Kwaghe International
Journal of Sciences and Technology

ISSN: 1595-7977

Index: Harvard, Boston, Sydney University, Dimensions, Lens, ResearchGet Scilit, Semantic, Google Scholar, Base etc

https://doi.org/10.58578/KIJST.v2i3.7896

Genotoxic Potentials of Varieties of Cassava (*Manihot esculenta*) in the Uptake of Heavy Metals from Vehicular Emission (Lead, Arsenic, Chromium, Cadmium, and Zinc): A Review

Pakka E. Fami, Amos J. T. Yaro, M. Alahira E., Sonka S. H.
Adamawa State College of Education, Hong, Nigeria
famielijahpakka@coehong.edu.ng

Article Info:

Submitted:	Revised:	Accepted:	Published:
Oct 2, 2025	Oct 25, 2025	Nov 6, 2025	Nov 11, 2025

Abstract

Cassava (*Manihot esculenta*) is a widely consumed staple crop, with numerous species cultivated for their agronomic traits such as yield, tuber size, and color. These species—including TMS90257, TMS84537, TMS82/00056, TMS82/00661, NR8212, NR8082, TMS50395, and TMS30555—are generally classified into three groups based on hydrocyanic acid concentration. This review investigates the genotoxic potential of various *Manihot esculenta* species in relation to their capacity to uptake harmful heavy metals from the soil. The primary sources of metal contamination examined are agrochemicals, particularly pesticides, and vehicular emissions. The review synthesizes findings from existing literature indicating that while cassava absorbs heavy metals such as lead, arsenic, cadmium, chromium, and zinc, the concentrations in most cases remain within World Health Organization (WHO) permissible limits. However, continued exposure to these elements poses significant health risks due to their cumulative toxic effects. The study underscores the importance of educating farmers and consumers about the implications of heavy metal uptake in food crops and advocates for stricter monitoring and awareness to mitigate potential health hazards. This review contributes to the broader discourse on food safety, environmental toxicology, and sustainable agricultural practices.

Keywords: Cassava; Heavy Metal Uptake; Genotoxicity; *Manihot esculenta*; Food Safety

Introduction

Cassava (*Manihot spp*) is one of the staple food consume globally especially in the tropical parts of the world comprising Africa and South America. It is a dicotyledonous plant belonging to the family euphobiaceae. Cassava is a root crop native to Central America and was introduced to West Africa by Portuguese explorers in the 16th and 17th centuries ((NRCS, 2005 and NAERLS, 2022). The crop is now processed into a wide range of industrial products such as ethanol, glue, poultry feed, glucose syrup and bread especially in South and Central America (IITA, 1990). Being a major source of cheap carbohydrate, large expanse of land is being allocated to the cultivation of Cassava as the demand of food surges and because the cultivation of the crop is usually not labor intensive as some crops. Once the crop is planted, it need minimal wedding unlike other crops like grains or cereal.

Species of Cassava There are different species of cassava and species selection for cultivation according to Bentley et al (2017) is influence by factors such as: high yielding with many big roots, early maturing, durable (stay well underground, for at least two years). Different species of Cassava have been bred and selected based on outstanding attributes like root yield, pests and diseases resistance/tolerance, high dry matter and food quality (NAERLS, 2022). There are many cultivars or varieties under cultivation. They can be distinguished by such morphological characteristics as leaf size, color and shape, branching habit, plant height, color of stem and petiole, tuber shape and color, time-to-maturity and yield. Cassava varieties are often classified according to the levels of cyanogenic glucosides (hydrocyanic acid, HCN) in the tuber and leaves. The major groups are: cassava with high HCN level 10 mg per 100gm fresh weight or more; an example of this is TMS 50395. Next is cassava with low HCN level, less than 5mg per 100gm fresh weight; the HCN is often concentrated in the peel; good examples of low HCN cassava like TMS 30001 and TMS

