Sub-Sahara African Academic Research Publications
December, 2022, Editions

JRATR
Journal of Renewable Agricultural Tech. Research
Vol. 26, No.1, ISSN 2813 – 9650

HAZARD ANALYSIS OF HEAVY METALS IN FOOD CROPS AND MANAGEMENT STRATEGIES

UMARU ABDULLAHI; AND NASIRU YAHAYA AHMED
Department of Agricultural and Bio-Environmental Engineering, School of Engineering Technology. Federal Polytechnic Bali, Taraba State, Nigeria.

Abstract
The contamination of heavy metals has spread widely across the environment, causing health risks to the human race and hazard for the environment. Heavy metal contamination of soil and food crops is an issue of global concern that ultimately results in toxicity and diseases in humans and animals through consumption of contaminated food crops. The major concern that requires sustainable advancement both statistically and on the basis of Qualitative assessment is food security. Recently, antagonistic impacts of unforeseen toxins have impacted the quality of crops and have created a burden on human lives, adding to dreariness and in severe cases even death. Consequently it is vital that communities with high levels of heavy metal pollution avoid eating large quantities of these food items. Also there is need for monitoring the levels of these injurious elements in food crops. This paper reflects the contamination of the food crops with heavy metals, the way of transport of heavy metal to food crops, degree of toxicity after consumption and the strategies to maintain the problem.

Keywords: Heavy metals, Food crops, Assimilation, Health hazard.

Introduction
Heavy metal is any metallic element that has a relatively high density and is toxic or poisonous even at low concentrations. The term applies to the group of metals and metalloids with an atomic density greater than 4 g/cm3, or at least 5 times greater than the density of water (Lentech 2004). Heavy metals include lead (Pb), cadmium (Cd), zinc (Zn), mercury (Hg), arsenic (As), silver (Ag), chromium (Cr), copper (Cu), iron (Fe), and the platinum (Pt) group. Heavy metal contamination is a major environmental health challenge and is potentially dangerous because of bioaccumulation through the food chain (Aycicek et al 2008), which arises from rapid industrial growth, advances in the use of agricultural chemicals, and the urbanising activities of man. This has led to the dispersion of heavy metals in the environment, resulting in the impaired health of the population, mainly by the ingestion of food crops contaminated by these harmful

elements (Zukowska and biziuj, 2007). Uptake of heavy metals by plants through absorption and subsequent accumulation along the food chain is a potential threat to animal and human health (Sprynsky et al 2007, Jordan et al 2006). The contamination of heavy metals has spread widely across the environment, causing health risks to the human race and hazard for the environment. A few hazardous Heavy metals (such as As, Pb, Cd, and Hg) relates to metabolic and other organic capacities as inconsequential. Certain metals, like Zn, Fe, Cr (III), etc., are important to carry metabolic cycles, including hemeproteins and catalysts. They are related to biota metabolism (Romheld et al 2012). Food and soil, crop/vegetable frameworks have given an exemplary illustration of the bio-diverse ecosystem communications in the climate. For food the basic source of yield is the soil, but it is prone to contamination by heavy metals from various origins (e.g., energy-serious enterprises, for example, nuclear energy stations and coal mine shafts, and chloro-soluble base synthetic ventures, like goldmines, purifying, electroplating, materials and calfskin) and nonpoint sources (e.g., soil/residue disintegration, farming spill over, and open cargo stockpiling). Notwithstanding their human wellbeing suggestions, Heavy metals unfavourably influences soil biota through microbial cycles (Gadd 2010). For instance, restorative plants utilized for customary human medical care ought to be analysed for Heavy metals tainting to forestall unfavourable impacts. When exposed to near refining or other modern environments, a variety of restorative species of plants have been found to cause bioaccumulation of various heavy metals (e.g., Cd, As, Cr, Cd, Cu, Pb, and Fe) (El Hamiani et al 2015). Both anthropogenic and natural sources release heavy metals into the environment. They can penetrate soils and groundwater, bioaccumulate in food webs, and harm biota because they are highly reactive and typically toxic at low quantities. The biotic effects of necessary and non-essential heavy metals are often highly distinct, and vary depending on the exact metal involved. This paper aims to provide a global overview of significant metal sources in agro-environments that are equivalent to the various anthropogenic activities and cycles (Parihar et al 2019). This also includes details about heavy metals contamination in soil environments where food crops are grown in fully occupied main-lands. Moreover, ecological and lives of humans in these subsystems are needed to be discussed to aid in the understanding of the physiological/atomic systems which constitutes to the uptake of Heavy metals in the crops (Sankla et al 2019).

