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Heavy Metal Accumulation in Vegetables, Water and Soil in Different Regions of India - A Review

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Abstract: Environmental contamination caused by heavy metals resulting from fast economic expansion and inappropriate waste and wastewater management is a big problem. Expansion in industry and urbanisation, along with population expansion, resulted in a rise in sewage discharge in cities and towns. Many small-scale farmers in urban and semi-urban areas in developing nations rely on urban streams to irrigate crops and vegetables. As a result, the toxins in wastewater represent a significant risk to both flora and wildlife. Depleting fresh water supplies causes a rise in the use of wastewater for irrigation, which eventually packs hazardous metals into soil and enters the food supply via vegetables and agricultural produce. Food safety is of the utmost importance to the people since it is the primary source of sustenance. There are three basic pathways for human exposure to pollutants: inhalation, absorption, and ingestion. Ingestion accounts for 90% of exposure when matched to other means of toxicity. As a result, contaminates in wastewater pose a substantial threat to both plants and wildlife. Depleting fresh water resources leads to an increase in the utilisation of wastewater for agriculture, which eventually packs harmful metals into soil and penetrates the chain of food through crops and agricultural products. Food safety is extremely important to individuals since it is their major source of nutrition. Human exposure to contaminants occurs through three fundamental pathways: inhalation, absorption, and ingestion. When compared to other modes of toxicity, ingestion represents for 90% of total exposure.

Keywords: Heavy metals, Ingestion, Wastewater.

I. Introduction

Heavy metals and metalloids with densities more than 5 g/cm^3 are a natural and structural component of the earth's crust. Some of them are toxic and tend to bioaccumulate in human body like Arsenic, Cadmium, mercury, lead etc. Many of them are non-biodegradable and ecologically persistent pollutants. They are first deposited on the soil's surface, then absorbed by plant roots and dispersed and aggregated into edible and non-edible sections, posing an immediate hazard to the food chain [1, 2]. Because of their extensive prevalence in ecosystems and non-degradability, they bioaccumulate in human tissues. The most often used heavy metals or metalloids are Hg, Pb, Cd, and As, and they have been related to acute or chronic human exposure and are hazardous even at low quantities [3].

A high arsenic level in the body causes a variety of illnesses, including cancer of the skin, cancer of the lungs, bladder cancer, and other non-malignant ailments [5]. Poisoning with arsenic can also cause bone marrow depressive symptoms, polyneuropathy, encephalopathy, hemolysis, hepatomegaly, and melanosis. Heavy metals, especially lead and cadmium, can result in fractures of the bones and abnormalities, as well as heart disease, failure of the kidneys, hypertension, and other significant liver, lung, neurological, and immune system illnesses [6, 7].