4(2)1425 and lastly the intermediate types, in which the levels of HCN range between 5 and 10mg per 100gm fresh weight; examples are TMS 30572 and TMS 30555 (IITA, 1990). Therefore, the common endemic varieties include TMS90257, e.t.c

The major diseases of cassava are leaf diseases, stem diseases and tuber rot (IIT, 1990). Cassava plant is not normally affected by diseases or pests, however according to the United States National Research Conservation Services (NRCS, 2005

Heavy Metals

Heavy metals otherwise known as poisonous metals are elements that have relatively high density and are toxic or poisonous in low concentration. Lead is a metal that looks bluish gray in color. It is found in the earth's crust in small amounts as an odorless and tasteless. Most of the lead that we see today comes from human activities. Lead is an important component of fuel and pesticides, excessive exposure to lead can cause lead poisoning. Chromium and zinc particularly are among the trace elements that the body needs to function optimally. Zinc is present in all body tissues and fluids. The total body zinc content has been estimated to be 30mmol (2g). Skeletal muscle accounts for approximately 60% of the total body content and bone mass, with a zinc concentration of 1.5–3mmol/g (100–200mg/g), for approximately 30% (WHO, 2004). Arsenic and cadmium are poisonous. Arsenic occurs naturally in the earth crust while lead is usually a product of fossil fuel, accumulation of arsenic is gradual but prolonged exposure will lead to issues such as; skin lesions, peripheral neuropathy, gastrointestinal symptoms, and diabetes. Cadmium can cause respiratory tract infection (cancer) and kidney problem. Table 1 shows the acceptable limits of some elements in the soil (ground) and air that is considered safe for humans and plants growth and development. Heavy metals doesn't originate from the cassava but are taking up from the soil on which they are planted (Ihejirika *et al*, 2022). Nwineewii (2020) also shows that leaves contains more heavy metals that the tubers. The concentration of heavy metals also varies with location perhaps due to natural deposit or the kind of activities taking place there (Adamu, *et al*, 2021). The species of cassava is also be a source in variation in its ability to retain heavy metal (Earnest *et al,* 2024).

Table 1. Maximum Limit of Metals in Soil and Ground Water

No	Dangerous substance	CAS No.	Maximum limits				
			In soil, (mg/kg)			In groundwater, µg/l	
			Target value	Reference value in residential zone	Reference value in industrial zone	Target value	Reference value
I. Heavy metals							
1.	Mercury (Hg)	–	0,5	2	10	0,4	2
2.	Cadmium (Cd)	–	1	5	20	1	10
3.	Lead (Pb)	–	50	300	600	10	200
4.	Zinc (Zn)	–	200	500	1500	50	5000
5.	Nickel (Ni)	–	50	150	500	10	200
6.	Chromium (Cr)	–	100	300	800	10	200
7.	Copper (Cu)	–	100	150	500	15	1000
8.	Cobalt (Co)	–	20	50	300	5	300
9.	Molybdenum (Mo)	–	10	20	200	5	70
10.	Tin (Sn)	–	10	50	300	3	150
11.	Barium (Ba)	–	500	750	2000	50	7000
12.	Selenium (Se)	–	1	5	20	5	50
13.	Vanadium (V)	–	50	300	1000	–	–
14.	Antimony (Sb)	–	10	20	100	–	–
15.	Thallium (Tl)	–	1	5	20	–	–
16.	Beryllium (Be)	–	2	10	50	–	–
17.	Uranium (U)	–	20	50	500	–	–
II. Other inorganic compounds							
18.	Fluoride (as F-ion, total)	–	450	1200	2000	1500	4000
19.	Arsenic (As)	–	20	30	50	5	100
20.	Boron (B)	–	30	100	500	500	2000

