International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 1 Volume No.8 January - February – 2024
DOI:10.46647/ijetms.2024.v08i01.041 ISSN: 2581-4621

Unveiling the Invisible Threat: A Review of Heavy Metal Exposure and its Devastating Health Consequences

Deepak Soni[1], Avinash Dass[2], Narender Yadav[3], Pranati Gupta[4]
[1]*Research Scholar, Department of Environmental Sciences, Savitribai Phule Pune University, Ganeshhind Road, Pune-411007, India*
[2] *Research Scholar, Department of Environmental Sciences, Central University of South Bihar, Gaya-824236, Bihar, India*
[3]*Research Associate Ministry of Environment, Forest and Climate Change, Indira Paryavaran Bhawan, Jorbagh Road, New Delhi – 110003, India*
[4] *Research Scholar Department of Chemistry, Central University of South Bihar, Gaya-824236, Bihar, India*

Abstract
The widespread of heavy metals in air, soil, and water is a grave concern that poses a significant global threat. The distribution of contaminants such as mercury, lead, and cadmium are widespread and are associated with serious health risks such as cancer, cardiovascular and respiratory diseases, and Alzheimer's disease. Exposure to these heavy metals is known to cause numerous adverse health and environmental consequences, including toxicity from mercury and arsenic, neurological impairments caused by lead, and acute and chronic effects on various ecosystems, including birds, fish, and other species.
This comprehensive review aims to highlight potential routes of exposure to the three most common heavy metal pollutants - mercury, cadmium, and lead - focusing on their uptake through drinking water, ambient air, and dietary sources. The review will delve into the mechanisms by which these metals enter the body and the various health implications associated with their exposure. Understanding how these metals enter the body and the negative effects they cause, emphasizes the need for effective mitigation strategies and stricter regulations to protect human health and safeguard the environment.
Keywords: Heavy metals, Cancer, Health effects, Exposure, Environment

Introduction

Heavy metals are metallic chemical elements that occur naturally in the earth's crust and possess a high density, which renders them potentially dangerous or poisonous, even in little amounts. Mercury, Cadmium, Arsenic, Chromium, Thallium, Lead, and other heavy metals are naturally present in the Earth's crust. These metals occur naturally in food, water, and air, and can enter the body in trace amounts through the consumption of food, water, or air. Furthermore, several metallic elements, like Copper, Selenium, and Zinc, are essential for the proper operation of the human body in minimal quantities, as they aid in metabolism. Bioaccumulation is the process by which heavy metals are rapidly absorbed and stored in the body, leading to their gradual accumulation over time.
Water supplies can also become contaminated with heavy metals. Contributors encompass industrial and domestic trash, including acid rain that corrodes soil and facilitates the seepage of toxic heavy metals into streams, lakes, rivers, and groundwater. Human exposure to three prevalent heavy metal contaminants, namely Mercury, Lead, and Cadmium, can have adverse effects on both human health and the surrounding environment. Mercury can negatively impact the emotional, physical, and neurological functioning of people of all ages, as well as their cardiovascular, renal, respiratory, and immunological systems. Specifically, infants and young children are very susceptible to the impacts

of mercury due to their limited cognitive processing abilities. The buildup of mercury in fish has been associated with several harmful consequences on fish and other aquatic organisms. These impacts include decreased fertility, impaired kidney function, delayed growth, aberrant behavior, and even death in birds and mammals that consume fish. Even minimal exposure to lead can result in neurological impacts in children and can negatively affect cardiovascular, renal, gastrointestinal, hematological, and reproductive functions. Lead undergoes bioaccumulation in the environment across a wide range of species, presenting a potential hazard to plants, animals, and microbes. Cadmium exposure has been associated with pulmonary irritation, kidney illness, bone fragility, and the possible development of lung, prostatic, and renal cancer. The primary factors responsible for the presence of cadmium in the general population are the intake of cigarettes and food.

