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A New Source of Heavy Metal Contamination in Human Foods: Farm Products in Unnao, Uttar Pradesh, India's Arid Ganga Plain

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ABSTRACT

Protecting the Ganga River from heavy metal contamination is essential for human health and the environment, as it is a key resource for millions of people. In crops produced on the dry Ganga plain in Unnao (located between 80°15′ and 80°34′E longitude and 26°24′ and 26°35′N latitude), the Micro-nutrients or heavy metals Chromium, Copper, Cadmium, Lead, Zinc, Manganese, and Iron are measured, a significant industrial city in North India, at three separate streams (upstream, midstream, and downstream). To determine whether sediment samples include Micro-nutrients & the associated health risks to people of commonly used micro-nutrients in the basin of River Ganga, the current study was conducted. Because AAS can accurately identify individuals and separate complicated combinations of substances, it is the method of choice for heavy metals analysis. Along the banks of the Ganga, Unnao is a major hub for leather processing, with over 450 tannery enterprises and other industries. One possible explanation for the large amount of micro-nutrients in the silt is that the soil disintegrated slowly, which reached 75–100% in 9–10 years. Crops had many times higher concentrations of micro-nutrients pollutants than the sandy soil. Since the public regularly eats these popular vegetables, these contaminants may be harmful to health. Eight separate locations provided soil samples, which were coded as Site A, Site B, Site C, Site D, Site E, Site F, Site G, and Site H, respectively. Each metal's mean value in the test samples varied from 5.23 to 92.40 mg/kg, whereas Cr's ranged from 20.5 to 27.7 mg/kg. 79.60–293.80 mg/kg of Cd and 1.20–5.00 mg/kg of Cu Zn, Mn (30.70–68.90 mg/kg), Fe (187.90–375.67 mg/kg), and Pb (382.70–500.40 mg/kg). Zn>Fe>Pb>Cu>Mn>Cr>Cd, as the trend indicates. The fact that all the metal values in the soil samples were noticeably greater than those in the blank samples implies that runoff and leaching are the main ways that metals move from industrial sites to residential areas.

Keywords: *Ganga, Unnao, Heavy metals, AAS, Soil, Sediment*

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1. INTRODUCTION

Among the micronutrients used to enhance and boost agricultural productivity are heavy metals. On the other hand, they propensity to gather and persist in the various environmental divisions after use [1,2,3]. Through absorption, the heavy metal Additionally, leftovers often build up in aquatic habitats' sediments. potentially becoming a persistent source of aquatic pollution. Accordingly, it is It is necessary to measure the content of micro-nutrients into account in sediment for risk assessment in accordance with the recommendations of EC 2000, EC 2008, and EU 2013. Despite the existence of numerous discourses and techniques on the assessment of sediment risk related to heavy metal toxicity, these are rarely used [4,5,6]. Soil fertility and nutritional status are significantly impacted by the amount of heavy metals present. For plants and other living things to flourish normally, certain metals, including zinc, copper, and selenium, are necessary. High levels of these metals, however, can be harmful. The ecosystem may accept other metals, like Pb or Cr, which are not considered necessary elements, at low concentrations, but at larger amounts, they become hazardous [7]. The biodegradation of organic pollutants can be hindered by heavy metals in soils, which puts biota at danger [8,9].

Polluted sites frequently contain lead, arsenic, chromium, zinc, cadmium, copper & mercury. Metallurgy and paint manufacturing are two examples of the industrial operations that Their presence leads to elevated concentrations in the soil

[10,11]. Because of the Carbonates, hydroxides, and sulfides precipitate and settle, becoming a part of the sediments, heavy metals can be found in sediments [12]. The issue of heavy metal pollution is far more severe since these metals do not break down naturally; instead, they remain in soil and sediment until being discharged into aquatic bodies, where they serve as sinks [13]. The primary sectors that support the contamination of river Ganga with micro-nutrients is attributed to the production of metals, tanneries, distilleries, paint and pigments, varnish, pulp and paper, elastomer, Heat-energy facilities, manufacturing of Alloys, galvanization, and mining activities. Additionally, the uncontrolled application of chemicals used to control pests and toxic chemical fertilizers that contain high amount of micro-nutrients in agricultural regions worsens the issue [14,15,16]. Steel, the galvanization of iron goods, tanneries, distilleries, paint and pigments, varnish, pulp and paper, rubber, thermal power plants, and mining operations are all responsible for the micro-nutrients pollution of river Ganga. Further exacerbating the problem is the unregulated use of hazardous chemical use to control Pests and as fertilizers to increase crop productivity in cultivated areas [17,18,19].