WHO/FAO, 2004

Lead

Lead (Pb^{2+}) is one of the commonest heavy metals that easily can diffuse into the environment. The main source of this contamination is related to industrial activities and products principally fossil fuels and agrochemicals (WHO, 2023). Other sources of lead pollution are vehicular emission, debris from fallout of paints, corrosive water pipes, mining and smelting of ores, pesticides and combustion (ASTDR, 2020). It is a metal that looks bluish gray in color that is found in the earth's crust in small amounts without an odor or a taste. Most of the lead that we see today comes from industrial process, food and smoking, contaminated drinking water and domestic activities (WHO, 2019). Lead has an atomic number of 82, molecular weight 207.2, density 11.34 g/cm3, and a melting point of 621.43 ◦F. It can be easily shaped, molded, and used to form alloys through mixing with other metals and can exist in both organic as well as inorganic form (Amit *et al*, 2020). Lead is a normal constituent of the earth's crust, with trace amounts found naturally in soil, plants, and water. If left undisturbed, lead is practically immobile. However, once mined and transformed into man-made products, which are dispersed throughout the environment, lead becomes highly toxic. Solely as a result of man's actions, lead has become the most widely scattered toxic metal in the world. Unfortunately for people, lead has a long environmental persistence and never loses its toxic potential, if ingested. The lead dispersed through gasoline exhausts, smelter emissions, and peeling paint, etc. never fully disappears from our environments nor has man evolved a good biological system to offer any protection from it. In the course of evolution of time, the global contamination of this highly toxic substance into man's environment has been a very short and recent period (Needleman, 1999). The excessive accumulation of lead in the soil or water bodies leads to some adverse effect in the physiological function of the body causing disease (Aliyu and Musa, 2021). A person can be exposed to lead by breathing contaminated air, eating contaminated food or soil and drinking water. Dust particles that have lead attached to them can be in the air. The maximum quantity of lead according to the WHO (2019:2023) is 10 µg/L, is 0.5 µg/m3 annually and not more than 5 ug/dl, in the blood. Exposure to lead can cause serious health complications in humans. In children, it can affect brain development, cause behavioral changes such as reduced attention span and increased antisocial behavior and ultimately reduced educational attainment (WHO, 2023). Exposure to Lead also causes anemia, hypertension, renal impairment, immunotoxicity and toxicity to the reproductive organs. Lead in the body is distributed to the brain, liver, kidney and bones. It is stored in the teeth and bones, where it accumulates over time (WHO, 2019). Lead can be measured from body tissues and structures such as plasma, urine, hair, teeth and bones these are not used clinically. Measurement of lead in bone reflects cumulative exposure over time and is not representative of current exposures (WHO, 2023). The surest way of preventing and containing lead pollution is to phase out the use of lead as an additive in paints or fuel and also to educate people about the danger of exposure to it. There is the need also to monitor compliance by industries that produced substance containing lead. Josephat *et al* (2019) in a study in Owerri, Nigeria reported 0.5267±0.3156 of lead concentration in cassava

Chromium

Is one of the trace elements needed for the proper functioning of the body (Sreemoyee, 2015). Chromium is widely distributed in the earth's crust and can exist in oxidation states ranging from -2 to +6. This different oxidation states of chromium are not equally assimilated by the body, for example, Chromium III is much less toxic than chromium (VI). Soils and rocks may contain small amounts of chromium, almost always in the trivalent state (WHO, 2003). Before Chromium can harm someone, many factors such as the dose (how much), the duration (how long), the form (chromium VI as opposed to chromium III), and how you come in contact with it will determine the severity (ASTDR, 2012). The respiratory tract is the major target organ for chromium (VI) toxicity, for acute (short-term) and chronic (long-term) inhalation exposures. Shortness of breath, coughing, and wheezing were reported from a case of acute exposure to chromium (VI), while perforations and ulcerations of the septum, bronchitis, decreased pulmonary function, pneumonia, and other respiratory effects have been noted from chronic exposure. Human studies have clearly established that inhaled chromium (VI) is a human carcinogen, resulting in an increased risk of lung cancer. Animal studies have shown chromium (VI) to cause lung tumors via inhalation exposure (ASTDR, 2012). The major rout to which chromium enters the body is through the air but they can have access to the body in limited forms through ingestion and dermal contact and chiefly leaves the body via the urine.