Mercury

The United Nations Endowment for the Prevention of Pollution (UNEP) (2002b) has conducted substantial research on the environmental pollutant mercury. However, there is still a limited understanding of its routes and the impact it has on human and environmental health. Throughout the industrial revolution, there has been a substantial increase in mercury levels, resulting in its extensive distribution in the environment and worldwide food supply networks. Even areas with minimal mercury emissions, such as the Arctic, are nonetheless susceptible to its worldwide dispersion. Greenpeace (1998) said that an estimated 40,000 to 80,000 individuals globally are likely experiencing mercury poisoning due to the consumption of contaminated seafood. Recent research indicates that human activities have caused a three-fold increase in the overall amounts of mercury in the atmosphere in industrialised regions. Additionally, the rate at which mercury is being deposited has grown by a factor of two to ten during the previous two centuries. Approximately 70% of human-caused air emissions are believed to come from burning fossil fuels and incinerating garbage. According to a research by the United Nations Environment Programme (UNEP) (2002b), the use of fossil fuels is projected to lead to an increase in mercury emissions. In addition, the possible consequences of global climate change are especially worrisome, as there is evidence of a rise in methyl mercury levels in lakes and streams that have recently experienced flooding. Moreover, it is observed that numerous countries suffer from a deficiency of fundamental knowledge concerning the utilisation, discharge, and quantity of mercury existing in the surroundings. Recent research has uncovered increased concentrations of mercury in certain seafood items, including sharks, swordfish, and tunas. As a result, certain nations have recommended that pregnant women refrain from consuming these particular types of seafood.

Lead

Lead extraction takes place in over forty nations globally, resulting in a total production of 3.150 million tonnes in 2004, as reported by the United Nations Educational, Scientific and Economic Council (UNEP) (2008a). UNEP reports that lead exposure is prevalent in nearly all countries globally, with the most elevated concentrations detected in the blood of around 200 million individuals worldwide. Greenpeace (1998) reported that ice core drilling in Greenland has uncovered a significant increase in lead levels during the Industrial Revolution. Lead deposition over the period from the 1960s to the 1990s was found to be eight times higher than in the pre-industrial era. Nevertheless, the utilisation of leaded fuel has diminished and the implementation of emission limits since the 1970s has led to a decline in lead levels detected in ice cores. UNEP's (2008a) data shows that global lead use for petrol additives declined significantly from 310 million tonnes between 1970 and 2004 to 14,400 tonnes. According to the United Nations Endowment for the Prevention of Pollution (UNEP) (2008a), the discharge of human-caused lead into the water fell considerably from 1983 to the mid-1990s. The total amount of lead emissions during this period was 120,000 tonnes. Most developed nations have observed a decline in overall lead emissions as a result of enhanced wastewater treatment. However, in numerous developing countries, such as Latin America and Small Developing Island States (SIDS), lead-containing items are not adequately disposed of due to a lack

DOI:10.46647/ijetms.2024.v08i01.041 ISSN: 2581-4621

of public consciousness. Moreover, the act of burning openly and unlawfully disposing of waste items containing lead, together with the manufacturing of plastics and paints, are probable sources of lead emissions that have a notable impact on the local and regional levels. It is crucial to acknowledge that exposure to lead has a substantial health influence and can have an adverse impact on development.

Cadmium

Anthropogenic activities have led to an elevation in the concentration of cadmium in the environment. From 1950 to 1990, global cadmium production nearly doubled, although consumption has remained generally stable at roughly 20,000 metric tonnes per year (UNEP, 2008b). Examinations carried out on ice cores from Greenland have revealed a deposition rate that was eight times greater than what was recorded in the pre-industrial era. However, recent study indicates that the rate of deposition has decreased since the late 1970s. Furthermore, a study conducted between 1990 and 2003 reveals that the emissions of cadmium, induced by human activities, in developing countries have decreased by an average of 50%. In 2008, the United Nations Endowment for Pre-Earmarkment (UNEP) conducted research that estimated manmade atmospheric emissions to be 2,903 metric tonnes in the mid-1990s. The main contributors of cadmium emissions are the non-ferrous metal sector and the combustion of fossil fuels. The estimated amount of cadmium in the aquatic environment is between 900 and 3,600 metric tonnes, mostly due to human activities that result in the deposition of cadmium in the atmosphere. In certain developing nations, the usage of cadmium has either been upheld or escalated. However, the regulations and restrictions in this particular area are not as comprehensive as those in other places. Furthermore, hazardous waste disposal practices that are not safe, such as landfill incineration or landfill discharge into rivers and wetlands, have posed risks to both human health and the environment. Greenpeace (1998) reported that cadmium usage could result in renal damage in around 250,000–500,000 individuals. Cadmium accumulates in agricultural soils by atmospheric deposition, the application of phosphate fertilisers, and the utilisation of sewage plant waste. This can result in an increase in the concentrations of cadmium in dietary items.