2. Material & Methods

2.1 Study Area: Sampling sites

The designated sampling sites span from 80°15′ to 80°34′E longitude and from 26°24′ to 26°35′N latitude. Eight sites nearby each location had soil samples taken at random in the Unnao district at three-month intervals, from July 2024 through April 2025, across three different streams.

Upstream (Entry Point) The Ganga enters Unnao district near Purwa Gahir in the Bangarmau area.

Mid-stream: The river has several bends, notably near Umriya Bhagwantpur, Rustampur, Rautapur, Ratua Khera, and Duli Khera. The Morahi River joins the Ganga near Baksar.

Downstream (Exit Point): The Ganga leaves Unnao district shortly after Baksar.

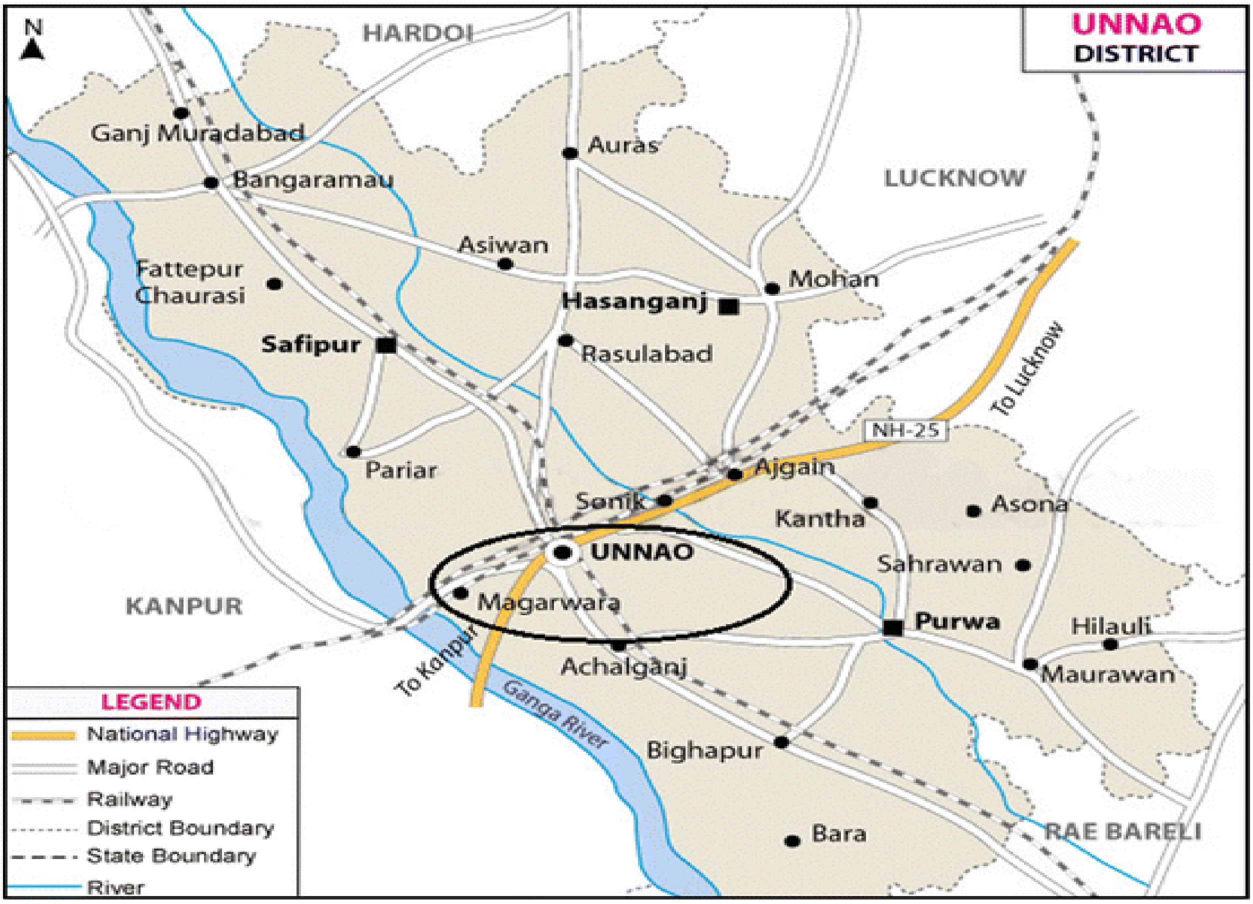


Fig. 1– Various sampling sites of Unnao District

Various sampling sites of Unnao District-
1-Purwa Gahir (Site A) - Upstream

2-Umriya Bhagwantpur (Site B) - Mid-stream
3-Rustampur (Site C) - Mid-stream
4-Rautapur (Site D) - Mid-stream
5-Ratua Khera (Site E) - Mid-stream
6-Duli Khera (Site F) - Mid-stream
7-Shuklaganj (Site G) - Mid-stream
8-Baksar (Site H) – Downstream

2.2 Sample Collection

The top layer of soil was removed at every sampling location, and soil samples were taken with a plastic spoon from 5–15 cm below the surface. This composite of each individual sample was then created by combining the sections that had been obtained. The Samples of dirt were stored in a polybag with the appropriate labels and transported to the laboratory for airing and spreading on thick brown paper. Large debris, coarse fragments, stones, fragments of roots, leaves, and other particles not well decomposed can be pulled out. Huge lumps of moist soil were broken disturbingly by hand.