The acceptable level of chromium in water is about for drinking water set by the food and drug administration of the united states (FDA) IS 0.1 mg/L for total chromium in drinking water, chromium(VI) of 0.005 mg/m3 chromium in air averaged over an 8-hour work day, for chromium(III) of 0.5 mg/m3 chromium in air averaged over an 8-hour work day, and for chromium(0) of 1.0 mg/m3 chromium in air averaged over an 8-hour work day(ASTDR, 2012).

Exposure to Chromium can cause immunological, hematological, reproductive, developmental, dermal, ocular toxicity, genotoxicity, reproductive effects and cancer. Chromium is used for making steel and other alloys while Chromium compounds, in either the chromium (III) or chromium (VI) forms, are used for chrome plating, the manufacture of dyes and pigments, leather and wood preservation, and treatment of cooling tower water. Smaller amounts are used in drilling muds, textiles, and toner for copying machines

(ASTDR, 2012). Cassava absorbs chromium from the soil from which it is planted and from agrochemicals such as herbicides, pesticides and other farm inputs that contains it which are eventually stored in the cassava plant. Cassava Stem Biochar (CSB) was shown to assist in removing chromium from the soil (Vasu *et* a*l,* 2024). Plants basically absorb chromium from agrochemicals and emissions from automobiles.

Zinc

Zinc is present in all body tissues and fluids. The total body zinc content has been estimated to be 30mmol (2g) (WHO, 2004) and skeletal muscle accounts for approximately 60% of the total body content and bone mass, with a zinc concentration of 1.5–3mmol/g (100–200mg/g), for approximately 30%. High concentrations of zinc are found in the choroid of the eye (4.2mmol/g or 274mg/g) and in prostatic fluids (4.6–7.7mmol/l or 300–500mg/l) (WHO, 2004). Zinc is an essential component of a large number of enzymes participating in the synthesis and degradation of carbohydrates, lipids, proteins, and nucleic acids as well as in the metabolism of other micronutrients. It stabilizes the molecular structure of cellular components and membranes and in this way contributes to the maintenance of cell and organ integrity. Furthermore, zinc has an essential role in polynucleotide transcription and thus in the process of genetic expression. Its involvement in such fundamental activities probably accounts for the essentiality of zinc for all life forms (WHO, 2004). Zinc is found as component of more than 300 enzymes and hormones and plays a crucial part in the health of our skin, teeth, bones, hair, nails, muscles, nerves and brain function as well as it is essential for growth. Zinc controls the enzymes that operate and renew the cells in our bodies. The formation of DNA, the basis of all life on our planet, would not be possible without zinc. Zinc deficiency is an important public health problem, affecting large number of women and children in India and worldwide (Bimola *et al*, 2014). It plays a vital role in the maintenance of immune functions, including cellular and hormonal immunity and zinc deficiency affects multiple aspects of innate and adaptive immunity. Changes in the intracellular concentration of free zinc control immune cell signal transduction by regulating the activity of major signaling molecules including kinases, phosphatases and transcription factors (Bamola *et al*, 2014). Zinc is also used as supplements in addition to oral rehydration solution in the management of acute diarrhea in children. European health authorities recommend zinc intakes for adults of 9.5 mg per day for males and 7 mg/day for females. In the U.S., the recommended intake for adults has been set at 11 mg/day for men and 8 mg/day for women. The requirement for dietary zinc may be as much as 50% greater for strict vegetarians whose major food staples are grains and legumes. A strong inverse relationship has been shown to exist between zinc and copper, too much of one can cause a deficiency in the other and a long-term use of zinc should be accompanied by copper. Josephat *et al* (2019) in a study reported 8.48 ±2.243 of zinc concentration in Owerri Nigeria which is almost in line with the 10ug/L recommended by the WHO. Few of the literature on zinc in cassava does not report any excessive deviation from the global standard limit that is to be observed or consume in food.