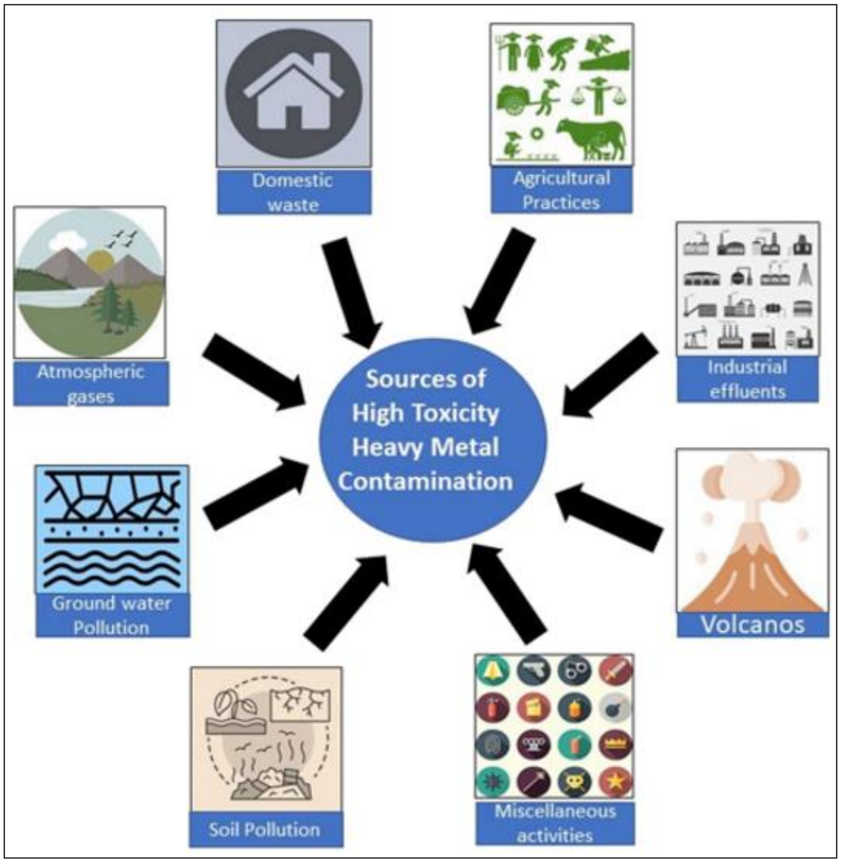

Fig. 1: Sources of Heavy Metal Pollution in Soil-Crop Systems [11]

There are many sources of heavy metals which includes natural like forest fire, weathering of rocks, volcanic eruptions, sea salt sprays and anthropogenic sources like burning of fossil fuels, industrial discharge in water bodies, harmful gases from industries in the environment, sewage sludge, using of harmful chemicals and fertilizers for farming, waste water irrigation. Vegetables are an essential part of the diet of individuals since they include plenty of dietary fibre, vitamins and minerals, and other elements. Because of their relevance in food safety reliability, contamination with heavy metals of vegetables must not be disregarded. Furthermore, the food network pyramid is the mechanism by which medically hazardous trace metals accumulate among human beings and other animals [8, 9].

Scientists from all across the world are studying water conservation. As the population grows globally, so does the need for freshwater for agriculture and daily consumption grows thus, threatening sustainable development in some regions of the world. Due to a decrease in availability of clean surface water or groundwater in many urban and semi-urban areas of India, farmers have turned to municipal and industrial wastewater as they are easily available and are less expensive sources of irrigation water. For several decades, wastewater has been utilised for farming and fisheries in various regions of the world, including India [10].

The toxicity of heavy metals is induced by their elemental, ionic, and oxidised forms, which have strong affinity for numerous reactive groups in plant tissue systems, including sulfhydryl, phosphoryl, carboxyl, amide, and amine. They additionally come into contact with soil minerals including phosphorus, potassium, nitrogen, calcium, magnesium, sulphur, and more, as well as several enzymes needed for normal physiological functions [4].

Overall, this article combines the outcomes of studies on wastewater irrigation conducted throughout India. Furthermore, it seeks to assess the influence of wastewater irrigation on heavy metal transfer to soils and then to plants growing in various locations of India. Finally, the goal is to evaluate the consumer risk posed by heavy metal translocation from plants to soils and finally to humans through the food chain.

II. Methodology

The search strategy was aimed to target all of the research that studied heavy metal pollution in vegetables and soil and its deleterious influence on the human population. Further, irrigation done with wastewater studies were also focused. We searched and retrieved relevant study material from Scopus index, ScienceDirect, Elsevier journals PubMed, and Google Scholar data using many search terms like "contamination of heavy metals", "Deposition of heavy metals in crops", "Waste water irrigation", "Heavy metals in soil and vegetables in India", "Heavy metal toxicity in soil due to wastewater irrigation practise", "Health risk assessment of heavy metal" etc. Furthermore, the selected publications were reviewed in order to identify particular research connected to the topic "Heavy metals in vegetable, soil, and irrigated water," and irrelevant material was removed. Finally, a thorough evaluation of the selected publications was performed to assess the content of metals & their possible health risks.