Source of heavy metal in agricultural soil and irrigation water.

Soils are a significant sink for heavy metals delivered into the climate by recently referenced anthropogenic exercises, and dissimilar to regular unfamiliar substances that are oxidized to carbon (IV) oxide by microbial movement, most metals do not go through microbial or compound degradation, and their complete obsession in soils goes on for quite a while after discharge (Adriano 2010). Heavy metals and metalloids may be accumulated in soils as a result of discharges from rapidly expanding modern regions, mine tailings, removal of high metal squanders, leaded gas and paints, land use of

composts, animal excrement, sewage slop, pesticides, wastewater water system, coal burning build-ups, petrochemical spillage, and environmental statements (Zhang et al 2010). Frequently recognized heavy metals like Lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and nickel (Ni) are the pollutants. Regardless, changes in their substance structure (speciation) and bioavailability are conceivable. The presence of harmful metals in soil can keep regular pollutants from biodegrading appropriately (Mashin and maier 2000). Significant metal contamination of soil can jeopardize individuals and the organic framework through: direct ingestion or contact with spoiled soil, the normal lifestyle (soil–plant-human or soil–plant–animal-human), drinking defiled ground water, decline in food quality (security and appeal) because of phytotoxicity, and reduction in land usability for agrarian creation because of phytotoxicity (Zhang et al 2010). The adequate security and rebuilding of heavy metal-tainted soil biological systems need their depiction and repair. At both the public and global levels, current legislation on natural insurance and general well-being is based on data that describes the compound qualities of ecological wonders, particularly those that exist in our developed way of life (Ling et al 2007). Risk assessment is a powerful logical tool that enables leaders to manage contaminated areas in a cost-effective manner while protecting public and biological system health.

Heavy metals happen spontaneously in the soil environment as a result of pedogenetic cycles of parent material lasting at levels that are considered safe (1000 mg/kg-1) and occasionally hazardous (1000 mg/kg-1). Fertilizer; Horticulture was the most important human effect on the land in general (Baster et al 2005). Plants require not just macronutrients but also essential micronutrients to build up and complete the lifecycle. Some soils are deficient in heavy metals which are necessary for solid plant development, and harvests might be supplemented with them as a soil development or foliar spray. Grain crops grown on Cu deficient soils are treated with Cu on a regular basis as a soil expansion, and cereal and root crops may also be given Mn. In major cultivating frameworks, large volumes of compost are frequently applied to soils to provide adequate N, P, and K for crop development. Following measurements of heavy metals (e.g., Cd and Pb) as contaminants are present in the mixes utilized to supply these components (Verma et al 2018), which may fundamentally extend their substance in the soil after being applied with compost. Cd and Pb, for example, have no recognized physiological effects. The use of some phosphatic composts accidentally introduces Cd and other potentially toxic components to the soil, such as F, Hg, and Pb. Pesticides; in the past, a few common insecticides used widely in agribusiness and agriculture included significant metal centralizations. For example, in the recent past, around 10% of the synthetics used as insecticides and fungicides in the United Kingdom were based on intensities containing Cu, Hg, Mn, Pb, or Zn. Copper-containing fungicidal splashes like Bordeaux mixture (copper sulphate) and copper oxychloride are examples of such pesticides (Baster et al 2005). For a long time, lead arsenate was used in natural product plantings to suppress parasitic microorganisms.