Arsenic

Arsenic is widely distributed throughout the earth's crust, generally as arsenic sulfide or as metal arsenates and arsenides (ASTDR, 2012). It is classified chemically as a metalloid, having both properties of a metal and a nonmetal; however, it is frequently referred to as a metal. Elemental arsenic (sometimes referred to as metallic arsenic) is a steel grey solid material. However, arsenic is usually found in the environment combined with other elements such as oxygen, chlorine, and sulfur (ASTDR, 2012). In water, arsenic occurs in one of two main forms: arsenite As (III) under reducing conditions and arsenate As (V) if the water is oxygenated. It can be released to the atmosphere, primarily as the trioxide, mainly by high-temperature processes or through volatilization from aerated soils. In the atmosphere, it is mainly adsorbed on particles, which are dispersed by winds and deposited on land and water (WHO, 2019). Depending on the dose, Arsenic can either be used to treat illness or be used as a poison to cause death. It has also been used as medicine to treat syphilis and amebic dysentery which ended with the introduction of penicillin and other antibiotics in the twentieth century (Gilbert, 2011).

Arsenic can be introduced into the environment firstly through natural activities such as volcanic activity, dissolution or desorption of minerals (particularly into groundwater), exudates from vegetation and wind-blown dusts. Next is by human activities, such as metal smelting, combustion of fossil fuels (especially coal), mining, timber treatment with preservatives, and, historically, agricultural pesticide production and use. Others include remobilization of historic sources, such as mine drainage water; and mobilization into drinking-water from geological deposits by drilling of tube wells (WHO, 2023). Arsenic gets to human body through ingestion, inhalation, or skin absorption (Saha, *et al*, 1999).

Inorganic arsenic is used in wood preservation, although its use for preservation of wood used for residential purposes has been phased out. Until the 1940s, inorganic arsenic was used as therapeutic agents in the treatment of various diseases, such as leukemia, psoriasis and chronic bronchial asthma. Arsine has some limited use semiconductor industry and in the synthesis of organoarsenic compound (ASTDR, 2012). The permissible limit of arsenic in the water is 50 to 10 ppb or 10 $\mu g/L^3$ (WHO, 2023). Arsenic get into cassava from the uptake from the soil or other pollutants containing it.

Cadmium

Cadmium is one of the elements that nature has blessed us with which rarely occurs in the purest form on its own but in a mixture with zinc, copper and lead ores. Cadmium was first produced in a commercial quantity by Germany which made Germany a leader of this new element until World War I (Thomas, 1994). Pure cadmium is a silver-white, lustrous metal, but cadmium in this form is not common in the environment. It is most often encountered in the earth's crust combined with chlorine (cadmium chloride), oxygen (cadmium oxide), and sulfur (cadmium sulfide) (Charles *et al*, 1993). Pure cadmium is a soft, silver-white metal. Cadmium chloride and cadmium sulfate are soluble in water (ASTDR, 2012). Cadmium oxide also exists as small particles in air (fume), the result of smelting, soldering, or other high-temperature industrial processes. Most cadmium used in the United States is obtained as a byproduct of the smelting of zinc, lead, or copper ores. Cadmium is used mainly in metal plating; in producing pigments, batteries, and plastics; and as a neutron absorbent in nuclear reactors (Charles *et al*, 1993). Cadmium is produced mainly as a by-product from mining, smelting, and refining sulphide ores of zinc, and to a lesser degree, lead and copper. As it is a by-product of zinc, the production of cadmium is more dependent on zinc refining than on market demand (NCM, 2003). The percentage of cadmium in zinc concentrates varies from mine to mine, ranging from 0.07 to 0.83 per cent with an average of 0.23 per cent. Small amounts of cadmium, about 10-15% of consumption, are produced from secondary sources, mainly from dust generated by recycling of iron and steel scrap. Cadmium and its compounds 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 (ASTDR, 2012).

