0.0833	0.0833
Cu	0.0375	0.0375	0.0393	0.0411	0.0250
Fe	0.274	0.130	0.273	0.0536	0.0493
Hg	0.0004	0.0003	0.0004	0.0002	0.0003
Li	0.0030	0.0034	0.0043	0.0032	0.0041
Pb	1.0560	1.0866	0.0674	0.0369	0.102
Zn	0.0393	0.0180	0.0430	0.0367	0.0107

S1= ohiya Phase 1 , S2= ohiya Phase 11, S3= Aba road, S4= umuagu junction.

The result of THQ and HI are shown in Table 7.THQ values obtained in this research are less than 1 indicating an allowable level of non-carcinogenic adverse health risk. If the THQ is less than 1, the exposed population is unlikely to experience adverse health effects [51]. The HI is used to estimate the potential human health risk when more than one Trace metal is consumed. So, it evaluates the non-carcinogenic risk potential of the combined metals. If the value of HI is greater than 1, there is a potential adverse health effects on the exposed population and mitigation measures are required [51]. The HI values in this study are more than 1 except for *control* which gave a value of 0.08772. Therefore, the high HI values indicate the contributory hazard effects of Trace metals which can lead to aggregate risk when the garden egg from those locations are consumed.

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Table 7: Target hazard quotient (THQ) and hazard index (HI) of metals in *Solanum aethiopicum* samples

Trace Metals	S1	S2	S3	S4	Control
As	0.00685	0.00007	0.01050	0.00343	0.00035
Cd	0.32128	1.82135	0.57081	0.14244	0.43159
Co	0.00046	0.00011	0.00071	0.00036	0.04523
Cr	0.02392	0.04748	0.01178	0.08318	0.08318
Cu	0.03748	0.13033	0.03928	0.04104	0.02498
Fe	0.27433	0.00076	0.27286	0.05362	0.04931
Hg	0.00021	0.00023	0.00032	0.00031	0.00022
Li	0.00210	0.00042	0.00172	0.00347	0.00032
Pb	0.05600	0.46372	0.06732	0.03672	0.10189
Zn	0.00017	0.00008	0.00018	0.00016	0.00046
HI	1.11407	2.01421	1.79498	1.96872	0.08772

S1= ohiya Phase 1 , S2= ohiya Phase 11, S3= Aba road, S4= umuagu junction.

Pb, Cd and Cr are carcinogenic agents and have been associated with causing cancer even at low doses [22]. Estimation of the possibility of cancer risks in the studied *Solanum aethiopicum* via intake of carcinogenic Trace metals was carried out using the Target Carcinogenic Risk (TCR) and the Cumulative Target Carcinogenic Risk (CTCR) factors. TCR and CTCR of Pb, Cd and Cr in the vegetable samples are given in Table 8. The TCR range of Pb for the garden egg in all the study locations is 1.09×10^{-6} - 2.12×10^{-5}, Cd is 5.41×10^{-5} - 3.12×10^{-4} while Cr is 1.77×10^{-5} - 1.25×10^{-4}. According to US-EPA [56] the threshold cancer risk limit is TCR 10^{-4}. TCR for Pb in all the studied fruit samples is below the US-EPA recommended threshold cancer risk limit. For Cd, apart from the TCR for Cd in that is below the threshold, the values of TCR of Cd in the fruit from the study locations violated the threshold limit. For Cr, only S1 and S2 violated the threshold limit with the same value of 1.25×10^{-4}. Therefore, remedial measures should be considered for these few study sites where Cd and Cr exceeded the recommended threshold limit. The cumulative cancer risk as a result of exposure to multiple carcinogenic Trace metals due to the consumption of a particular type of vegetable was assumed to be the sum of the individual Trace metal risks [54]. Also, except for the CTCR of Pb all the studied fruit exceeded the recommended threshold risk limit (10^{-4}) for Cd and Cr and therefore mitigation measures would

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be required in those sites. From this study, *S1* has the highest chances of cancer risk (2.17×10^{-4}) while *S4* has the lowest chances of cancer risk (1.03×10^{-6}) were both greater than 1×10^{-4} [55]. These risk values indicate that consumption of *garden egg* would result in an excess of 5 cancer cases per 10,000 people exposure [17]. However, the CTCR values for the Trace metals in the fruit are below the recommended moderate risk limit set by the US-EPA (10^{-3}) [56].

Table 8: Target carcinogenic risk (TCR) factors of Pb, Cd and Cr in *Solanum aethiopicum*

Trace Metals	S1	S2	S3	S4	CTCR
Pb	1.67×10^{-6}	2.00×10^{-4}	3.03×10^{-6}	1.03×10^{-6}	6.70×10^{-6}
Cd	1.22×10^{-4}	2.17×10^{-4}	1.64×10^{-4}	1.04×10^{-4}	5.03×10^{-4}
Cr	3.59×10^{-5}	1.77×10^{-5}	1.25×10^{-4}	1.05×10^{-4}	1.79×10^{-4}

S1= ohiya Phase 1 , S2= ohiya Phase 11, S3= Aba road, S4= umuagu junction.

; CTCR = Cumulative Target Carcinogenic Risk

CONCLUSION

The fruit samples used in this study are safe for consumption except samples from S1 and S2 which showed a high concentration of Cd, Cr and high cancer risk rendering it unsafe for consumption. The findings on the EDI, TCR, THQ, and HRI revealed that consumption of *Solanum aethiopicum* could pose CRs to human health due to the high concentration of Pb, Cr and Cd.

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