Heavy Metal Poisoning Causes and Risk Factors

Exposure to heavy metals can lead to a type of poisoning known as heavy metal poisoning. There are several potential causes of heavy metal poisoning, such as being exposed to heavy metal dust while working in a factory, consuming seafood from regions with high mercury levels, taking herbal remedies that contain heavy metals, eating uncoated dinnerware, or drinking water contaminated with heavy metals. One must be alert to potential exposure sources and take appropriate measures to avoid heavy metal toxicity.

Heavy Metal Poisoning Symptoms

In cases of chemical accidents or when a youngster swallows a toy containing lead, for example, ingesting a high quantity of metal at once can cause acute poisoning. Acute poisoning symptoms might vary from a lack of consciousness and numbness to vomiting, nausea, and confusion. When a little amount of the metal is consumed over an extended period of time, however, chronic toxicity develops. Constant poisoning can cause a wide variety of symptoms, including numbness, tingling, dehydration, and diarrhoea. Lead poisoning causes a cascade of symptoms that manifest over time, including but not limited to: constipation, muscle and joint pain, weakness, and exhaustion. For children, especially those who drink formula mixed with tap water, lead contamination of drinking water can have a detrimental effect on cognitive functioning and growth and development. Even though lead has been out of circulation for quite some time, it is still able to get into the water system via antiquated pipes. Even while certain water filters can eliminate lead, it's still a good idea to get your water tested if you're worried about the level of lead in it.

Heavy Metal Poisoning Diagnosis

Numerous tests, including X-rays, analyses of blood or urine, and other specialised examinations, can identify different types of heavy metals. These tests can detect the specific heavy metals that may be

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 1 Volume No.8 January - February – 2024
DOI:10.46647/ijetms.2024.v08i01.041 ISSN: 2581-4621

present and assess the degree of heavy metal intoxication. A complete blood count (CBC), electrocardiogram, protein analysis, liver function, abdominal radiograph, and kidney function tests are common. The doctor may also inquire as to the patient's occupation, interests, food, and any other activities that could expose them to harmful substances. It is important to mention that these tests are typically not performed frequently; they should only be administered if the patient has a history of heavy metal exposure or if there is a reasonable suspicion that they may be present.

Heavy Metal Poisoning Treatments and Home Care

Staying away from the poison's origin is crucial for preventing the disease from getting worse. Finding the right precautions to take is something your doctor can help you with. It may be required to pump the stomach in order to extract the metals in certain instances. One possible treatment for severe poisoning is chelation, which involves injecting the patient with medicines to bind the heavy metals. The body eliminates these medications through the urinary system. Chelation is a viable therapeutic option for heavy metal poisoning, but it should only be used in cases where the levels are high and the symptoms are obvious, and it is not appropriate for all cases.

Heavy Metal Poisoning Prevention

If you’re worried about heavy metal poisoning, your doctor can give you personalized advice.

General tips include:

Heavy metal workers must use masks or other protective gear. To guarantee safe fish consumption, consult local fish advisories. If a home was built before 1978, a lead paint test and abatement should be done by a professional. Finally, examine product labels for heavy metals.

Table 1. Description of toxic heavy metals, their forms, sources, permissible limit and their effects.