2.3 Sample Preparation

Subsequently, the gathered samples underwent the ensuing preparatory procedure; Samples of dirt were allowed to air dry for 24 hours, subsequently crushed gently with a pestle and mortar, and then filtered through a 2-mm sieve. This size has been taken as the international standard because the soil passing through this mesh contains almost all the nutritionally significant nutrients in the ground. Using a pH meter, the pH of the soil was determined.

2.4 Sampling Digestion

Soil samples were prepared for micronutrient analysis. Each 0.5 g sample was placed in Kjeldahl flasks containing HCl, HNO_3, and H_2SO_4 acids and heated slowly to digest for 10-15 minutes after white fumes appeared. The samples were cooled and diluted, and modifications were made to analyze lead, chromium, zinc, iron, copper, manganese, and boron. The solutions were distributed into 50 ml volumetric flasks for dilution. Heavy metals were investigated by means of atomic absorption spectroscopy, following standard procedures. Blank samples were evaluated using an atomic absorption spectrophotometer to maintain quality control.

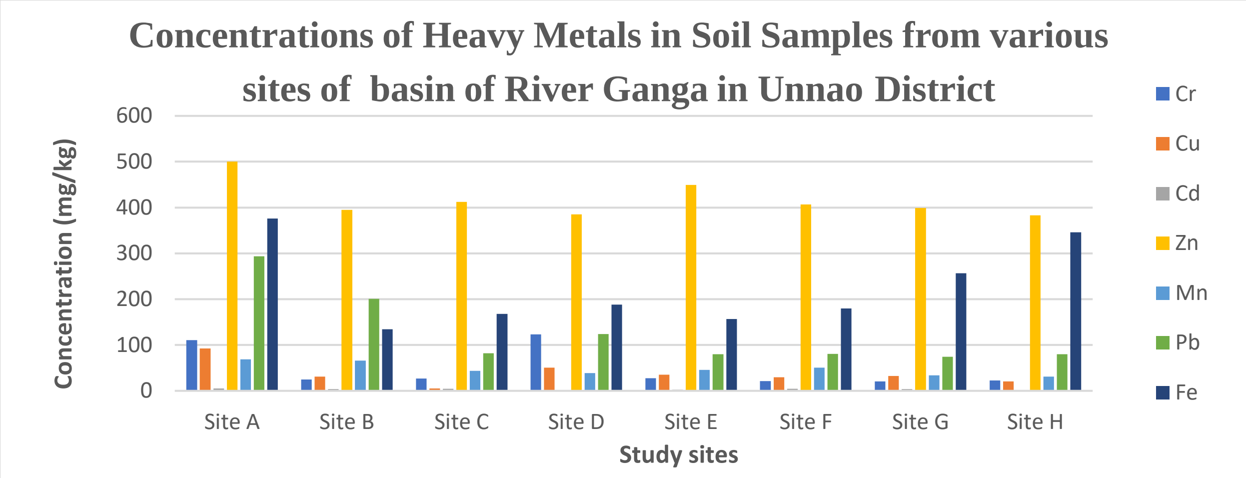
3. RESULT & DISCUSSION

Soil samples collected from each location along different streams were evaluated for the average content of metals. The findings are graphically shown in Figures 2–9 and illustrated in Table 1. These were the concentrations that were noted: The following changes occurred: Pb from 79.60 mg/kg to 293.80 mg/kg, Zn from 382.70 mg/kg to 500.40 mg/kg, Mn from 30.70 mg/kg to 68.90 mg/kg, Fe from 187.90 mg/kg to 375.67 mg/kg, Cr from 20.5 mg/kg to 27.70 mg/kg, Cu from 5.23 mg/kg to 92.40 mg/kg, and Cd from 1.20 mg/kg to 5.00 mg/kg.