Heavy metals are commonly found in the environment as a result of substrate erosion. These naturally occurring heavy metals are generally in forms that are inaccessible to plant roots. However, due to a rise in human activities that release more biologically accessible forms of heavy metals into the environment, this has altered in recent years (Mapanda et al 2005). Agriculture is one of the major human activity that contributes to heavy metals being released into the environment. Using waste water to irrigate agricultural soils resulted in considerably greater amounts of heavy metals in the edible parts of the crops produced on these soils, according to (Arora et al 2008). Heavy metals may be present in factory wastewater, which build over time in soil deposits along waste water routes as in creatures that live near them. Human exposure to polluted wastewater is common, especially in densely populated metropolitan areas or when wastewater is utilized for agricultural purposes.

Heavy metal contamination

Climate is an environmental factor in which people, plants, beings, minute living beings. It comprises land, the atmosphere and the hydrosphere component. Earth is a framework that is characterized by the four pillars, the living organisms (biosphere), the atmosphere (air), the lithosphere (land) and water (hydrosphere) which are all employed in a combination. Natural toxins, just like contaminations, are synthetic substances that are available at more elevated levels than in any segment of the climate (Masindi and Muedi 2018). During the most recent years, the process of industrialization has developed at a rapid phase. This manner has expanded the interest for abuse of the Earth's regular assets which is a growing concern ecological contamination. A few poisons, such as inorganic particles, natural toxins, organometallic substances, vaporous poisons, radioactive substances and Nano-based materials, have actually poisoned the climate. Heavy metals have existed on earth since the existence of earth. Because of an amazing increment in the usage of substantial metals which brought about a fast-approaching flood of metallic substances in both the earthbound climate and the oceanic climate (Martin and Johnson 2012). The Heavy metal contamination has occurred due to anthropogenic activities, primarily due to metal mining, purification, foundries, and other metal-based ventures, as well as metal draining from various sources such as landfills, squander dumps, discharge, animals and chicken fertilizer, overflows, cars, and road works. The usage of Heavy Metals (Heavy metals) in the industries like agriculture, pesticides, insect poisons, manures etc., has been an optional wellspring of heavy metal contamination. Eruptions from volcanoes, consumption of metals, from the environment are all examples of natural events that might increase heavy metal contamination. This contamination can travel from soil and water causing soil breakdown, and land degradation, which are all examples of natural factors that might increase heavy metal contamination (Tchounwall et al 2012).

Heavy metal uptake and bioaccumulation in food crops

Crops grown on contaminated lands with Heavy Metals accumulate in the plants edible parts, which are then ingested by humans. Because heavy metals are resistant from degradation, and have long half-life periods, thus difficult to excrete out. Many metals

are hazardous at low doses, Heavy metal poisoning is a major problem in crops (Auch et al 2010). Long-term exposure to heavy metal contaminated crops can result in a variety of health problems, including bone thinning, skin problems, improper endocrine gland function, blood pressure, neoplastic growth, impairment of sexual characteristics, asthma and other respiratory issues, heart diseases, and brain impairments. Heavy metal contamination in crops is a concern worldwide that leads to toxidromes and a variety of illnesses in humans, flora and fauna, when polluted soils and food crops are consumed (Khan et al 2010).

