OPEN ACCESS Freely available online

ISSN: 2168-9881
Agrotechnology

Research Article

Heavy Metals Levels and Adult Health Risk Assessment in Horticultural Systems in Mbare Musika and Mutoko, Zimbabwe

Samuel Kodani*, Elias Chipunza, Stanislaus Zvarimwa

Department of Chemical Engineering, National University of Science and Technology, Bulawayo, Zimbabwe

ABSTRACT

Levels of cadmium, chromium, cobalt, nickel and lead were determined in cabbages, tsunga (mustard), green beans and tomatoes from Mbare Musika vegetable market in Harare and one of its major supplier, Mutoko. Cabbages and tsunga exceeded the stipulated safe limit for lead levels whereas the tomatoes and sugar beans went above the 0.02 ppm threshold for cadmium. Hazard Quotients of the vegetables showed adult health consequences especially on lead and cadmium and also Hazard Indices were all above unit according to ATSDR (Agency for Toxic Substances and Disease Registry). Horticultural inputs assessment showed that irrigation water exceeded WHO stipulated thresholds for cadmium and chromium. Chromium and lead levels were high in fertilizers indicating most heavy metals within the horticultural system in Mutoko are of anthropogenic origin. There is need for an intervention in regulating heavy metals levels in the agricultural inputs.

Keywords: Hazard quotient; Hazard index; Risk; Agricultural inputs; Heavy metals

INTRODUCTION

Most state governments regulate heavy metals concentrations in fertilizers, agricultural minerals, agricultural remedies, and lime products according to Lawrence RC and Brian WS [1]. Heavy metals contamination is imminent and inevitable in agricultural systems as these get introduced in more ways than one as depicted in Figure 1. Heavy metals are naturally occurring, inherent in the soil at varying levels but mostly in agricultural systems are of anthropogenic origin. Varol et al. noted that due to their non-biodegradability and toxic nature, and bioaccumulation behavior, the issue of agricultural soil pollution has become a global issue [2]. They noted that high heavy metal contents in agricultural areas reduce crop quality and yields typically as summarized. This study will focus on Cadmium, chromium, cobalt, nickel and lead and the need to promote food safety by coming up with a "Prevention Policy" as alluded to by Harnell et al. [3]. They recommended that this policy should be convened if there happen to be challenges observed within the sources and the system. The Policy looks at controlling and reducing future additional input pollutants to the current levels into systems with the intention of protecting the environment and threats to public health.

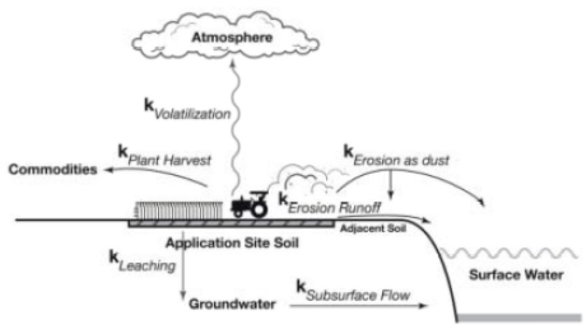

Figure 1: Pathway through which heavy metals are lost from a fertilizer application site at rate "K".

Heavy metals are elements with high molecular weight, some of which have no known beneficial biological functions in living systems. Most of the required heavy metals are wanted at very low concentrations. At higher levels they act as poisons to human health and other living systems. Cadmium and lead have no known beneficial biological uses in the human body. Ruqia N et al., noted that there is a tendency of bio accumulation of these

Correspondence to: Samuel Kodani, Department of Chemical Engineering, National University of Science and Technology, Bulawayo, Zimbabwe, E-mail: kodanisamuel@gmail.com

Received: 30-Aug-2022, Manuscript No. AGT-22-17903; **Editor assigned:** 05-Sep-2022, PreQC No. AGT-22-17903 (PQ); **Reviewed:** 19-Sep-2022, QC No. AGT-22-17903; **Revised:** 26-Sep-2022, Manuscript No. AGT-22-17903 (R); **Published:** 03-Oct-2022, DOI: 10.35248/2168-9881.22.11.280

Citation: Kodani S, Chipunza E, Zvarimwa S (2022) Heavy Metals Levels and Adult Health Risk Assessment in Horticultural Systems in Mbare Musika and Mutoko, Zimbabwe. Agrotechnology. 11:280.

metals in plants in environments of their elevated levels [4]. WHO/FAO announced that vegetables being a useful component of the human diet will stand out as one major route through which heavy metals enter into the human food chain [5]. Mapanda F et al., proved that the use of waste water from sewage treatment plants is one direct route which contributes to bio accumulation of heavy metals in the soil and vegetative parts of plants being irrigated [6]. Annex 2 states the need to do a balancing of nutrient supply to the plants to relieve the environment of potential pollutants [7]. The Annex recommends that innovative good agricultural practices like conservation and precision agriculture, fertilizer and water quality as well as application methods could be used for the control of heavy metals in horticultural systems. Cadmium tends to be more mobile in soil systems and therefore more available to plants than many other heavy metals according to Alloway (Table 1). Cd_2 is the principal species in soil solution and accumulation of cadmium in food crops at soil concentrations that are not phytotoxic is a significant concern that is hyper accumulation is common. Plant species differ widely in their tendency to accumulate cadmium. Cabbage amongst other vegetables, actively accumulate cadmium showing a linear relationship between soil and vegetable content. Soil chemistry like absorption/desorption also influences cadmium mobility and uptake by plants whose uptake is about 10-fold more rapid than lead. Phosphate fertilizers have been identified to contain significant cadmium concentrations. Goyer and Clarkson noted that chronic cadmium exposures result in kidney damage, bone deformities, and cardiovascular problems.