Table 1: Average concentration of Heavy Metals in Soil Samples from Several Streams of the basin of River Ganga in Unnao District

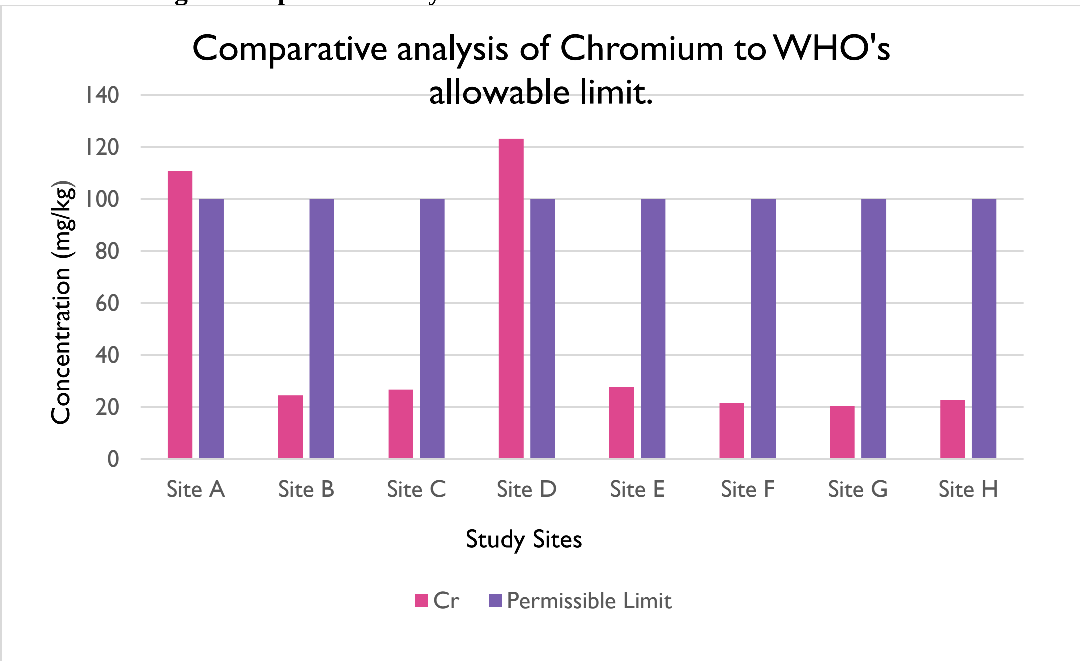
Parameters(mg/kg)	Cr	Cu	Cd	Zn	Mn	Pb	Fe
Site A	110.7	92.4	5	500.4	68.9	293.8	375.67
Site B	24.5	30.7	3.9	395.2	65.8	200.9	134.5
Site C	26.7	5.23	4.2	412.3	43.6	82.1	167.7
Site D	123.2	50.9	1.9	385.1	38.9	123.6	187.9
Site E	27.7	35.2	2.6	449.5	45.8	79.6	156.8
Site F	21.6	29.8	4.5	406.8	50.9	80.8	179.9
Site G	20.5	32.5	3.7	399.2	33.8	74.2	256.3
Site H	22.8	20.6	1.2	382.7	30.7	79.9	345.7

Fig 2: Average concentration of Heavy Metals in Soil Samples from Several Streams of the basin of River Ganga in Unnao District



