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Contamination of groundwater with heavy metals and its impact on soil and plants – A review

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ABSTRACT

Heavy metals are naturally occurring compound elements that exist in many forms in the environment and the Earth's biosphere. It is any metallic chemical element with a high density that is hazardous or dangerous at tiny concentrations. Mercury (Hg), lead (Pb), arsenic (As), copper (Cu), and nickel are examples of heavy metals (Ni). These elements are mostly found in water and soil. These natural elements are created by the weathering of parent materials and should occur as a result of human actions. Heavy metal contamination is a severe issue due to its toxicity and ease of propagation in the biotic world. It also has serious consequences for animals, soils, crops, and humans. In this work, we will primarily examine heavy metal contamination in groundwater and its impact on soil. These elements are beneficial to both plants and humans, but exceeding the safe limit generates pollution and has a negative impact on the ecosystem. Heavy metal contamination in soil degrades land and poses a risk to soil and plant growth.

Key words: *Effect on soil and plants, Environmental consequences, Heavy metal contamination in groundwater, Remediation of heavy metal contamination.*

Introduction

Heavy metals are a well-defined group of inorganic chemical dangers, and it is any metallic chemical element with a high density that is hazardous or dangerous at tiny concentrations. that are mostly encountered in contaminated areas. Lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), and mercury (Hg) are the elements. Groundwater is the most important natural water supply for both drinking and agriculture. Groundwater contamination is currently one of the most serious environmental challenges (Zürk *et al.,* 2009). Toxic pollutants are contaminating the environment and causing serious negative impacts on local consumers. Pollutants are regularly introduced into the aquatic environment, mostly as a consequence of enhanced industrial activity, technological growth, a growing human population, and abuse of natural resources, agriculture, and industrial and household waste run-off. Heavy metals have been classified as one of the most dangerous contaminants due to their tendency, inclination, and toxicity to accumulate in organisms and penetrate the food chain, as well as their inability to degrade. Heavy metals are particularly hazardous to humans, causing harm to the cardiovascular and gastrointestinal tracts, as well as the central nervous system, endocrine glands, kidneys, liver, lungs, and bones. Heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem via direct ingestion or contact with contaminated soil, the food chain (soil-plant-human

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or soil-plant-animal-human), drinking contaminated groundwater, reduction in food quality through phytotoxicity, and reduction in land usability for agricultural production (Ling *et al.,* 2007). On the other hand, specific toxic metals, such as As, Ag, Hg, Cd, and Pb, have no biological value to plants and animals; rather, they are hazardous. These elements contaminate the environment at higher concentrations (Shanker and Cervantes *et al.,* 2005).

Sources of heavy metals: Rapid worldwide industrial expansion has resulted in a greatly elevated danger of heavy metal pollution in the environment. Non-point sources include soluble salts (natural and artificial), insecticides and pesticides, disposal of industrial and municipal wastes in agriculture, and excessive use of fertiliser application. Point sources include emissions, effluents, and solid discharge from industries, vehicle depletion, and metals from melting down and mining. There is also rapid industrialization and disorderly urbanization, as well as the long-term use of enormous amounts of fertiliser and pesticides. Chromium comes from the metallurgical, paint, and tanning industries; nickel comes primarily from the steel industry and the combustion of coal and liquid fuel; cadmium comes from metal (mostly zinc) smelters, with grease used in motor vehicles being another source of contamination along roads; and lead comes from the paint, metallurgical, and glass industries (Rodrigues *et al.,* 2017; D'amore, and Al-Abed, 2005).

The effects of heavy metal contamination on soil, plants, and humans

These heavy metals and metalloids are highly poisonous, causing unwanted consequences and significant issues even at low metal concentrations. Heavy metals are more dangerous to people, animals, and other living beings on the planet. Metals are significant because they have the potential to reduce agricultural output owing to the possibility of bioaccumulation and biomagnification in the food chain and high impacts on groundwater pollution (Shiowatana and McLaren, 2001). There are more heavy metals accessible, particularly those Pb, Cr, As, Cd, and Hg are the elements (Mercury).