Table 1: The behavior of Cadmium in the environment.

Source	Cadmium is emitted to soil, water, and air by non-ferrous metal mining and refining, manufacture and applications of phosphate fertilizers, fossil fuel combustion, and waste incineration and disposal. Cadmium can accumulate in aquatic organisms and agricultural crops.
	Fate
Air	Cadmium (as oxide, chloride, and sulfate) will exist in air as particles or vapors (from high temperature processes). It can be transported long distance in atmosphere, where it will deposit (wet or dry) onto soils and water surfaces.
Soil	Cadmium and its compound may travel through soil, but its mobility depends on several factors such as pH and amount of organic matter, which will vary depending on the local environment. Generally, cadmium binds strongly to organic matter where it will be immobile in soil and be taken up by plant life, eventually, entering the food supply.
Water	Cadmium exists as the hydrated ion as ionic complexes with other inorganic substances. Soluble forms migrate in water insoluble forms of cadmium are immobile and will deposit and absorb to sediments.

Lead behaves differently to cadmium. According to Davies, lead is prone to accumulation in surface horizons of soil because of its low water solubility and its speciation is rather simple with Pb^{2+} as the dominant soluble form. It forms a number of highly insoluble precipitates including $Pb(OH)_2$, $Pb_3(PO_2)_2$, and $PbCO_3$. Plant uptake factors for lead are low, in the range 0.01-0.1. Lead contamination is more common in urban soils. Goyer and Clarkson noted that neurologic problems, especially in children, are the principal concern for chronic lead exposure. Consumption of lead contaminated soil itself, rather than crops is a more likely exposure hazard. With nickel, McGrath noted that it is moderately soluble in soil water and increases at low pH. The predominant soluble species in most agricultural soils is Ni^{2+}. Nickel sulphides likely control the Ni^{2+} concentration in soil solution according to his observations. He noted that the nickel concentrations in plants generally reflect that of their soils and plant transfer coefficients ranges from 0.1 to 1.0 and nickel toxicity appears quite low. It is a nutritionally essential metal for some plants, microbes, and invertebrates. There is no known biochemical function for nickel in humans. Crop contamination with nickel in fertilizers and related products seems an unlikely human health problem. According to Shirkhanloo et al., the trace amounts of nickel and cobalt are indicated to be either necessary or toxic depending on their concentration range [8].

In plants, heavy metal presence usually do not show any observable signs of health adversity but in some instances obvious signs show as depicted in Table 2. Hot spots of retarded growth to poor germination of seeds can be visible signs. According to Ghani et al., despite proper fertilizer recommendations and application, affected crops may fail to show positive plant health improvement [9]. Growth can be retarded as well as premature fruit drop, poor nutrient content, plant nutrient acquisition challenges, poor germination percentage, poor chlorophyll formation hence photosynthesis, low plant biomass and protein content amongst other observable changes on normal plant health. They even commended that it is very complex to make conclusions on partial investigations as depicted in Table 2 on some common influence of certain heavy metal levels on certain plants.

Table 2: Recommended maximum concentrations of heavy metals in irrigation water.

Element	Recommended maximum	Remarks
Cd	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/L. Has potential for accumulation in living systems.
Co	0.05	Toxic to tomato plants at 0.1 to 1.0 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Cr	0.1	Not generally recognized as an essential growth element. Lack of knowledge on its toxicity to plants.
Ni	0.2	Toxic to a number of plants at 0.5 mg/l to 1 mg/l.
Pb	5	Can inhibit plant cell growth at very high concentrations.

Mbare Musika is the major vegetable market in Harare, Zimbabwe. Four vegetables namely mustard (tsunga), cabbages, tomatoes, green beans were picked for this study by virtue of their mineral mining capabilities. With the current economic recession in Zimbabwe, these are also the major vegetables on majority of people's tables. Mbare Musika serves as the distribution hub of vegetables for all suburbs around Harare and also most intercity markets. Despite being the major supply center, quality control of the produce commercialized is not guaranteed and as is always a fact that looks are deceiving. Heavy metals do not show on the outside in most cases but concentration levels will be disastrous within as shown in Figure 2.

Figure 2: Activities at Mbare Musika on a normal day with vendors bargaining for the cheapest price on vegetables.

The major horticultural producer F and vendors favor Mbare Musika because of its location and bargaining activities. It is the major vegetable and hardware trade center in Harare and strategically located as a transport hub for all major local and international bus routes. Mutoko is one major vegetable supplier to Mbare Musika as shown in Figure 3.