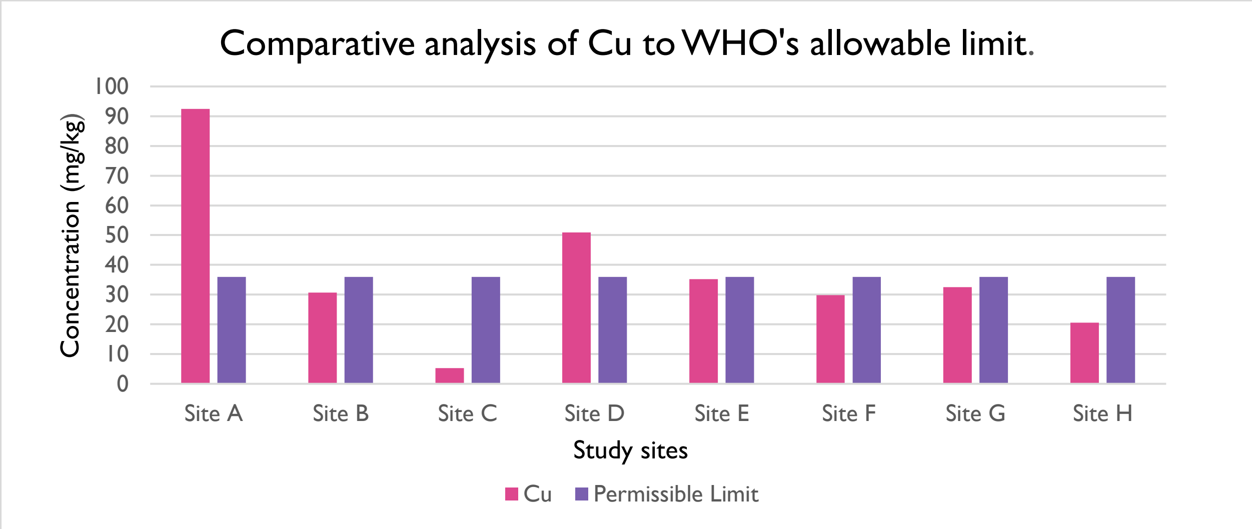
The World Health Organization (WHO), among other notable organizations, has set rules pertaining to heavy metals. The WHO has defined the following maximum acceptable values for soil samples: Lead 85 mg/kg, Manganese 25 mg/kg, Copper 36 mg/kg, Zinc 50 mg/kg, Chromium 100 mg/kg, Cadmium 10 mg/kg, and Iron 95 mg/kg [21]. In an evaluation of micro-nutrients in the basin of river Ganga located in Unnao district, UP, India, chromium (Cr) levels were found to be low, with the exception of sites A and D. Copper (Cu) levels were notably high at sites D and H. Cadmium (Cd) levels were low in the upstream area (site A) and downstream (site H), but exhibited high levels in the mid-stream locations (sites B, C, D, E, F, G). Lead (Pb) levels were elevated in the upstream (site A) and mid-stream (site B, D) areas. Zinc (Zn) levels were recorded as high across all streams, while manganese (Mn) and iron (Fe) levels were also high in all streams. The WHO's maximum permissible limit was much higher than the average chromium levels (Fig 3). Although it is considered an important nutrient, excessive intake, absorption, or combination of chromium can have negative health effects [22]. The chromium concentration in each of the soil samples that were gathered was found to be within the WHO's maximum allowable limit.

Fig 3: Comparative analysis of Chromium to WHO's allowable limit.



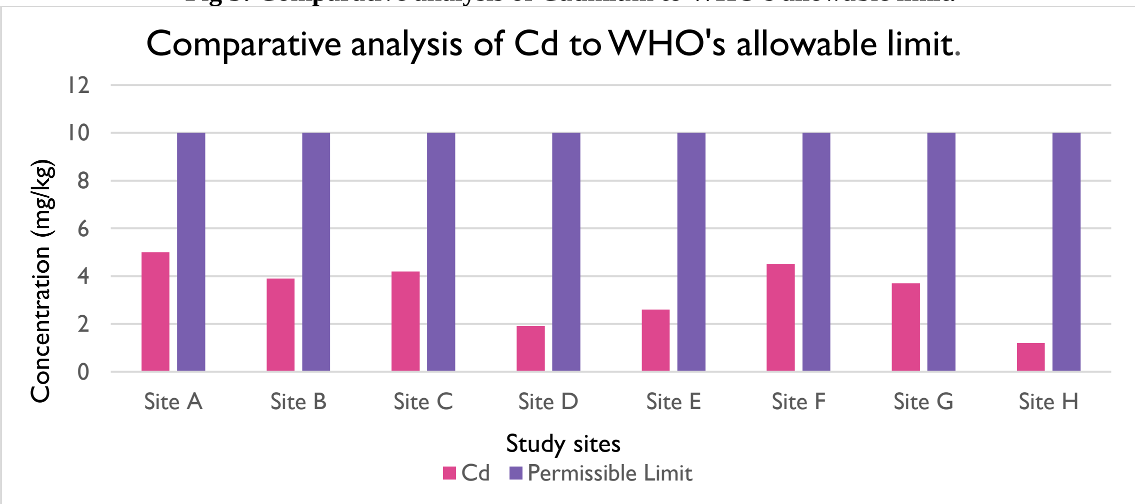
Human cells contain copper, a necessary trace metal, but too much of it can cause liver damage, coma, and even death [23]. Almost all the samples had copper (Cu) levels that were below the WHO's maximum allowable limit (Fig 4). Sites A and D provided the samples that were over the predetermined threshold.