III. Discussion

Sources of Heavy Metals

Atmospheric accumulation had been discovered as a major conduit of toxic metals in crops and agricultural farms. Soil contamination caused by metals that are present in the environment affects soil conditions and increase bioaccumulation via root absorption [12, 13]. The continued use of chemical fertilisers and herbicides, although raising the world's food supply by several orders of magnitude, has disrupted the normal functioning of agricultural fields, loading crops with harmful substances such as heavy metals [14].

Many nations that are developing have high levels of heavy metals due to industry, irrigation of wastewater, and other human activities. Because agriculture uses 70% of all water, wastewater management is critical to attaining agricultural sustainability. Even recycled wastewater contains pollutants such as heavy metals, which damage the soil and vegetation. Furthermore, petrol contributes significantly to increased levels of toxic metals [15].

Furthermore, petrochemical activities pollute soil through numerous spills of oil, disposal of waste, chemical expulsion, and burning of gases into the environment, posing significant health concerns to the ecology and people [16].

Crops irrigated with tainted sewage water might be a primary dietary pathway. Heavy metals gather in vegetable crops primarily through their growth mediums (soil, air, minerals), which are absorbed by the plant's roots or leaves. Cultivation areas near roadways are also prone to air pollution from metal-containing aerosols. These aerosols may be get accumulate on soils and assimilated by plants, or they may be deposited on fruits and leaves and subsequently absorbed [17].

Fertilisers as well as insecticides, sewage waste, wastewater, and surface water runoff are the most common sources of heavy metal contamination [19]. Furthermore, agricultural practises in polluted soil typically leads in the absorption of metals by plants, which poses a health risk to both humans and cattle.

Soil's fundamental constituent is rock, which weathers to generate fragments that are loose are called as the soil's parent material, with varying properties. The initial substance of the soil is an important supply of toxic metal, analysing the soil's original toxic metal content [18].

IV. Heavy Metals in Vegetables and Soil

A. Bioaccumulation in Vegetables and Soil in Wetlands of Kolkata

Soil samples were gathered over two years (2016 and 2017) to analyse heavy metal contamination in a wetland in eastern Kolkata, a key food basket. The crops investigated were bottle gourd, ladies' finger, and maize. The roots and edible portions of these plants were tested for heavy metals like, chromium, cadmium, mercury, and lead. Maize, bottle ground, and ladyfingers were the food crops with the greatest HM content. The three vegetables gathered heavy metals in a particular order: Pb, Cd, Cr, and Hg. The greatest Cr levels were found in samples of soil, subsequent to tubers and fresh eatable from all crops species. Soil specimen have lower amounts of Pb and Cd than tubers of plants and eatable portions, indicating that these heavy metals were anthropogenic rather than soil-contaminated. The level of Heavy metal content in soils, root systems, and edible sections fluctuates seasonally, with the monsoon being the highest deposition period, followed by the postmonsoon and premonsoon [20].

Researchers investigated the buildup of air-borne contaminants in plants that are edible and cultured soil horizons in a system of organic farming in a low-rainfall tropical zone of India, such as Udaipur. The study examined six crops of vegetables (tomato, brinjal, spinach, amaranthus, carrot and radish), two production techniques (open field and glasshouse), and seven harvests for each crop. The levels of heavy metals in plants were high in leaf (spinach and amaranths), then in fruits (tomatoes and egg plants), and least in plant roots (carrot and radish). The sequence of substances was Zn > Pb > Cu > Ni > Cd. This study discovered that heavy metal accumulation in the Udaipur area is continuously rising over time.

Open fields with such depositions showed substantial quantities of organic carbon but low biomass from bacteria and interaction in the agricultural soil horizon [21].

B. Magnitude of HM in Vegetables and Fruits in West Bengal

Toxic metal concentration was measured in specimens of fruits, vegetables, and soil from six sites in Kolkata's agricultural zones. The average concentration of copper in washed samples from various areas is under the acceptable limits according to WHO. Lead concentrations in most samples, as well as cadmium and chromium levels, exceeded permissible limits. The study examines contamination with heavy metals in fruits and crops and emphasises the dangers of consuming fresh yields of vegetables and fruits. Heavy metal contamination was mostly caused by automotive exhaust, pesticides, and industrial exhaust, since no soil samples exceeded the permitted concentration [17].