Figure 3: Wholesale of vegetables from various sources of origin at Mbare Musika.

There is rampant quarrying and illegal gold mining activities in Mutoko. These are potential sources of contamination to the water bodies and also fouling of the air and soil through chemicals and dust emissions. Quarrying and the gold rush in Makaha and other areas in Mutoko should be backed up by an environmental impact assessment. This will be meant to determine the extent to which the agricultural environment has been or the rate at which it is going to be degraded. It has been found necessary to assess heavy metal levels in the vegetables together with inputs from Mutoko to find a correlation of source inputs and products for contamination rate and source identification as well as remediation recommendations. Not all heavy metals are toxic to plants especially at low concentrations. Excessive accumulation in plant tissues will arise at high environmental concentrations. Limits have to be established on the extent and rate at which heavy metals are allowed to accumulate in soil and water within the area.

According to Maleki et al., food safety issues and potential health risk are a major public and environmental concern worldwide [10]. After quantitative analysis of heavy metal levels, the Hazard Quotient (HQ) can be used to characterize foodstuffs on potential risk to human health. For this characterization, five elements cadmium, chromium, nickel cobalt and lead are used as in accordance to US EPA [11]. This characterization is dependent on age, body weight, and heavy metal concentration and consumption rate of the vegetables. The idea is to keep these levels to as low a level as is possible to promote safety in the human food chain. This prompts the need to promote good agricultural practices by regulating levels of heavy metals in agricultural inputs and produce. Choice of crops to grow in particular environments is also critical due to hyper accumulation effects.

Irrigation water is very important for the success of any agricultural venture and this applies to Mutoko farmers too. The area is blessed with some rivers that flow through the large part of the year (Figure 4). This means in summer, farmers can grow maize and towards winter put vegetables in their fields. Water forms the solution around soil particles in which the roots of the plants are embedded and absorb nutrition. The strength of this solution determines the extent to which certain nutrients are absorbed and accrue within parts of the plant including its edible components. The source of water determines the quality as well. It is not all water that can be used for irrigating any crop hence the need for irrigation suitability tests. Depending on where the source passes through, the levels of heavy metals will vary from one place to another and from one kind of source to another.

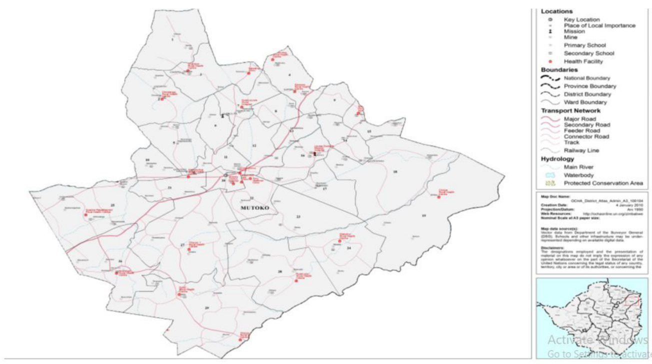

Figure 4: Map of Mutoko showing the hydrology and boundaries.

Mutoko has one of the most innovative horticultural systems in Zimbabwe (Figure 1). It lies at 17°10'S and 32°30'E and is 140 km from Harare along the Harare, Nyamapanda Border leading to Mozambique. Despite it being a dry area where erratic rains fall, irrigation plays a vital role for the success of Mutoko farmers. Around Mushimbo and Kapfunde villages, the tradition is siphoning and flooding. Water is siphoned from big dams and pools along rivers and without pumps or electricity for distances over a kilometer to water their gardens. With this system, intensive horticulture ensues. Sources of water range from rivers, dams, weirs, boreholes and wells. Methods of water application range from manual, flooding, as well as drip irrigation. Soils can be categorized into two major groupings and is peculiar within the North and West and distinct from the South and East of the area according to Mvumi et al. [12]. Transport of produce to the market is not much of a hassle as these two areas lie along a major highway linking Harare and Mozambique. With all these innovations and well positioned inputs, heavy metals can play a determining factor to the success of these farmers hence need to regulate them in all inputs.

Statement of the problem

Vegetables are inevitably a large part of many diets. These vegetables may act as one major pathway through which heavy metals enter the human food chain. When plants are grown in soils with high levels of heavy metals, these accrue in the vegetative parts of the plant and if these are eatable, then they get introduced to the human food chain. Presence of high heavy metals levels in the vegetables depict fouling of the horticultural system and pose a risk to human health. Exports can be a challenge if quality is compromised by heavy metals contamination. Local consumers need protection and safeguarding of human health should take precedence hence the reason for this study to promote safety and security of our diets from heavy metal contamination.

Aims of the study

The study intended to make an assessment of heavy metal levels on four vegetables sampled from Mbare Musika. Confirmation of the assessment results was verified by visiting one of the sources of vegetables to Mbare Musika which is Mutoko. Inputs like irrigation water, soils and fertilizers were sampled and assessed for heavy metal levels then correlated to Mbare Musika vegetables heavy metal levels for contamination source identification. Once source of origin of the heavy metals has been established, remediation steps can then be initiated.