Metal uptake and transportation pathways

Heavy metal take-up by roots from debased soils and surface water, just as immediate exchange of toxins from the climate on plant surfaces, can bring about critical metal defilement of plants (Zhang et al 2010). Lead and Cd are suspected malignancy causing synthetics and have been connected to the aetiology of an assortment of sicknesses, including cardiovascular, renal, blood, apprehensive, and bone illnesses. Notwithstanding the way that Zn and Cu are fundamental segments, their exorbitant focus in food and feed plants is of incredible concern attributable to their harmfulness to people and living things (Kabata et al 2007). Development of yields for human or trained being utilization may possibly prompt the take-up and amassing of these metals in consumable plant leaves, representing a danger to human and living thing wellbeing (Lim et al 2008). Unnecessary dietary gathering of heavy metals like Cd and Pb in the human body may bring about genuine clinical issues. For the greater part, dietary induction is the dominating method of receptiveness, regardless of the way that in profoundly contaminated regions, internal breath can assume a significant part (Dieckow et al 2009). The significant channel of human receptiveness to generous metals is the soil-to-manage trade of heavy metals. The developing human populace has started an interest for more food. Pesticides, manures, fertilizers, composts, and wastewater have all been utilized all the more frequently in the water framework accordingly. Food crops developed on metal-drained soil can ingest and gather metals in critical amounts to influence food quality (Emurotu et al 2017).

Transportation via the food chain and occurrence in human food

Heavy metals contaminate land and leach out to water bodies, show their effect by persisting in the food cycle, have antagonistic effects on biota since they are very responsive and toxic at low concentrations (Golubkina et al 2019). Toxic metals gets accumulated by plants from roots. Heavy metal travels through the water stream by applets to the internal cells (endodermis). This endodermis function as a protective layer for Heavy metal movement. The casparian strip prevents water stream and the Heavy metal enters the symplastic phase. Heavy metal transportation (in low concentrations) through root to APP have accounted for of immobilization by contrarily charged gelatins inside the root cell divider (Arias et al 2010). Insoluble Heavy metal salts hasten in

intercellular spaces of root cells. Essentially, Heavy metal amassing in plasma layers of root cells or in rhizodermal vacuoles and cortical cells of roots. Significant segment of Heavy metal is discharged from internal cells (endodermis) during the detoxification process by the plant. Foundations of hyper accumulator species break up metals in soil (Meyers et al 2008), increment metal take-up and movement, and make hyper accumulator species to endure higher Heavy metal particles focuses. Other detoxifying components include specific metal take-up, discharge, ligand binding, all contribute to Heavy metal resistance. The transfer of Heavy metal from lower part of plant to upper (root-shoot) is aided by xylem, which is most likely supported by occurrence (Liao et al 2006). On mesquite plants, demonstrated X-beam planning and observed high Heavy metal statements in xylem and phloem cells. It was found that Heavy metal traveled to the leaf from the vascular stream via apoplastic pathway (Sankla and Kumar 2019). In xylem, Heavy metal can frame edifices with amino/natural acids. In any case, inorganic Heavy metal can likewise be moved. Movement (i.e., Heavy metal present in aeronautical parts/driving roots) can be executed for understanding level of Heavy metal movement (Saba et al 2019). Notwithstanding, the admission of Heavy metal tainted plants has been a significant openness to people and creature. Consumable/wild plants developed/filled nearby phosphate businesses can be Heavy metal bio-pointers of harmful metals. Occupants and labourers of these businesses/regions might be presented to Heavy metal tainting (Barbillon et al 2019).

Hazardous effects of crops containing heavy metals on health of humans

Heavy metal contaminating eateries has a progression bearing unfavourable consequences for the health of humans because of their pervasive and refractory nature. Unnecessary metals have the capacity to bypass preventive mechanisms like compartmentalization, homeostasis, cellular failure, oxidative breakdown, and ship, resulting in toxic and fatal consequences (Flora et al 2008). The significant manifestations of TEs harmfulness in people are scholarly handicap in youngsters, CNS problems, dementia and sadness in grown-ups, a sleeping disorder, kidney and liver sicknesses, passionate shakiness, and vision unsettling influences, expanded the dreariness and death rate. Metal toxicants cause oxidative stress in individuals, which is described by: a) expanded creation of Reactive Oxygen Species/Reactive Nitrogen Species (ROS/RNS) b) exhaustion/debasement of internal enemy of oxidant and free-revolutionary scroungers c) restraint/decrease in digestion and catalysts identified with decontamination process. In spite of the fact that toxicity arising from unexpected or word related openness to generous quantities of metals normally influences organ frameworks, seriousness of the harmfulness relies upon the kind and type of the TEs, openness course and duration and, likewise by person's defencelessness (Jan et al 2011). Harmful substances (metals) ingested in the course of debased crops can result in a variety of long-term illnesses. TEs consumption in polluted eatables might degrade several important nutrients of the body. This depletion is also linked to decreased