C. Comparison of Heavy Metal Accumulation in Rajasthan

This study investigated the deposition of possible toxic metals (copper, manganese, zinc, and iron) in certain commonly grown vegetables in Rajasthan that are irrigated with wastewater. The daily consumption of heavy metals was also investigated in the adult and juvenile populations. Continuous treatment of agricultural land with wastewater ended in heavy metal accumulation and poisoning of crops of Rajasthan. Irrigation with waste water spinach gathered a greater amount of iron, manganese, copper, and zinc as irrigation with fresh water spinach, suggesting better metal accumulation. The study discovered that eating vegetables grown in wastewater-farming fields exposes adults and children to high levels of metals. Heavy metal levels in all vegetables were below the range of standard values given by the Joint FAO/WHO [22].

D. Deposition of Heavy Metals in Fruits and Vegetables Samples of Solapur District of Maharashtra

This study seeks to investigate the presence of toxic metals (Pb, Cd, As, and Hg) in 24 veggie & fruits grown in Solapur, Maharashtra. Health risks related with eating vegetables and fruits were investigated. The heavy metal levels and condition of the local vegetation land with soil were additionally evaluated. ICP-MS was used to evaluate samples of vegetables and fruits. Levels of metals in veggies and fruits reported below: Pb (0.17 ± 0.38 mg/kg), mercury (0.06 ± 0.09 mg/kg), Cd (0.02 ± 0.007 mg/kg), and As (0.002 ± 0.003 mg/kg). Garlic has the highest heavy metal content, abide by potatoes. All together, veggies have a greater metal content than fruits.

The study found that metal levels in most veggies and fruits in Solapur district are below acceptable limits. Consuming a lesser amount of some vegetables with high MPI, HRI, and HI values might mitigate the negative impact [18].

E. Contamination of Toxic Heavy Metals in Vegetation Land and Crops in Uttar Pradesh

This study examined the distribution, bioaccumulation, and concentrations of toxic metals in farming soil and vegetation in Uttar Pradesh, India, that are watered by the Kali River. Samples of soil and crops collected from 17 riverbank locations had their heavy metal concentrations analysed. Fe>Zn>Mn>Cu>Ni>Pb>Cr>Cd and Mn>Fe>Zn>Cu>Cr>Ni>Pb>Cd were metal counts for the soil and plant, respectively. Heavy metals are accumulated in the soil and vegetation along the Kali River. International criteria state that most sample locations have metal concentrations that fall within safe ranges. Increased transfer factor of Cd, Cr & Pb was seen in some plant specimens, indicating a possible entry into the food chain. The study discovered low to moderate levels of heavy metal contamination in regions that get irrigation from the Kali River, indicating that eating agricultural products might be harmful to one's health [23].

F. Bioaccumulation of Heavy Toxic Metals in the Soil, Vegetation and Water Specimens of Mahalgaon, Nagpur

This research location is a large vegetable farming area, which serves Nagpur's vegetable market. The Nag River, which has become extremely polluted with urban garbage and toxic metals, is utilised to water vegetables and farms in this area. This study looked into the absorption of toxic metals (Cu, Mn, Fe, Zn, Ni, and Pb) in the soil, water, and plants irrigated with Nag River water. Fe and Zn contents in soil samples surpassed WHO/FAO standards, but Cu and Mn concentrations were somewhat higher. Pb and Ni contents in soil were below detectable levels. Heavy metal bioaccumulation differs between plants.

The heavy metal bioaccumulation rate are as follows: Zn > Fe > Cu > Ni > Mn > PB. Chawli and spinach had the highest soil-plant transfer coefficients for Cu, Mn, Fe, Zn, Ni, and Pb, followed by Flower and Bathua. However, heavy metal contents in all vegetables surpassed WHO/FAO recommendations [24].