Objectives of the study

i. To estimate risk to human adults health from the heavy metal levels in tomatoes, sugar beans, cabbages and tsunga at Mbare Musika and Mutoko.

ii. To investigate sources of heavy metal contamination of vegetables through soil, water and farmer fertilizers assessment in Mutoko.

The outputs to the study are heavy metals level profiles for the irrigation water, soil and fertilizers as inputs at Mushimbo and Kapfunde villages in Mutoko. Profiles were also made for vegetables from Mbare Musika and the two villages. Hazard quotients and indices were the outcome of the primary data on vegetable heavy metal profiles. The expected impact will be food safety, employment creation and poverty alleviation through quality vegetables products for enhanced lucrative markets and positive health consequences derived from vegetables consumption

METHODOLOGY

The study started by making an assessment of heavy metal levels in vegetables at Harare's major market of Mbare Musika. Vegetables were bought directly from the farmers early in the morning, and coded on source of origin before the middle men hijack the trade. These were put in khaki bags, labeled and taken to the laboratory for sample preparation prior to analysis. These vegetables were reduced in size by chopping with knives, put in trays, weighed and dried in an oven at 105°C overnight. These were then cooled and reweighed to get moisture percentage by difference. They were then ground after drying to reduce particle size and homogenized. Five gram (5 g) samples were weighed into porcelain crucibles, heated at 600°C for at least four (4) hours in a muffle furnace. After cooling, the ash was extracted into 500 ml beakers using 25 ml of 1:4 Hydrochloric acid. This was digested over a water bath for an hour avoiding drying of the samples. After cooling, this solution was transferred to 100 ml volumetric flasks and made up to the mark using distilled water. After shaking the solution was filtered through Whatman No:2 filter paper. Aliquots were taken for dilution and reading at the Atomic Absorption Spectrophotometer (AAS), Varian 1275. The readings were reverted to fresh weight and results from the various readings of the same vegetable averaged after a second round of sampling at the market. The results were then fed into equations for the Hazard Quotients (HQ) and Hazard Index (HI) for risk characterization of the various vegetables as depicted in equation 1 and 2 respectively. Decision on the need to investigate the source was made after interpreting the Hazard Quotient and Index of the various vegetables on safety basis of heavy metal levels as recommended by ATSDR.

The calculation for the Hazard Quotient (HQ) is as follows:

$$HQ = \frac{(Div) \times (C_{metal})}{R_f D \times B_0} \qquad \text{(Equation 1)}$$

Where:

Div-daily intake of vegetables in Kg/day.

Cmetal-concentration of metal in vegetables in $mgKg^{-1}$

RfD-oral reference dose for the metal ($mgKg^{-1}$ of body weight per day)

Bo-the human body mass in Kg

The Hazard Index is taken as the sum of all the Hazard Quotients due to the elements as follows:

Hazard Index=Sum of all Hazard Quotients

=Sum of Hazard Quotient for (cadmium + nickel + lead, cobalt + chromium)

$$HI = \sum HQ = \sum HQCd + \sum HQNi + \sum HQPb + \sum HQCo + \sum HQCr \qquad \text{(Equation 2)}$$

Where $\sum$-is the summation notation. To assess the risk due to more than one element, the Hazard Index is used, see Equation 2. This is a summation of the various Hazard Quotients due to the various elements. Anything above unit (1) for the Hazard Quotient and the Hazard Index shows a potential risk to human health.

The source of origin of the vegetables was visited for sampling and potential risk source identification. Soil samples were taken from vegetable fields with the crop of interest. These were stored in polythene bags and taken to the laboratory. There, they were weighed, naturally dried, weighed again and the result used to determine moisture content by difference. The soil was then crushed for homogenization and extraction of the heavy metals done using aqua regia, an equimolar mixture of nitric and hydrochloric acids. The extraction solution was diluted and filtered. Aliquots were prepared for reading at the AAS and measured in Parts per Million (ppm) as the unit of concentration.

Water was sampled from the irrigation sources of each farmer under study and recorded as to the source and mode of irrigation used. Plastic bottles used for the collection were rinsed three (3) times with source water and the rinse water thrown away. The bottles were then filled with the water almost too full capacity and stoppered. These were labelled and taken to the laboratory for analysis. During sample preparation for analysis, the water was filtered, dilutions made into volumetric flasks, then topping up to the mark with distilled water with addition of strontium chloride. The prepared samples were then read on the AAS and read in units of parts per million.

Vegetables were picked directly from the field. A representative sample of the vegetable in question was picked at random and stored in khaki envelopes. These were chopped, weighed and dried in the oven at 105°C overnight. Next day after cooling, these were cooled, reweighed to determine moisture by difference. The dry samples were ground and stored in plastic jars with lids prior to analysis. A homogenous sample of the vegetables was weighed, put into porcelain crucibles and heated in a muffle furnace at 600°C. On cooling, it was extracted with dilute acid, heated on an oven, diluted in a volumetric flask and made up to the mark with distilled water. It was then read at the AAS. Results of the reading were recorded in parts per million. After collation of results, they were compared with internationally acceptable standards and recommended on heavy metal levels safety. The results were compared with the Mbare Musika analytical results and used for the identification of the source of contamination for the various heavy metals.