malnutritional abilities, immunological defences, hampered psychosocial resources, intrauterine development impediment, and increased threat of upper GI cancer (Iyengar and Nair 2000). Extreme sensitivity to Cd may amplify pneumonic effects. Sub chronic inward Cd breath might also have a negative influence on the kidneys. Moreover Lead (Pb) toxic has been linked to the Brain/CNS and the GIT in both adolescents and adults, the impact may be severe or long-term. Stomach discomfort, desiring trouble, joint pain, pipedreams migraine, hypertension, fatigue, renal brokenness, restlessness, and vertigo are all symptoms of intense Pb openness (Jainshakar et al 2014). Pb over time can cause allergic reactions, chemical imbalances, birth defects, CNS damage, renal damage, solid shortcoming, loss of mobility, malnutrition, in severe cases death (Sankla, et al 2020).

Food safety regulation strategies and the health hazards mitigation.

Many studies have been conducted on the uptake, collection, and elimination of TEs in model plants at the research facility scale by a few scientists. Despite this, few investigations are conducted in the field in a straightforward manner. As a result, there is a need to look into the gaps in terms of the practicality of ways to reduce TEs in daily food sources and in high-need food items, similarly drinking water which is an essential component in the prevention and elimination of Heavy metals. There have been many advances in molecular biology and biotechnology applications of a few plant and animal species, the altered/controlled ingestion of harmful components, as well as categorizing these components into non-consumable parts, but it is still not fully accomplished (Sankla, et al 2020). As a result, more unified vegetables-based initiatives are predicted to boost the production of toxic component-free palatable plant parts.

Quality exchange/change in articulation of particular receptor/chemical/component carrier may also be used to effectively regulate the retention of hazardous components in vegetable yields. The adjustment of exudates of roots gives a powerful measure to stifle harmful components in soil. This process can provide forestalling of the passage of TEs into the jungle. Endeavours can promptly begin in those harvests on which densely spread population depends for food. One main consideration is the absence of subsidizing (Mosa et al 2016), with the goal that the consumer sector is fundamental to produce successful financing for TEs research. TEs tainting by and by exists in regular assets, yet, whenever kept up beneath as far as possible, long haul biological system imperativeness can be kept up without influencing the natural way of life.

Ranchers should be educated about the dangers of using excessive amounts of compost and other synthetics, as well as the natural hazards of flooding crops in various water bodies (wastewater, sewage, and mechanical water) so as to balance the requirement for vegetables growth with low TE levels. Ability to manage environmental sources, like soil and water, helps maintaining sustainability for crops cultivation. The information gathered should include wastewater quality indexing data to support for aquatic system water testing at rural areas to establish public health. Capable organizations should complete general wellbeing schooling inside the utilization region to teach people in

general the possible impacts of unpredictable waste usage risks and the wellbeing perils related to the use of vegetables developed using untreated/contaminated. It should be capable of measuring TEs contamination & supplement stacking of aquatic system and soils to secure wellbeing, both of ranchers and buyers. Considering the expected harmfulness, diligent nature and combined conduct just as the utilization organic materials and vegetables, it is essential to test the breakdown of food materials to guarantee the number of impurities concerning modern day issues (Sankla, et al 2020, Mosa et al 2016). Standard overview and observing projects of the grouping of TEs in food items have been done for quite a long time in the vast majority of the created nations and similar practices ought to be carried out in agricultural nations.