The recommended maximum for cadmium in drinking water 3µg/L and 5µg/m3 (annual average) for air (WHO, 2023). A study by Josephat et al (2019) in Owerri Nigeria shows that the cassava contains 0.1167± 0.0833. Effects of excessive intake of cadmium include kidney effect, difficulty in calcium metabolism, respiratory problems and cancer. To prevent this, a high standard of sanitation should be maintained, cadmium compound should be regulated, avoid smoke and enlightenment should be done on the effect of cadmium.

Conclusion

Cassava (*Manihot esculetum*) is an important food crop and major source of carbohydrate to millions especially in tropical countries. Exposure to chemicals such as agrochemical and polluted land has the potential to infect crops such as cassava with some harmful element especially when used in excessive quantities. Lead infect cassava principally through pesticide, herbicides and automobile emission. It is a very dangerous element that can cause serious health complications. It is readily found in the incompletely burnt smoke from engines. Cassava absorbed lead chiefly through the soil while absorbing nutrient through the roots. The recommended level of all these five element comprising of lead, zinc, arsenic, chromium and cadmium according to the world health organization (WHO) is 10µg/L, 50µg/L, 5µg/L, 10µg/L and 1µg/L respectively. To avoid or minimize exposure and contamination to harmful metal in farming and consuming cassava, there is the need to be deliberate in the way we farm, choices of chemicals and exposure to sources of contamination of these heavy or poisonous metals. There should be enlightenment on the effects of heavy metal and the way it circulate in the environment and importantly how to contain it. A high standard of hygiene should be promoted and demanded to avoid any possibility of contact with heavy metals. More studies and research should also be made in the area of heavy metals to have deeper understanding and more knowledge in our interaction with heavy metals and their compounds around us.

References

Adamu C. S., Ekoja, O. F., Bello, S. G. and Salihu, B. S. (2021). Heavy Metals on Cassava Processing and the Environmental Effects in Central Nigeria. *Advanced Earth and Environmental Science journal* (2)2, 01-06

Agency for Toxic Substances and Disease Registry, the Public Health Service (ATSDR) (2012). Toxicological Profile for Cadmium. Pp. 01;01-487

Agency for Toxic Substances and Disease Registry, the Public Health Service (ATSDR) (2012). Toxicological Profile for Chromium. Pp. 01;01-592

Aliyu, H. S. and Musa, A. (2021). Lead: A concise review of its toxicity, mechanism and health effect. *GSC Biological and Pharmaceutical Sciences*, 15(01), 055–062

Amit, K., Amit, Kumar., Cabral-Pinto, M.M.S. , Ashish, K., Chaturvedi ., Aftab, A. S., Gangavarapu, S., Raju, Mondal., Dipak, K. G., Sandeep, K. M., Smita, S. K., Shakeel, A. K., and Krishna, K. Y. (2020). Lead Toxicity: Health Hazards, Influence on Food Chain, and Sustainable Remediation Approaches. Int. J. Environ. Res. Public Health.Pp. 02-38. doi:10.3390/ijerph17072179arsenic. Pp. 01-559.

Bentley, J., A. Olanrewaju, T. Madu, O. Olaosebikan, T. Abdoulaye, T. Wossen, V. Manyong, P. Kulakow, B. Ayedun, M. Ojide, G. Girma, I. Rabbi, G. Asumugha, and M. Tokula. (2017). Cassava farmers' preferences for varieties and seed dissemination system in Nigeria: Gender and regional perspectives. IITA Monograph, IITA, Ibadan, Nigeria. ISBN 978-978-8444-82-4. 90 pp.01-108

Bimola, D. C., Nandakishore, T., Sangeeta, N., Gomi, B., Omita, D. N., Sungdirenla, J. Singh, M. A. (2014). Zinc in Human health. *Journal of Dental and Medical Sciences,* 13(7), PP 18-23