RESULTS AND DISCUSSION

All lead levels on average were within the stipulated threshold for human consumption in vegetables according to WHO/FAO standards. Cabbage had a hyper accumulative tendency to accruing lead as compared to the other vegetables as depicted in Figure 5. Safe lead limit in vegetables had been set at 1.5 ppm according to WHO/FAO [13].

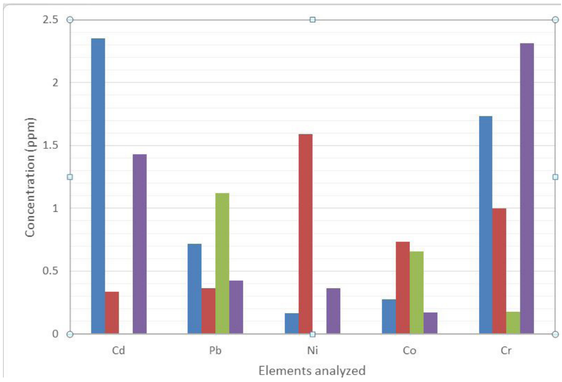

Figure 5: Average levels of heavy metals in vegetables from Mutoko and Mbare Musika.

Cabbages and tsunga had high lead levels as compared to beans and tomatoes proving a contrasting tendency of leafy vegetables having a hyper accumulative tendency towards the element and possessing possible health consequences in the human body. Cobalt levels were within the stipulated threshold accepted for human adult consumption by WHO/FAO [13]. With an acceptable daily intake limit of 0.05 mg/day, this rate cannot be exceeded considering the consumption rate of vegetables at the study rate. Chromium levels exceeded the stipulated limit for tomatoes and sugar beans and were within limits for cabbages and tsunga on average. That points to hyper accumulative tendencies of the fruity vegetables for chromium. Nickel was within stipulated levels for all samples. Cadmium was really high, above the 0.02 ppm threshold for the fruity vegetables as compared to the leafy vegetables as depicted in Figure 5. Thus proves that the fruity vegetables have a tendency of hyper accumulating cadmium and chromium whereas the study leafy vegetables actively accrue lead, nickel and cobalt.

Hazard Quotient for tomatoes showed possible health consequences on cadmium as depicted in Figure 6. Both Mbare Musika and Mutoko tomatoes showed HIs above unit and only on cadmium. The rest of the elements had Hazard Quotients below one which in theory can be considered as having no health consequences. In practice, no evidence exists to prove that there are no health consequences with Hazard Quotient below 1 hence need to practice strict regulation of heavy metal levels in all agricultural inputs and safeguard agricultural produce against all heavy metal contaminations [14-16].

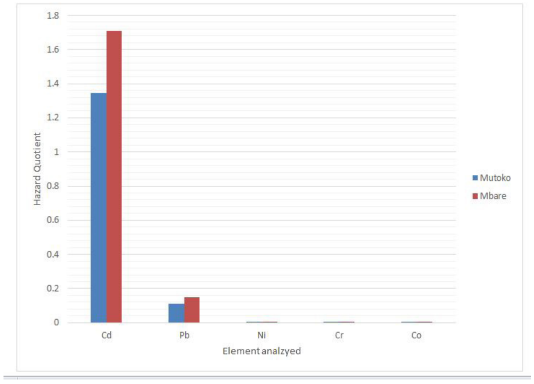

Figure 6: Comparison of Hazard Quotients for adults consuming tomatoes from Mbare Musika and Mutoko.

Lead exceeded the stipulated thresholds of 1 for the Hazard Quotient on leafy vegetables in this study as depicted in Figure 7. Chromium, cobalt, nickel and cadmium levels can theoretically be considered safe on health consequences when consumed at the study rate and below as depicted in Figure 7. However, according to Varol et al., even if there are low levels of heavy metals in vegetables, it is dangerous to make an assumption on their safety [2]. Attention should also be paid to non-carcinogenic risks associated with the heavy metal of interest at high vegetable intake.

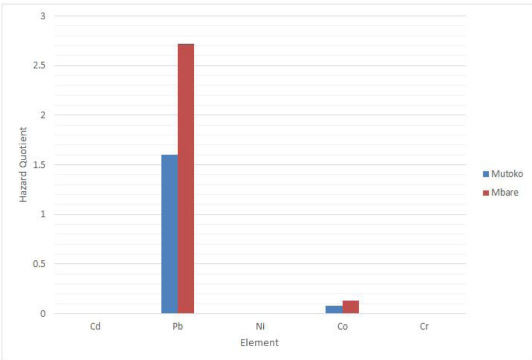

Figure 7: Comparison of Hazard Quotients for adults consuming cabbages from Mbare Musika and Mutoko.

No sugar beans were collected from Mutoko hence this study is only reporting on Mbare Musika sugar beans. From results of the Mbare Musika samples, Hazard Quotient on cadmium exceeded the unit level acceptable for adult human consumption with no health consequences as depicted in Figure 8. Sugar beans have a hyperactive tendency of accruing cadmium making it the obvious risky element on health consequences on fruity vegetables grown in the Mutoko environment [12]. There is needed to keep lead levels to as low levels as is possible because of its accumulative effects in the human body. There seem to be no health consequences from lead, nickel, cobalt and chromium in sugar beans as depicted in Figure 8.