Fig 4: Comparative analysis of Copper to WHO's allowable limit.



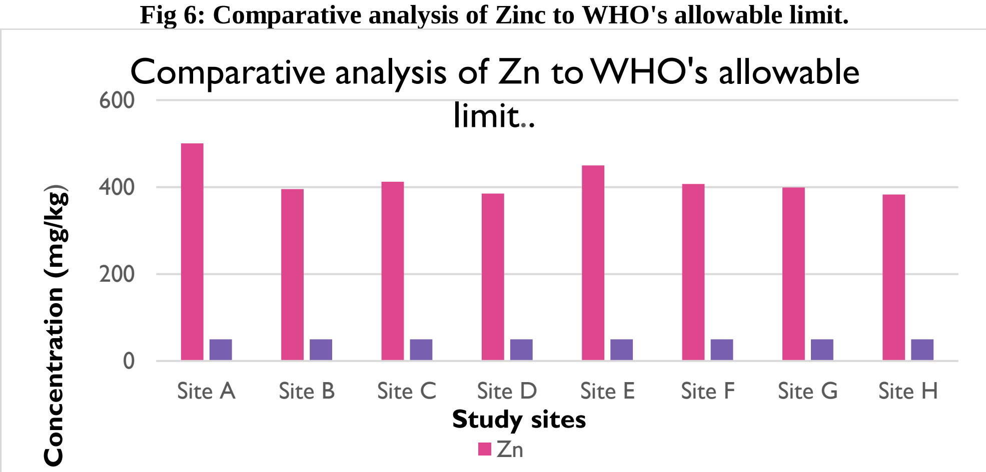
Because of human activity, cadmium is present in the environment and will remain there [24]. All soil samples obtained, apart from Sites A and D, had cadmium concentrations below the WHO-established maximum allowable range (Fig 5).

Fig 5: Comparative analysis of Cadmium to WHO's allowable limit.



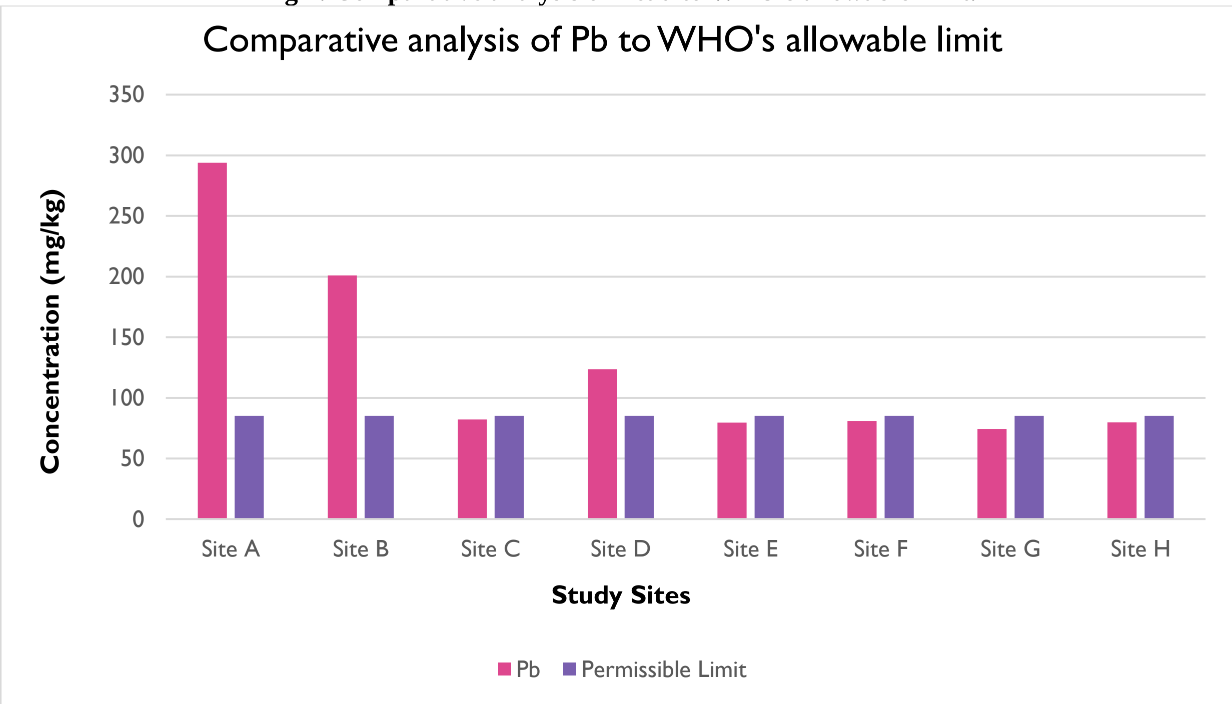
The average zinc (Zn) levels were higher than the WHO-established upper limit (Fig 6). Toxicological symptoms including nausea, vomiting, and stomach discomfort can be brought on by zinc.