Lead (pb): Lead is a poisonous metal. even though it is present in small doses. It is found in paints as a powder and in high concentrations in mixed leaded petroleum products. (Khan *et al.,* 2008). Lead poisoning inhibits ATP generation in plants, induces lipid peroxidation, and damages DNA through excessive ROS production. In addition, lead severely lowers seed germination, root elongation, seedling development, plant growth, transpiration, chlorophyll synthesis, and water and protein content (Pourrut and Shahid *et al.* 2011).

Chromium (Cr): Chromium is the primary component in stainless steel. Adding anti-corrosive qualities by adding metallic chromium to make stainless steel was a significant advance in steel manufacturing (Coblentz and Stair, 2008). Steel may be given a polished mirror appearance using chromium plating, and it is also possible to chromium plate plastics and household items, which are frequently used in bathroom fixtures [CRC Press/Taylor and Francis, 2015]. If Cr dissolves into the soil and becomes poisonous in that location, no plant can live; if they do survive, Cr influences plant growth and development by modifying the germination process as well as the growth of roots, stems, and leaves, which may affect total dry matter production and yield.

Arsenic (As): Arsenic is mostly used in lead alloys and is used in semiconductor electronic devices; arsenic is a frequent n-type dopant. It is mostly used to make pesticides, herbicides, and insecticides. The very negative impact and effect on photosynthetic apparatus, disturbance of plant water status, interaction with functional groups of enzymes, and substitution of critical ions from adenosine triphosphate (ATP) in plants growing in As-contaminated soils. (Winkel *et al.,* 2008; Rafiq *et al.* 2017).

Cadmium (cd): Cadmium is a byproduct of zinc manufacturing and exists as a small component in most zinc ores. Cadmium has long been used as a corrosion-resistant coating on steel and telluride solar panels. Cadmium is a non-flammable metal that is insoluble in water. Even low Cd levels have a negative impact on plant development and metabolism. Cadmium is known to cause the production of reactive oxygen species, to obstruct the usage, absorption, and transport of vital nutrients and water, and to alter photosynthetic machinery, resulting in plant tissue death. The impact of Cd toxicity is highly dose-specific and significantly correlated with soil nutrient status.

Mercury (Hg): Mercury and the halogen bromine are the only elements that are liquid in nature.

Groundwater pollution analysis: A total of twenty-five samples were collected from twenty-five different places in the same area or district. The samples are gathered in various regions from various locations, such as borewells, small farm ponds, agricultural fields, and surrounding industrial sites. Water quality criteria are determined by the Bureau of Indian Standards (BIS), Indian Standards (IS), and the WHO (Mahajan PV).

Water quality index: The water quality index is the most effective instrument for monitoring both surface and groundwater contamination. This water quality indicator assigns a score between 0 and 100. We were aware of nine factors in this case. Calcium, Magnesium, Chloride and Total Dissolved Solids. The water quality scale runs from 1 to 5, with 1 being the least concerned and 5 being the most concerning.

Index of heavy metal pollution/Index of heavy metal evaluation

Heavy meatal pollution (Hpi) indicates the presence of polluted water in the presence of heavy metals, which are useful or not for drinking purposes or other usage. These metals are determinates by using atomic absorption spectroscopy or ICP method can use. This index is calculated (Hpi); $HPI=\Sigma ni=1Wi.Qi / \Sigma ni=1Wi$ ———-**(1)** & $Qi=\Sigma i=1nMi\ (\Sigma)\ Ii / Si\Sigma Ii\times 100$———(2) In this case, Qi and Wi are the I th parameter's sub-index and unit weightage, respectively. The number of parameters evaluated is n. Mi, Ii, and Si are the monitored heavy metal readings, as well as the ideal and standard values of the I th parameter.