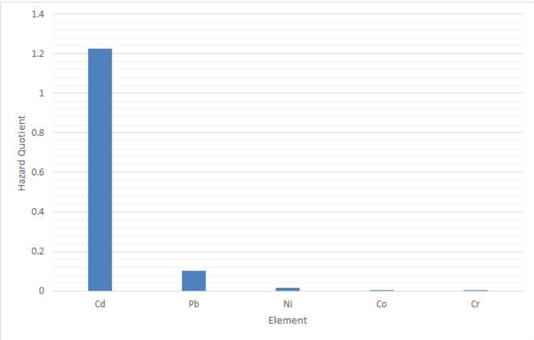

Figure 8: Hazard quotients for sugar beans from Mbare Musika.

Both sources of the vegetable did not tally on Hazard Quotients from any of the heavy metal under study as depicted in Figure 9. This might have been caused by a misrepresentation of the origin of vegetables sampled from Mbare Musika by the farmers. They must have come from elsewhere and not Mutoko. As depicted in Figure 9, no cadmium and nickel were detected in tsunga from Mutoko justifying the accession above [17]. Another possibility is that the places sampled might not have been the source of vegetables found in Mbare Musika during the days of market sampling. There are other possibilities like other chemicals from pesticides and other agrochemicals contributing to such anomalies observed in Figure 9.

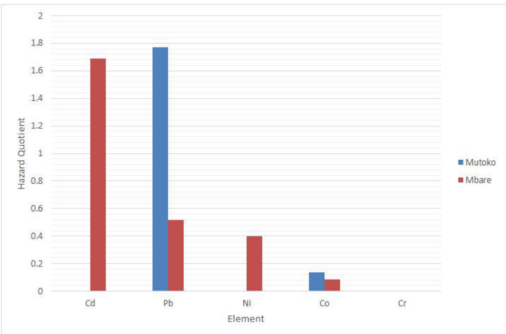

Figure 9: Comparison of Hazard Quotients for adults consuming tsunga from Mbare Musika and Mutoko.

Summation of the Hazard Quotients gave the Hazard Indices which showed combined risk of the heavy metals under study on health consequences as indicated in Figure 10. All Hazard indices for the four vegetables indicate that accumulatively, there is an increased health risk consequences for adults consuming the sampled vegetables from Mbare Musika and Mutoko at the stipulated rate and above. HIs were all above unity indicating a need for an intervention [12].

About forty six percent (46%) of people in Mutoko doing horticultural practices use river water for irrigation as depicted in Figure 11. Well water comes second with about forty one (41%) percent. The rest like dams' weirs and boreholes are minor sources used by the populace as indicated in Figure 11. The few dams in Mutoko are sited at irrigation schemes which are not many in number [18].

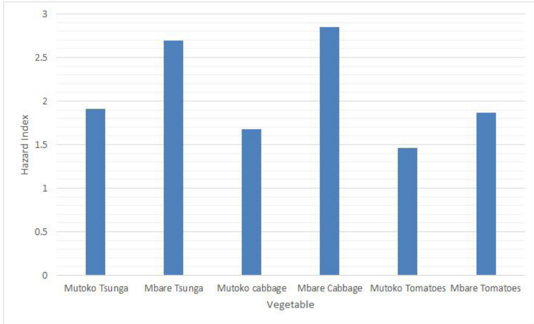

Figure 10: Hazard Indices (HIs) of the various vegetables from Mbare Musika and Mutoko.

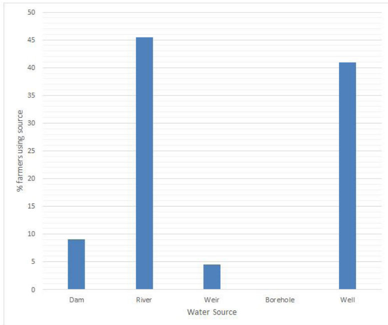

Figure 11: Percentage farmers using the various water sources for irrigation in Mutoko.

The method of water application determines the extent of contamination attributed to the source and nature of water. Manual irrigation is only possible at small scale hence area that can be contaminated is also relatively small. Flooding contribute to the major irrigation mode for the majority, about 40.91% of farmers, in Mutoko as depicted in Figure 12. Flooding creates hotspots of accruing heavy metals within the field; otherwise a lot of work has to be done to ensure uniform distribution of the water. Flooding allows all sediments within the water to percolate into the soil and usually more water than required is let into the field. The best way to ensure less contamination of the soil environment is use of sprinklers and center pivots which adds a thin film of water at a low rate around its sphere of influence as compared to flooding.

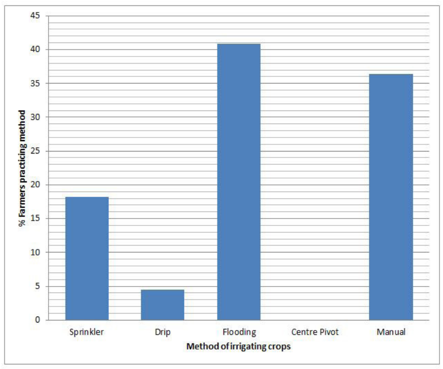

Figure 12: Methods of water application in irrigation for horticultural purposes within Mutoko farmers.