Fig 6: Comparative analysis of Zinc to WHO's allowable limit.



Children are the most impacted victims of lead (Pb), which primarily affects the brain but also affects other organs throughout the body and builds up over time. [25]. Lead (Pb) consumption and inhalation harm individuals and pregnant women over time, increasing the incidence of congenital abnormalities and hypertension, respectively. Lead (Pb) had the highest average concentration, far greater than the WHO's maximum allowable limit at Site A. In terms of concentration levels, Site D and Site B are next in line. The WHO's requirements were not met by other soil samples that were gathered (Fig 7).

Fig 7: Comparative analysis of Lead to WHO's allowable limit.



High concentrations of manganese (Mn) and iron (Fe) in soil can pose significant health risks to humans. While both are essential trace elements, Neurological disorders are among the many health problems that can result from high levels, hyperactivity and aggression from manganese and organ damage, liver cirrhosis, increased cancer risk, fatigue & joint pain from iron. Both are recorded in excess on almost each site. (Fig 8 & Fig 9)

Fig 8: Comparative analysis of Manganese to WHO's allowable limit.

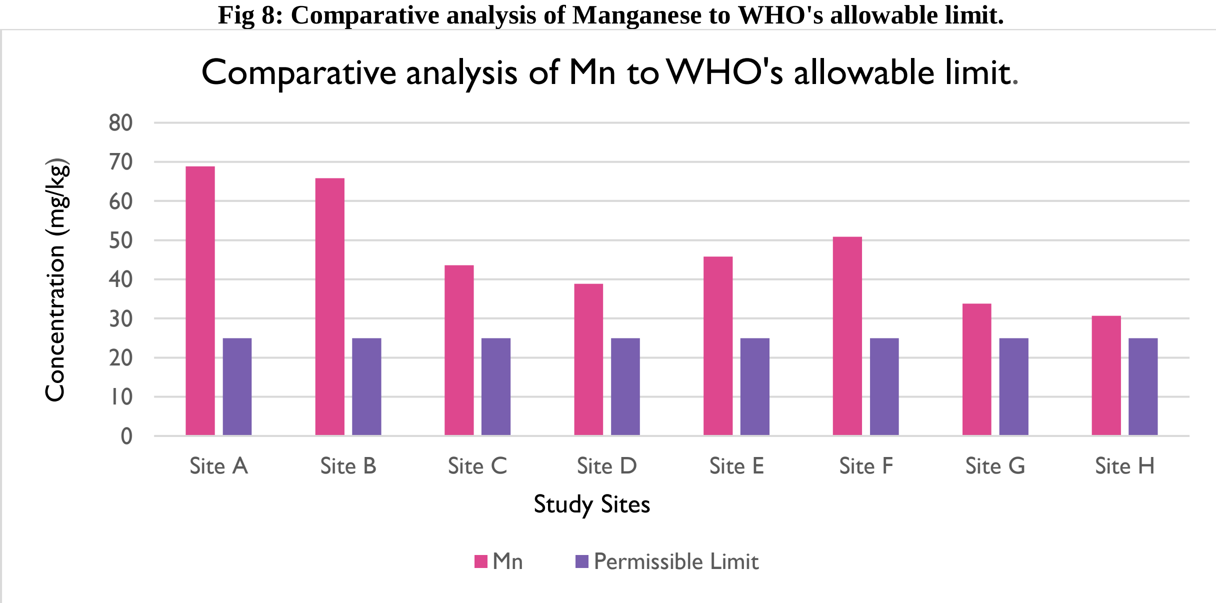
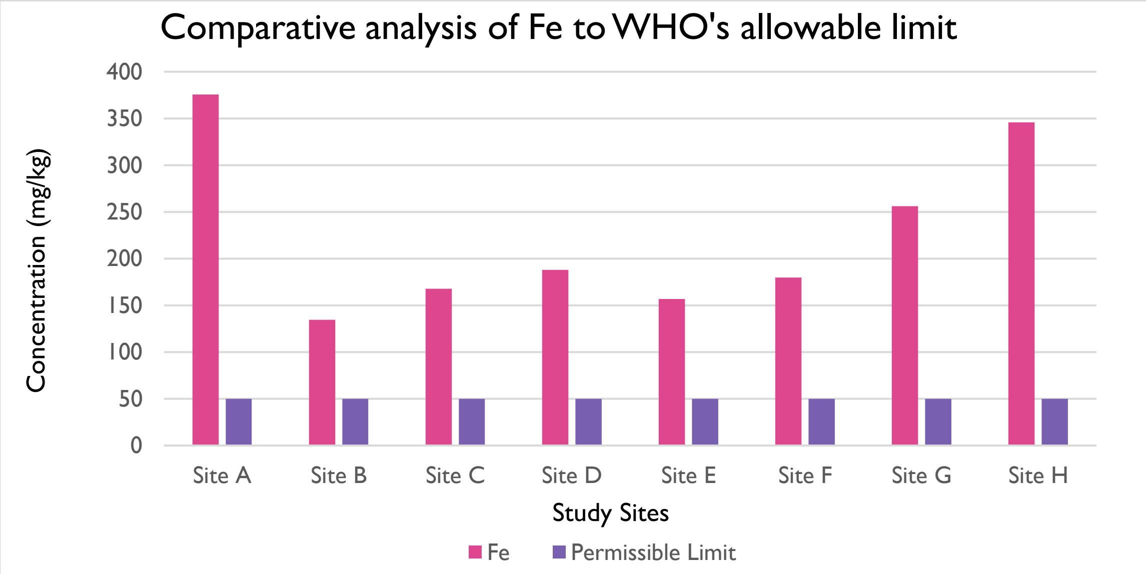


Fig 9: Comparative analysis of Iron to WHO's allowable limit.



4. CONCLUSIONS

The results indicate that the distribution and availability of the parameters under investigation varied according to industrial activity, as demonstrated by the concentration value ranges found for nearly all micro-nutrients in the soils tested at the various sample sites. In the Ganga basin, heavy metals are having a detrimental effect on human health and the environment which are seriously polluting the river and the soil