Heavy Metals	Pollutants	Source	Permissible limit(mg/L)	Effects	References
Mercury	Methyl Mercury (MeHg)	Fungicides, Insecticides, Bactericides	0.01	Neurotoxicity, Nephrotoxicity	Cope et al., 2004, Terziev et al., 2019
	Hg vapour	Dental Amalgam		Blood-Brain Barriers, Hypogastrium,	Beckers et al., 2017
	Hg^0 (Elemental)	Cosmetics		Bronchopneumonia	Birsan et al., 2023, Nduka et al., 2019
	$HgCl_2$	Production of PVC		Kidney Disfunctioning	Park et al., 2012
	Hg_2Cl_2	Purgative		Gastro-Intestinal Pain, Chest Pain	Langford et al.,1999
Cadmium	Cadmium oxide, cadmium sulphide	Tobacco	0.06	Cardiovascular Diseases	Fagerberg et al., 2021

DOI:10.46647/ijetms.2024.v08i01.041 ISSN: 2581-4621

	Cadmium Carbonate ($CdCO_3$)	Cadmium coatings, plating on metals		Carcinogenesis	Fatima et al., 2019, Sharma et al., 2015
	Cadmium chloride, Nickel-cadmium	Used in electroplating and prevents corrosion		Osteotoxicity And Multiple Bone Fractures	Fatima et al., 2019, Salek Maghsoudi et al., 2021
	Cadmium-metallothionein (Cdmt)	Stabilizers for plastic and paint pigments		Renal Disorder, Kidney Damage, Diabetes	Fatima et al., 2019, Hayat et al., 2019
	Cadmium chloride ($CdCl_2$) Cadmium hydroxide ($Cd(OH)_2$)	Vegetables, fishes		Reproductive Failure, Infertility	Duttaet al., 2022, Massányi et al., 2020
Lead	Lead sulphate	Pigments–dyes–paints	0.1	Neurotoxicity, Carcinogenicity	Tagne-Fotso et al., 2016
	Tetra-ethyl lead	Waste incineration, dust		kidney	Gidlow et al., 2004, Papanikolaou et al., 2005
	Lead acetate, lead nitrate	Textile industry, Rubber industry		Nephritis, vomiting, pulmonary inflammation	Hoet et al., 2005
	Tetramethyl lead (TML)	Tobacco consumption		Anaemia Dementia, Cerebral palsy, Encephalopathy	Bandyopadhyay et al., 2014, Singh et al., 2018
	Pb tetrachloride and tetra cetate	Alcoholic beverages		gastrointestinal (GI) tract infection, tubular necrosis	Boskabady et al., 2018, Grant et al., 2020

Conclusion

The toxic effects of heavy metals on human health and the environment are a global concern due to their transport via air, soil and water. Depending on the concentration and various major sources, the potential routes of entry into the body through water, air and food are numerous. These metals are necessary for the functioning of cells, metabolism and hormones in humans, however, when the limit is exceeded, it can lead to serious and potentially life-threatening health effects. The toxic effects of these metals on the soil are particularly damaging, as they kill microorganisms that are essential for soil fertility and nutrition. The International Agency for Research on Cancer (IARC) has reported that arsenic toxic effects can lead to cancer of the prostate, liver and blood, as well as skin Mercury is the primary cause of carcinogenic damage to the brain, lungs, skin, and colon. Lead is responsible for the development of colorectal cancer, intestinal cancer, and central nervous system cancer. Cadmium has toxic effects on the stomach, breast, lungs, and kidneys in humans. Additionally, in China, lead toxicity in children was attributed to the consumption of a particularly attractive dish, and in women, the use of food storage cans resulted in high lead levels in their blood. Additionally, cadmium is the primary contributor to Alzheimer's disease. Furthermore, phosphate fertilizers, due to their high usage, are beginning to accumulate in soils and enter into food chains. The World Health Organization (WHO) has identified mercury as a hazardous toxic metal that has a severe impact on aquatic life, and the consumption of mercury-tainted foods by humans has been linked to a variety of malignant diseases, including Minamata, as well as a range of physiological effects.

References

Aas, W. and Nizzetto, P. B. (2018) Heavy metals and POP measurements 2016. Norwegian Institute for Air Research. EMEP/CCC-Report 3/2018

Bacterial pollution induced community tolerance (PICT) to Cu and interactions with pH in long-term polluted vineyard soils. Soil Biol. Biochem. 43, 2324–2331.

Bandyopadhyay, D., Ghosh, D., Chattopadhyay, A., Firdaus, S. B., Ghosh, A. K., Paul, S., ... & Dalui, K. (2014). Lead induced oxidative stress: a health issue of global concern. *Journal of Pharmacy Research*, *8*(9), 1198-1207.