Heavy metal contamination treatment or remediation

There are various forms of heavy metal contamination remediation, however we will focus on some of them in order to address meta pollution in groundwater. To repair heavy metal-contaminated soil, water, and sediments, many techniques such as physical, chemical, and biological approaches are proposed. Thermal treatment, adsorption, chlorination, chemical extraction, ion exchange, membrane separation, electro kinetics, bioleaching, and other procedures fall within this category. Heavy metals may spread swiftly and easily after they have been disseminated in the soil.

Chemical-Biological Remediation: This technique of chemical–biological integrated treatment is regarded as a very cost-effective and environmentally sound method of treating heavy metal-containing wastewater. The use of this comprehensive therapy rather than individual chemical or biological treatments has been found to be beneficial and to provide considerable outcomes in heavy metal removal.

Vitrification: High-temperature (heating) treatment of the contaminated/polluted region results in the creation of vitreous material, generally an oxide solid, which reduces the high mobility of metal pollutants. This approach is extensively used and successful all around the world. It may be utilised in any weather condition (Farrell *et al.,* 2010). The temperature may rise throughout this process until the metals become volatile or until the organic pollutants in the region are destroyed [1995, Lewis Publishers]. As the melted soil generally offers more conductance for the current, the melt expands outward and downward. Vitrification is not a traditional immobilisation technology, but it is easily applicable to the reclamation of contaminated soils, and the use of these procedures can cause the qualification of contaminated metal to convert into normal form (USEPA Handbook, 1992).

Phytoremediation: It simply states that phytoremediation is the employment of green plants in the removal or recovery of pollutants from an area. The phytoremediation process is environmentally friendly, simple to implement, does not require any specific equipment, and results in re-usable land. The rhizosphere and environmental circumstances have a significant impact on the system's efficiency. Specifically, the soil must be suited to the demands of the plant in order for the plant to remove toxins from the soil. The most essential factor in phytoremediation is soil ph. The pH of the region must be between 5.8 and 6.5 in order for the nutrients to be absorbed. The absorption of nutrient elements occurs in three stages: (1) transportation of nutrients to the root circle and root surface; (2) absorption of nutrient ions into the roots; and (3) transportation of nutrient ions which entered the root to the essential portions via the transmission branches. The two major ideas for nutrition transfer to the root surface are "Carbonic Acid Theory" and "Intersection and Contact Change". (Adilolu, R. Brohi *et al.,* 2012). Phytodegradation, rhizofiltration, phytoextraction, phytostabilization, phytovolatilization, and phytodegradation are the additional types of phytoremediation.

Future Prospects: Heavy metals are known to have major health consequences, including reproductive impairment and genetic, epigenetic, and metabolic changes in both the human body and the environment. Physical separation, isolation, immobilisation, toxicity reduction, and extraction are common remediation strategies. When compared to a single procedure, the usage of integrated remediation results in more successful remedial implementation. to determine the best corrective strategy for challenging in-situ operating situations such as site features (geographical location, pH levels, particle size, clay, soil type, depth, water content, climate, types of co-contaminants, etc.). In future study, more emphasis should be placed on assessment methodologies for measuring remediation efficacy while creating new remediation technologies. If the government properly followed all of the above directions, we would be able to minimize heavy metal pollution in ground water and see a significant reduction in the number of heavy metals in the environment.

Conclusion

This study explores the contamination process and its consequences on animals, plants, soils, humans, and the entire ecosystem, as well as a study of anthropogenic activities that cause severe pollution in groundwater and soil. We've already spoken about how the repair process can proceed. We discussed several different types of remediation techniques, and selecting an effective remedial option requires a thorough understanding of the sources of heavy metals, their chemistry, and the possible threats to the environment and individuals. We also came to the conclusion that integrated procedures comprising EK techniques and Phyto-remediation were more successful in regulating the polluted zone or region. There are several sorts of integrated therapy that should be explored, including chemical, physical, and biological treatments. We also determined that these integrated technologies have the potential to be extremely useful for in-situ operations in both emerging and industrialised countries where agriculture, urbanisation, and industrialisation are producing or releasing an inheritance of environmental degradation.

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