Charles, B., Jonathan. B., MD; Joseph, C., Bernard, G., Alan, H., Richard, J. J., Jonathan, R.,

Department of Health and Human Services (DHHS) (2007). Toxicological Profile for

Gilbert, S. (2011). A Small Dose of Arsenic. Toxipidia. Pp. 01-07

Ihejirika, C. E., Ndubuisi, E. C., Njoku, J. D., Emereibeole1, E. I., Ebe, T. E., Njoku-Tony, R. F., Ihejirika, O. C., Imo, E. O., Nwachukwu, I. N., Chinakwe, E. C., Uyo, C. N., Ezikeudu, C. E. and Ursula, N. N.(2021). Heavy metal contamination of Cassava (Manihot esculenta Crantz) grown on quarry soils in Umunneochi Abia State and its health implications. *International Journal of Environmental Quality* (45) 1-9

International Institute for Tropical Agriculture (IITA) (1999). Cassava in Tropical Africa A Reference Manual. Supported by United nation International Emergency Fund (UNICEF)

Josephat, N. O., Judith, N. N., Ukaoma, A. A. and Odangowei, I. O. (2020). Heavy Metals in Cassava (Manihot esculenta Crantz) Harvested from Farmlands along Highways in Owerri, Nigeria. *Turkish Journal of Agriculture - Food Science and Technology,* 8(4): 800-806, 2020\

National Agricultural Extension and Research Liaison Services (NAERLS) (2022). CASSAVA Production, Processing and utilization An Extension Bulletin No. 224. Sponsored By WAAPP - Nigeria Agricultural Transformation Agenda Federal Ministry of Agriculture and Rural Development Pp. 01-22.

National Resource Conservation Service (NRCS) (2005). Cassava *Manihot esculenta Crantz*. Plant Guide. Pp. 01-06

Needleman, H. L. (1999). History of Lead Poisoning in the World. Pp. 01-08

Nordic Council of Ministers (NCM) (2003). Cadmium Review. Pp 02-26

Nwineewii, J. D. (2020). Heavy Metal Concentrations in Cassava Leaves and Tubers Harvested from Some Communities in Gokana, Rivers State, Nigeria. *International Journal of Research and Scientific Innovation* (I7)5, 1-6

Saha, J. C., Dikshit A. K., and Bandyopadhyay M. (1999). A Review of Arsenic Poisoning and Its Effects on Human Health. Pp 01-50

Sreemoyee, C. (2015). Chromium Toxicity and Its Health Hazards. *International Journal of Advanced Research.* 3(7), 167-172

Thomas, O. L. (1994). Cadmium Material Flow. United State Department of the Interior, Bureau of Mines. Pp 01-22

Vasu, G., Prabu, D., Selvaraju, S., Saikat, B., Naveen, B.S. (2024). Cassava Stem Biochar (CSB) for Chromium Removal from Produced Water: Sustainable Adsorption and Environmental Implications. *Journal of Technology and Biotechnology*

WHO (2003). Guidelines for drinking-water quality, 2nd ed. Vol. 2. Health criteria and

WHO (2019). Preventing Disease through Healthy Environments: Exposure to Arsenic: A Major Public Health Concern. Pp. 01-06

WHO (2019). Preventing Disease through Healthy Environments: Exposure to Lead: A Major Public Health Concern. Pp. 01-06

WHO (2019). Preventing Disease through Healthy Environments Exposure to Cadmium: A Major Public Health Concern. Pp. 01-06

WHO (2023). Preventing Disease through Healthy Environments: Exposure to Lead: A Major Public Health Concern. Pp. 01-07

World Health Organization (WHO) (2019). Preventing Disease through Healthy Environments Exposure to Arsenic: a Major Public Health Concern. Department of Public Health, Environmental and Social Determinants of Health World Health Organization Pp. 01-6

World Health Organization and Food and Agriculture Organization of the United Nations (2004). Vitamin and Mineral Requirements in Human Nutrition. Second Edition. Pp. 01-362