G. Toxic Metal Levels of Water, Vegetation Land and Vegetables in Sites of Delhi

Vegetable crops are widely planted in peri-urban farms around New Delhi, the nation's capital city. The study sought to assess heavy metal loads in soil, water used for irrigation, and crops in New Delhi's semi-urban regions, as well as to determine the source of polluted by toxic metals. Metals like Cu, Zn, Pb, and Cd were discovered in soil, water used for irrigation, okra, and lettuce specimens from five semi-urban regions of Delhi. The soil and irrigation water samples had more Pb and Cd than Cu and Zn. A significant number of vegetable samples included higher levels of Zn, Pb, and Cd, while Cu content was less than acceptable limits. Spinach showed a greater contamination level than okra.

Metallic substances from thermal power stations, factory waste, effluent, and pesticides have poisoned soil and crops. As a result, specific precautions should be considered when producing vegetables in peri-urban areas of Delhi [25].

H. Aggregation of Toxic Metals in Vegetable Specimens and Soil Specimens in Jhansi

This study looked at the amounts of cadmium, Lead, nickel, cobalt, zinc, copper, & manganese in soil specimen and some vegetables like, coriander, onion, and tomato samples gathered from farming regions in Jhansi, India. The bio-concentration ratio and non-carcinogenic health risks of vegetables were also investigated to identify their ability to acquire pollutants from ground and pose non-carcinogenic medical risks when ingested. The study revealed that Cd, Pb, and zinc content in Indian soil surpassed background levels. Cd contents in soil and the coriander samples exceeded permitted levels. Similarly, the lead levels in coriander leaves and onion surpassed the allowed limit. The mean EDI and THQ for all of the heavy metals in the examined region were lower than the FAO/WHO (2019) permitted levels for human intake.

However, EDI and THQ values at sample sites exceeded acceptable levels [8].

I. Heavy Metal Contamination of Farming Land, Irrigation Water and Crops in Agricultural Areas of Delhi

Vegetables polluted with toxic metals represent a health danger. This study investigates heavy metal contamination in irrigated water, farming land & veggies in four peri-urban areas and one wholesale locations in Delhi, India, and forecasts the resulting health risk. The average metal absorption by vegetables from soil dropped in a particular order: Cd, Zn, Cu, and Pb. Okra, cauliflower, and spinach exhibited the maximum absorption of metals based on translocation factor, from highest to lowest. Only okra from peri-urban areas above the permitted cadmium level, whereas vegetables from wholesale sites exceeded the lead limit (potato, coriander leaves chilies, pea, and carrots in order of health risk index).

In summary, vegetable specimens from peri-urban Delhi exhibited higher concentrations of zinc, lead, and cadmium than the allowed limit when compared to market locations. Vegetable specimens from Okhla, Yamunapusta, and Najafgarh contained higher levels of heavy metal contamination than Alipur. Metal contamination can come from the irrigation of wastewater, chemical fertiliser, or aerial deposits [26].

V. Conclusion

Heavy metal pollution is a big worry as a result of increased urbanisation and industrialization, posing a threat to population. In underdeveloped nations, the use of waste from industry water and sewage sludge as chemical fertilisers, as well as irrigated with badly treated effluent, are important sources of soil contamination and pollution in vegetable crops.

To prevent metallic contaminants from entering the food chain, effective remediation procedures and precise soil mapping are necessary. Extensive research has been conducted on soil amendments and adsorbents to remove metal contaminants. Biological remediation, including phytoremediation and microbe-augmented remediation, is a cost-effective and ecologically friendly solution for moderately contaminated soils. Eco-friendly technologies, such as non-metal-based nanotools, and increased farmer knowledge can improve regional prudence, minimise health concerns, and give financial security. Long-term exposure with the contaminated foods can harm human health because of increased intake and accumulation. Clinical investigations on heavy metal contents in vegetables are few in India, making risk assessment difficult to evaluate. Further research is needed on metal absorption by various cell organs and membranes. Exposure to heavy metals can be dangerous over time Frequent monitoring of heavy metal levels in plants is recommended to prevent excessive propagation in the food chain for humans. Enforcing heavy metal regulations in factories is critical for reducing the public's exposure to these pollutants.

Conflict of Interest: NIL

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