Barajas-Aceves, M., 2005. Comparison of different microbial biomass and activity measurement methods in metal-contaminated soils. Bioresour. Technol. 96, 1405–1414. Bastida, F., Zsolnay, A., Hernández, T., García, C., 2008. Past, present and future of soil quality indices: a biological perspective. Geoderma 147, 159–171.

Bartnicki J., Gusev A., Aas W., Gauss M. and J.E Jonson. (2017) Atmospheric supply of nitrogen, cadmium, mercury, lead, and PCDD/Fs to the Baltic Sea in 2015. EMEP Centres Joint Report for HELCOM. EMEP/MSC-W Technical Report 2/2017. Norwegian Meteorological Institute. Oslo, Norway. Available in the web: • EMEP Status Report 1/2018.

Beckers, F., & Rinklebe, J. (2017). Cycling of mercury in the environment: Sources, fate, and human health implications: A review. *Critical Reviews in Environmental Science and Technology*, *47*(9), 693-794.

Berg, J., Brandt, K.K., Al-Soud, W.A., Holm, P.E., Hansen, L.H., Sørensen, S.J., Nybroe, O., 2012. Selection for Cu-tolerant bacterial communities with altered composition, but unaltered richness, via long-term Cu exposure. Appl. Environ. Microbiol. 78, 7438–7446.

Bhattacharyya, P., Tripathy, S., Chakrabarti, K., Chakraborty, A., Banik, P., 2008. Fractionation and bioavailability of metals and their impacts on microbial properties in sewage irrigated soil. Chemosphere 72, 543–550.

BÎRSAN, M., STAN, C. D., MIELCAREK, K., NOWOKOSKI, P., SOCHA, K., PALIMARICIUC, M., ... & CIURBA, A. (2023). MERCURY EXPOSURE IN COSMETICS AND HUMAN HEALTH RISK. *Farmacia*, *71*(5).

Boskabady, M., Marefati, N., Farkhondeh, T., Shakeri, F., Farshbaf, A., & Boskabady, M. H. (2018). The effect of environmental lead exposure on human health and the contribution of inflammatory mechanisms, a review. *Environment international*, *120*, 404-420.

Bouskill, N.J., Barker-Finkel, J., Galloway, T.S., Handy, R.D., Ford, T.E., 2010. Temporal bacterial diversity associated with metal-contaminated river sediments. Ecotoxicology 19, 317–328.