Conclusion

Natural impurities, food handling and safety, and health of humans are inter-connected. The presence of Heavy metals in the climate has increased altogether in late many years. Wellsprings of Heavy metal in crops can change in the creating and created world. Heavy metal exchange from ground soil to trim frameworks is unpredictable and requires complex components. Synergistic harmfulness of metals in food crops is also a major metal poisoning and contamination issue. The human wellbeing hazards have been broadly explored on a worldwide scale, however a couple of those works have utilized appropriate epidemiological techniques. To forestall wellbeing chances, existing remediation alternatives center on lessening the convergence of hefty metals in soil and the natural way of life. Fast and precise planning of soil contamination is expected to forestall the exchange of metallic toxins into the natural pecking order and to figure reasonable remediation techniques. Eco-attainable mechanical advancements, for example, Nano-devices and the consciousness of ranchers could support neighbourhood economies and vocations with certain monetary assurances.

Reference

Adriano DC. Trace Elements in Terrestrial Environments: Biogeochemistry, Bioavailability, and Risks of Metals. Vol. 860. New York: Springer; 2001

Arora M et al. Heavy metal accumulation in vegetables irrigated with water from different sources. Food Chemistry. 2008;111(4):811-815

Arias JA et al. Effects of Glomus deserticola inoculation on Prosopis: Enhancing chromium and lead uptake and translocation as confirmed by X-ray mapping, ICP-OES and TEM techniques. Environmental and Experimental Botany. 2010;68(2):139-148

Auch AF et al. Digital DNA-DNA hybridization for microbial species delineation by means of genome-to-genome sequence comparison. Standards in Genomic Sciences. 2010;2(1):117-134

Aycicek M, Kaplan O and Yaman M. Effect of cadmium on germination, seedling growth and metal contents of sunflower (*Helianthus annus* L.). *Asian J Chem.* 2008; 20: 2663–2672.

Barbillon A et al. Health risks assessment in three urban farms for different scenarios of urban agricultural users: A case of soil trace metals contamination. *JAS*. 2019;10(3):352-370.

Basta N, Ryan J, Chaney R. Trace element chemistry in residual-treated soil: Key concepts and metal bioavailability. 2005;34:49-63.

Dieckow J et al. Land use, tillage, texture and organic matter stock and composition in tropical and subtropical Brazilian soils. European Journal of Soil Science. 2009;60(2):240-249