All irrigation water sources on average exceeded the recommended cadmium levels limit for irrigation water of 0.01 ppm according to FAO/WHO, as seen in Figure 13. The standard deviation for cadmium was 0.0147 hence did not show much difference amongst the waters sources levels. The standard deviation for lead was 0.0437 hence did not show much significant difference amongst the waters as well [19]. Lead had a safe maximum limit of 5.0 ppm in irrigation waters and none of the samples surpassed this level. Considering its accumulative effects in living tissues until it reaches lethal levels, action is necessary to keep it in check to as low levels as is possible. Chromium is well spread in varying concentrations amongst the water sources with a standard deviation of 0.532. All sources exceeded the chromium threshold of 0.1 ppm indicating a need for an urgent intervention. There is a risk from effects of chromium levels in the irrigation waters and safety of the irrigated vegetables may become questionable. Standard deviation for cobalt was 0.0182 hence showing little spread amongst the various water sources. Cobalt levels were within stipulated levels in all irrigation water sources. Nickel was not detected in all water sources hence its influence could be regarded as having no health consequences.

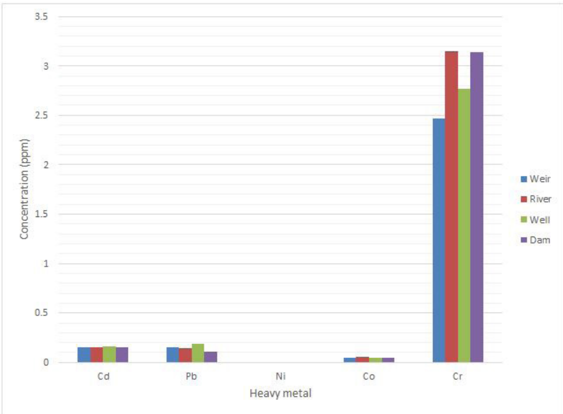

Figure 13: Levels of heavy metals in the major irrigation water sources used in Mutoko.

Average levels of heavy metals in soils from Mutoko showed that the soils are within recommended thresholds for the elements under study as depicted in Figure 14. Soil is the medium in which the plants thrive and obtain their nutrition. According to Curtis RL and Smith WB, estimates of distribution coefficients (soil-to-water concentration ratios) for each metal largely determine projections of soil metal accumulation over time, though there is high uncertainty in these estimates. Some vegetables actively accrue heavy metals to unprecedented levels even though their levels being small in the soil [20].

Fertilizers were the most varied inputs on heavy metal distribution as depicted in Figure 15. Since use of fertilizers and related products is a repetitive practice, it is necessary to consider cumulative changes over decades of applications according to Curtis RL and Smith WB [1]. Chromium had the highest standard deviation of 129.15, followed by lead with a standard deviation of 48.17. This calls for stringent assessment requirements in quality control of inputs with heavy metal levels taken as a criteria for rejection. There is high use of fertilizers in the

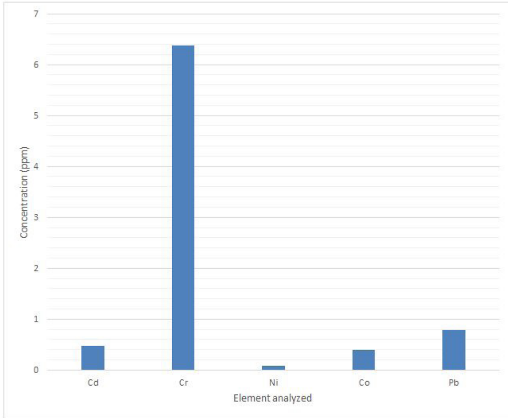

Figure 14: Average concentration of heavy metals in soils from Mutoko.

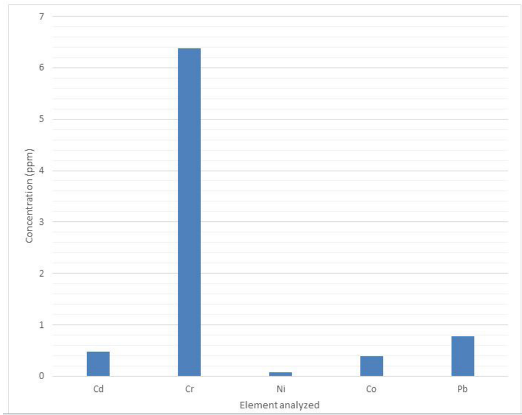

Figure 15: Standard deviations of various heavy metals in basal fertilizers collected in Mutoko.

horticultural fields of Mutoko and could act as the most probable source of contamination to the horticultural system [21].