Brochier-Armanet, C., Boussau, B., Gribaldo, S., Forterre, P., 2008. Mesophilic Crenarchaeota: proposal for a third archaeal phylum, the Thaumarchaeota. Nat. Rev. Microbiol. 6, 245–252.
Cavani, L., Manici, L.M., Caputo, F., Peruzzi, E., Ciavatta, C., 2016. Ecological restoration of a copper polluted vineyard: long-term impact of farmland abandonment on soil biochemical properties and microbial communities. J. Environ. Manag. 182, 37–47.
Charlton, A., Sakrabani, R., Tyrrel, S., Casado, M.R., McGrath, S.P., Crooks, B., Campbell, C.D., 2016. Long-term impact of sewage sludge application on soil microbial biomass: an evaluation using meta-analysis. Environ. Pollut. 219, 1021–1035.
Chen, J., He, F., Zhang, X., Sun, X., Zheng, J., Zheng, J., 2014. Heavy metal pollution decreases microbial abundance, diversity and activity within particle-size fractions of a paddy soil. FEMS Microbiol. Ecol. 87, 164–181.
Chodak, M., Gołębiewski, M., Morawska-Płoskonka, J., Kuduk, K., Niklińska, M., 2013. Diversity of microorganisms from forest soils differently polluted with heavy metals. Appl. Soil Ecol. 64, 7–14. Dai, J., Becquer, T., Rouiller, J.H., Reversat, G., Bernhard-Reversat, F., Lavelle, P., 2004. Influence of heavy metals on C and N mineralisation and microbial biomass in Zn-, Pb-, Cu-, and Cd-contaminated soils. Appl. Soil Ecol. 25, 99–109.
Das, S., Sen, M., Saha, C., Chakraborty, D., Das, A., Banerjee, M., 2011. Isolation and expression analysis of partial sequences of heavy metal transporters from Brassica juncea by coupling high throughput cloning with a molecular fingerprinting technique. Planta 234, 139–156.
Deng, L., Zeng, G., Fan, C., Lu, L., Chen, X., Chen, M., He, Y., 2015. Response of rhizosphere microbial community structure and diversity to heavy metal co-pollution in arable soil. Appl. Microbiol. Biotechnol. 99, 8259–8269.
Desai, C., Parikh, R.Y., Vaishnav, T., Shouche, Y.S., Madamwar, D., 2009. Tracking the influence of long-term chromium pollution on soil bacterial community structures by comparative analyses of 16S rRNA gene phylotypes. Res. Microbiol. 160, 1–9.
Dos Santos, J.V., Varón-López, M., Soares, C.R.F.S., Leal, P.L., Siqueira, J.O., de Souza Moreira, F.M., 2016. Biological attributes of rehabilitated soils contaminated with heavy metals. Environ. Sci. Pollut. Res. 23, 6735–6748.
Dutta, S., Gorain, B., Choudhury, H., Roychoudhury, S., & Sengupta, P. (2022). Environmental and occupational exposure of metals and female reproductive health. *Environmental Science and Pollution Research*, *29*(41), 62067-62092.
Fagerberg, B., & Barregard, L. (2021). Review of cadmium exposure and smoking‐independent effects on atherosclerotic cardiovascular disease in the general population. *Journal of internal medicine*, *290*(6), 1153-1179.
Fatima, G., Raza, A. M., Hadi, N., Nigam, N., & Mahdi, A. A. (2019). Cadmium in human diseases: It's more than just a mere metal. *Indian Journal of Clinical Biochemistry*, *34*, 371-378.
Feng, G., Xie, T., Wang, X., Bai, J.Y., Tang, L., Zhao, H., Wei, W., Wang, M.L., Zhao, Y., 2018. Metagenomic analysis of microbial community and function involved in Cdcontaminated soil. BMC Microbiol. 18, 11.
Fernández-Calviño, D., Bååth, E., 2016. Interaction between pH and Cu toxicity on fungal and bacterial performance in soil. Soil Biol. Biochem. 96, 20–29. Fernández-Calviño, D., Arias-Estévez, M., Díaz-Raviña, M., Bååth, E., 2011.
Gao, Y., Zhou, P., Mao, L., Zhi, Y.E., Shi, W.J., 2010. Assessment of effects of heavy metals combined pollution on soil enzyme activities and microbial community structure: modified ecological dose-response model and PCR-RAPD. Environ. Earth Sci. 60, 603–612. Ge, S., Wang, S., Yang, X., Qiu, S., Li, B., Peng, Y., 2015. Detection of nitrifiers and evaluation of partial nitrification for wastewater treatment: a review. Chemosphere 140, 85–98.
Gauss, M., Tsyro, S., Fagerli, H., Hjellbrekke, A.-G., and Aas, W. (2018b) Acidifying and eutrophying components, Supplementary material to EMEP Status Report 1/2018, available online at www.emep.int, The Norwegian Meteorological Institute, Oslo, Norway.

DOI:10.46647/ijetms.2024.v08i01.041 ISSN: 2581-4621

Genchi, G., Sinicropi, M. S., Carocci, A., Lauria, G., & Catalano, A. (2017). Mercury exposure and heart diseases. *International journal of environmental research and public health*, *14*(1), 74.

Gidlow, D. A. (2004). Lead toxicity. *Occupational medicine*, *54*(2), 76-81.

Giller, K.E., Witter, E., Mcgrath, S.P., 1998. Toxicity of heavy metals to microorganisms and microbial processes in agricultural soils: a review. Soil Biol. Biochem. 30, 1389–1414. Gomez-Alvarez, V., Teal, T.K., Schmidt, T.M., 2009. Systematic artifacts in metagenomes from complex microbial communities. ISME J. 3 (11), 1314–1317. Gómez-Sagasti, M.T., Alkorta, I., Becerril, J.M., Epelde, L., Anza, M., Garbisu, C., 2012. Microbial monitoring of the recovery of soil quality during heavy metal phytoremediation. Water Air Soil Pollut. 223, 3249–3262. Gołębiewski, M., Deja-Sikora, E., Cichosz, M., Tretyn, A., Wróbel, B., 2014. 16S rDNA pyrosequencing analysis of bacterial community in heavy metals polluted soils. Microb. Ecol. 67, 635–647.