El Hamiani O et al. Metal concentrations in plants from mining areas in Morocco: Health risks assessment of consumption of edible and aromatic plants. Soil, Air, Water. 2015;43(3):399-407
Emurotu J, Onianwa PJ. Bioaccumulation of heavy metals in soil and selected food crops cultivated in Kogi State, north central Nigeria. Environmental Systems Research. 2017;6(1):1-9.
Gadd GM. Metals, minerals and microbes: Geomicrobiology and bioremediation. Microbiology. 2010;156(3):609-643.
Golubkina N et al. Effects of crop system and genotype on yield, quality, antioxidants and chemical composition of grown leek. Advances in Horticultural Science. 2019;33(2):263-270
Iyengar GV, Nair P. Global outlook on nutrition and the environment: Meeting the challenges of the next millennium. Science of the Total Environment. 2000;249(1-3):331-346
Jan A, Ali A, Haq Q. Glutathione as an antioxidant in inorganic mercury induced nephrotoxicity. Journal of Postgraduate Medicine. 2011;57(1):72
Jaishankar M et al. Toxicity, mechanism and health effects of some heavy metals. Interdisciplinary Toxicology. 2014;7(2):60
Jordao CP, Nascentes CC, Cecon PR, Fontes RLF and Pereira JL. Heavy metal availability in soil amended with composted urban solid wastes. *Env Monitoring and Assess*. 2006; 112: 309–326.
Kabata-Pendias A, Mukherjee AB. Trace Elements from Soil to Human. Germany: Springer Science & Business Media; 2007
Khan S et al. Soil and vegetables enrichment with heavy metals from geological sources in Gilgit, northern Pakistan. Ecotoxicology and Environmental Safety. 2010;73(7):1820-1827
Lenntech. Water treatment and air purification 2004. Water Treatment, Rotterdamseweg, Netherlands. www.excelwater.com/thp/filters/ Water-urification.htm.
Ling W et al. Use of bentonite to control the release of copper from contaminated soils. Soil Research. 2007;45(8):618-623.
Lim HS, Lee JS, Chon HT, Sager M. HM contamination and health risk assessment in the vicinity of the abandoned Songcheon. Journal of Geochemical Exploration. 2008. 1;96(2-3):223-230.
Liao Y et al. Effect of transpiration on Pb uptake by lettuce and on water soluble low molecular weight organic acids in rhizosphere. Chemosphere. 2006;65(2):343-351
Maslin P, Maier RM. Rhamnolipid-enhanced mineralization of phenanthrene in organic-metal co-contaminated soils. Bioremediation Journal. 2000;4(4):295-308
Masindi V, Muedi KL. Environmental contamination by heavy metals. HM. 2018;10:115-132
Martin YE, Johnson EA. Biogeosciences survey: Studying interactions of the biosphere with the lithosphere, hydrosphere and atmosphere. Progress in Physical Geography. 2012;36(6):833-852
Mapanda F et al. The effect of long-term irrigation using wastewater on HM contents of soils under vegetables in Harare. Agriculture, Ecosystems & Environment. 2005;107(2-3):151-165
Meyers DE et al. Uptake and localisation of lead in the root system of Brassica juncea. Environmental Pollution. 2008;153(2):323-332
Mosa KA et al. Potential biotechnological strategies for the cleanup of heavy metals and metalloids. Frontiers in Plant Science. 2016;7:303
Parihar K et al. Water quality status of Yamuna River and its toxic effects on humans. Environmental Analysis and Ecological Studies. 2019;6(1):597-601
Romheld V. Diagnosis of deficiency and toxicity of nutrients. In: Marschner's Mineral Nutrition of Higher Plants. USA: Elsevier, Academic Press; 2012. pp. 299-312
Saba D et al. Bioaccessibility of lead in Dittrichia viscosa plants and risk assessment of human exposure around a fertilizer industry in Lebanon. Jour. of environmental mangt. 2019;250:109537
Sankhla MS, Kumar R. Contaminant of Heavy Metals in Groundwater & Its Toxic Effects on Human Health & Environment. IJES & NR. 2019;18(5):555996.
Sankhla MS, Kumar R, Prasad L. Variation of chromium concentration in Yamuna River due to change in temperature and humidity. Journal of Seybold Report ISSN NO. 2020; 1533:9211.
Sprynskyy M, Kosobucki P, Kowalkowski T and Buszewsk B. Influence of clinoptilolite rock on chemical speciation of selected heavy metals in sewage sludge. *JHM*. 2007; 149: 310–316.
Tchounwou PB et al. Heavy metal toxicity and the environment. Molecular, Clinical and Environmental Toxicology. 2012;101:133-164
Verma RK, Sankhla MS, Kumar R. Mercury contamination in water & its impact on public health. International Journal of Forensic Science. 2018;1(2)
Zhang M-K et al. Use of single extraction methods to predict bioavailability of heavy metals in polluted soils to rice. Communications in Soil Science and Plant Analysis. 2010;41(7):820-831

Zukowska J and Biziuk M. Methodological evaluation of method for dietary heavy metal intake. *J Food Sci.* 2008; 73(2): R21–R29. DOI: https://doi. org/10.1111/j.1750-3841.2007.00648.