around it. Additionally, the soil next to the river contains heavy metal residues, which could affect agricultural output and endanger soil health. Certain heavy metals, like iron and copper, can build up in the food chain and may cause fish and other animals to have higher quantities, which could be dangerous for human consumption. Promoting environmentally friendly farming methods that employ fewer heavy metals is crucial. To successfully remove heavy metal residues before they are released into the river, install strong wastewater treatment systems. Establish continuous monitoring initiatives to assess the levels of micro-nutrients in the river and its environs regions. Increase public knowledge of the dangers posed by heavy metals and the urgent need to save the river.

Data analysis conducted recently has demonstrated that the quality of Ganga water is deteriorating progressively, and in many areas, even in the upper stretches of the Ganga, the water is not appropriate for domestic use. While the prohibition of toxic heavy metals has yielded a positive outcome, reflected in the decreasing range of micro-nutrients in Ganga water, the alarming trend of increasing trace and toxic elements is a cause for concern. Prolonged exposure to contaminated Ganga water and/or the consumption of fish from the Ganga may result in serious health issues, including cancer. It is essential to perform research to analyze the impact of micro-nutrients on the flora and fauna of the Unnao district. Environment friendly administration practices for soil should be integrated. The cultivation of food crops near industrial facilities should be discouraged, and the government should ultimately enforce measures to ensure compliance with environmental guidelines by industries.

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