Grant, L. D. (2020). Lead and compounds. *Environmental toxicants: human exposures and their health effects*, 627-675.

Griffiths, B.S., Philippot, L., 2013. Insights into the resistance and resilience of the soil microbial community. FEMS Microbiol. Rev. 37, 112–129.

Hai, B., Diallo, N.H., Sall, S., Haesler, F., Schauss, K., Bonzi, M., Schloter, M., 2009. Quantification of key genes steering the microbial nitrogen cycle in the rhizosphere of sorghum cultivars in tropical agroecosystems. Appl. Environ. Microbiol. 75, 4993–5000. Hallenbeck, P.C., Grogger, M., Mraz, M., Veverka, D., 2016. Draft genome sequence of a thermophilic cyanobacterium from the family Oscillatoriales (strain MTP1) from the Chalk River, Colorado. Genome Announc. 4 e01571-15.

Hayat, M. T., Nauman, M., Nazir, N., Ali, S., & Bangash, N. (2019). Environmental hazards of cadmium: past, present, and future. In *Cadmium toxicity and tolerance in plants* (pp. 163-183). Academic Press.

Hoet, P. (2005). Speciation of lead in occupational exposure and clinical health aspects. *Handbook of Elemental Speciation II–Species in the Environment, Food, Medicine and Occupational Health*, 252-276.

Langford, N. J., & Ferner, R. E. (1999). Toxicity of mercury. *Journal of human hypertension*, *13*(10), 651-656.

Massányi, P., Massányi, M., Madeddu, R., Stawarz, R., & Lukáč, N. (2020). Effects of cadmium, lead, and mercury on the structure and function of reproductive organs. *Toxics*, *8*(4), 94.

Nduka, J. K., Kelle, H. I., & Odiba, I. O. (2019). Review of health hazards and toxicological effects of constituents of cosmetics. *Poisoning in the Modern World-New Tricks for an Old Dog*, 59-76.

Papanikolaou, N. C., Hatzidaki, E. G., Belivanis, S., Tzanakakis, G. N., & Tsatsakis, A. M. (2005). Lead toxicity update. A brief review. *Medical science monitor*, *11*(10), RA329.

Park, J. D., & Zheng, W. (2012). Human exposure and health effects of inorganic and elemental mercury. *Journal of preventive medicine and public health*, *45*(6), 344.

Rehman, K., Fatima, F., Waheed, I., & Akash, M. S. H. (2018). Prevalence of exposure of heavy metals and their impact on health consequences. *Journal of cellular biochemistry*, *119*(1), 157-184.

Salek Maghsoudi, A., Hassani, S., Mirnia, K., & Abdollahi, M. (2021). Recent advances in nanotechnology-based biosensors development for detection of arsenic, lead, mercury, and cadmium. *International Journal of Nanomedicine*, 803-832.

Sharma, H., Rawal, N., & Mathew, B. B. (2015). The characteristics, toxicity and effects of cadmium. *International journal of nanotechnology and nanoscience*, *3*(10).

Singh, N., Kumar, A., Gupta, V. K., & Sharma, B. (2018). Biochemical and molecular bases of lead-induced toxicity in mammalian systems and possible mitigations. *Chemical research in toxicology*, *31*(10), 1009-1021.

Tagne-Fotso, R., Leroyer, A., Howsam, M., Dehon, B., Richeval, C., Members of Health Examination Centres of Nord-Pas-de-Calais region network, & Nisse, C. (2016). Current sources of lead exposure and their relative contributions to the blood lead levels in the general adult population of Northern France: The IMEPOGE Study, 2008–2010. *Journal of Toxicology and Environmental Health, Part A*, *79*(6), 245-265.

DOI:10.46647/ijetms.2024.v08i01.041 ISSN: 2581-4621

Terziev, V., & Petkova-Georgieva, S. (2019). Human health problems and classification of the most toxic pesticides. *IJASOS-International E-journal of Advances in Social Sciences*, *5*(15).