CONCLUSION

Heavy metal contamination of vegetables is imminent in vegetables grown in Mutoko. Cadmium and lead stand as then elements of major concern when it comes to health consequences. Hazard Quotients showed that health consequences arose mostly from cadmium in the leafy vegetables and lead in the fruity vegetable. Hazard Indices reflected possible health consequences especially on all vegetables under study especially when consumed at the study rate and above. Fertilizers and irrigation water stood out as the major sources of heavy metal contamination. Mining and abuse of fertilizers, pesticides and other chemicals in Mutoko are possible sources of heavy metal contamination to the vegetables.om the data presented in this study one can deduce that heavy metals are inevitable in horticultural systems of Mutoko and are mostly of anthropogenic origin. There should be vigilance in enforcing regulations to heavy metal levels in agricultural inputs to ensure environmental and human food chain safety and security.

RECOMMENDATIONS

There is need for an intervention to optimize heavy metal levels in agricultural inputs and also produce. Regulations should take into account heavy metal levels in agricultural inputs as criteria for rejection. Audits should be conducted frequently to monitor the rate at which these are accruing in the soil and water. That audit could enhance recommendations on suitability of certain areas for growing certain vegetables for commercial purposes. Future studies should look into which parts of the various vegetables accrue the highest concentration of heavy metals hence dissuade people from taking such components. There is need to consider various soil types on heavy metal absorption, adsorption and release to crops hence make recommendations on crops to be grown accordingly to sensitive areas without amassing high heavy metal levels. The transport system for ferrying vegetables to, and storage at the market should also be assessed for possible contamination sources. Last but not least, Hazard Quotients and Index should be conducted for infants who are the most vulnerable group as humans.

REFERENCES

1. Curtis RL, Smith WB. Heavy Metal in Fertilizers: Considerations for Setting Regulations in Oregon 2002.
2. Varol M, Gündüz K, Sünbül MR, Aytop H. Arsenic and trace metal concentrations in different vegetable types and assessment of health risks from their consumption. Environmental Research. 2022:206:112252.
3. Harnell M. Threshold values in the context of European Soil Protection Policies: Report to. 1999.
4. Nazir R, Khan M, Masab M, Rehman HU, Rauf NU, Shahab S, et al. Accumulation of heavy metals (Ni, Cu, Cd, Cr, Pb, Zn, Fe) in the soil, water and plants and analysis of physic-chemical parameters of soil water collected from Tanda Dam Kohat. J Pharm Sci & Res. 2015;7(3):89-87.
5. FAO/WHO. General standards for contaminants and toxins in food and feed (Codex Stan 193-1995). 2014.
6. Mapanda F, Mangwayana EN, Nyamangara J, Giller KE. Uptake of heavy metals by vegetables irrigated using wastewater and the subsequent risk in Harare, Zimbabwe. 2007;32(15-18):1399-1405.
7. Annex 2. Heavy metals and organic compounds from wastes used as organic fertilizers. ENV. 2004.
8. Shirkhanloo H, Mirzahosseini SA, Shirkhanloo N, Moussavi-Najarkola SA, Farahani H. The evaluation and determination of heavy metals pollution in edible vegetables, water and soil in the south of Tehran province by GIS. Archives of Environmental Protection. 2015;41(2):64–74.
9. Ghani A. Toxic effects of heavy metals on plant growth and metal accumulation in maize (Zea mays). 2010.
10. Maleki A, Gharibi F, Alimohammadi M, Daraei H, Zandsalimi Y. Concentration levels of heavy metals in irrigation water and vegetables grown in peri-urban areas of Sanandaj, Iran. J Adv Environ Health Res. 2014;1(2):81-88.
11. US Environmental Protection Agency Integrated risk information system. 2010.
12. Mvumi B, Donald T, Mhunduru J. A report on Baseline Data available for Mutoko district, Mashonaland East Province. 1998.
13. WHO/FAO. Report of the 24th session of the codex committee on nutrition and foods for special dietary uses. Joint FAO/WHO Food Standards Programme Codex Alimentarius Commission. Geneva, Switzerland. 2003.
14. Agency for Toxic Substances and Disease Registry. Toxicological profile for cadmium and nickel. Agency for toxic substances and Disease Registry, US Department of Health and Human Services, Public Health Service. 1999a.
15. Agency for Toxic Substances and Disease Registry. Toxicological profile for Lead. Agency for toxic substances and Disease Registry, US Department of Health and Human Services, Public Health Service. 1999b.
16. China EPA. Maximum levels of contaminants in foods. Beijing, China: China State Environmental Protection Administration. 2005.
17. Fertilizers, Farm Feeds and Remedies Act Chapter. 1996.
18. Joint FAO/WHO Codex Alimentarius Commission. Joint FAO/ WHO Food Standards Program Rome, Italy: Food and Agriculture Organization of the United Nations. 1984.
19. Kumar N, Soni H. Characterization of heavy metals in vegetables using Inductively Coupled Plasma Analyzer. 2007:11(3).
20. Opaluwa OD, Aremu MO, Ogbo LO, Abiola KA, Odiba IE, Abubakar MM, et al. Heavy metal concentrations in soils, plant leaves and crops grown around dump sites in Lafia Metropolis, Nasarawa State, Nigeria. Adv Appl Sci Res. 2012;3(2):780-4.
21. Tafadzwa P. Way back when I used to sell at the farmers market, actually just Mbare. 2016.