



# Metal Ions Analysis of Water in the Industrial Area in Gaya District of Bihar State - India

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**Abstract:** The groundwater quality assessment conducted in the Manpur Block near Falgu River was aimed at evaluate the suitability of the water for drinking purposes. The study measured various water quality parameters, including hardness, turbidity, conductivity, pH, TDS (total dissolved solids), alkalinity, chloride, content and dissolved metals. These parameters were compared with the acceptable limits prescribed by the BIS (Bureau of Indian Standards) to determine if the water meets the required standards for safe consumption. The study included analysis of the acceptability of groundwater sample, metal contamination, potential risks, and analysis of surrounding groundwater. Some of the groundwater samples collected were found to be acceptable within the BIS limits for drinking water quality, while others exceeded these limits. The average concentrations of metals in the groundwater samples followed the trend: Mn (Manganese) > Zn (Zinc) > Fe (Iron) > Ni (Nickel) > Cu (Copper) > Cr (Chromium). This indicates that manganese and zinc are the most prevalent metals, while chromium and copper were found in the least amounts. Presence of certain metals such as nickel and iron beyond the acceptable limits can invite a serious health hazard to the local population, especially if the water is consumed regularly without proper treatment. The study assessed not only the water quality of the Falgu river but also the quality of nearby groundwater, which may be affected by industrial activities in the congested area. This relationship is important to understand the broader environmental impact on water resources.

**Keywords:** Cotton industry, piper diagram, water, chemical analysis, manganese

**Introduction:** The assessment of groundwater quality in the Manpur Block of Gaya district, Bihar, is of utmost importance due to the potential contamination risks posed by various human activities, industrialization, population growth, and inadequate waste management. Groundwater, being a widely distributed and essential source of drinking water, is susceptible to changes in its physical and chemical properties as it flows through different geochemical and biological environments (Xu et al. 2019; Zhu et al. 2011). As India belongs to tropical region, it experiences water scarcity due to seasonal rainfall and high evaporation rates which results in groundwater depletion and contamination (Ferrant et al. 2014). Excessive water extraction, intentional or unintentional contamination and shrinking of available water due to both natural and anthropogenic factors in India cause adverse impact on groundwater resource (Shah et al. 2000; Zhang et al. 2018). Industrialization and population growth further deteriorated the situation on account of hazardous chemicals, heavy metals, and waste materials into water sources. One of the most important forms of contamination is the presence of heavy metals in groundwater, often as a result of industrial waste discharges. These metals, including lead, mercury, and arsenic, affect human health, aquatic life,



and the wider ecosystem (Grutzmacher et al. 2013). Untreated industrial effluents with these toxic substances accumulate in water bodies and adversely influence groundwater quality.

Studies of groundwater quality have been conducted in various regions in India, including Western Delhi, Jharkhand, Uttarakhand, Rajasthan, Tamil Nadu, and others (Adhikary et al. 2009, Avishek et al. 2010, Jain et al. 2010, Tank et al. 2010, Vasanthavigar et al. 2010, Ravikumar et al. 2011, Mondal et al. 2010, Singh et al. 2012, Srikanth et al. 2013 and Kumar et al. 2016). There is a notable gap in research for the Manpur block area of Gaya district which suggests an urgent need for a dedicated groundwater pollution database for this region to understand the metal content in groundwater and its related risks to human health. In India, dominated by a tropical climate, seasonal rainfall and high evaporation, water seeping from the ground interacts with natural and anthropogenic pollutants, which can result in deterioration of water quality, especially in areas with high industrial activity or inadequate waste disposal practices. This research aims to fulfill this gap by providing critical data on groundwater quality, which can inform future water management strategies, regulatory policies, and public health interventions in the region.

### **Study area**

The Manpur block area in Gaya district, Bihar, is the focus of this study due to its significance as a source of groundwater and its potential contamination risks. The region's geography, climate, and human activities provide context for understanding groundwater quality and the challenges faced by the local population. Manpur block is located within Gaya district, Bihar, and is surrounded by several neighboring blocks—Gaya block to the west, Atri block to the east, Tankuppa block to the south, and Bodhgaya block to the west. The region experiences a tropical climate with an average annual rainfall of around 600 mm. The rainy season lasts from July to October, primarily driven by the monsoon. This seasonal rainfall pattern affects groundwater recharge, as water infiltrates into the ground during the rainy season and is available for extraction in the dry months. The Falgu River, which flows through the study area, is a significant water body, but groundwater is the primary source of water supply for the local population. The groundwater is primarily accessed through dug wells and hand pumps, which typically reach depths of 1 to 5 meters below the ground level. Agriculture is one of the main occupations in the region, contributing significantly to the livelihood of the people. The use of groundwater for irrigation and other agricultural activities places considerable pressure on local water resources. The region is also known for its handloom industry, with weaving being a significant economic activity. The production of textiles and fabrics often requires water for dyeing and washing processes, further increasing the demand for groundwater. Manpur block also hosts industries such as handloom production and a railroad tie factory. The presence of these industries, especially the handloom and factory activities, may contribute to groundwater contamination through the discharge of wastewater containing chemicals, dyes, and other industrial effluents.

### **Methods and materials**

The methodology for groundwater sampling and analysis in the Manpur block study is outlined in a systematic way to ensure accurate and reliable results for assessing water quality.

### **Sampling:**

A total of 14 groundwater samples were collected from different locations in the Manpur block, using a Geographical Positioning System (GPS) to ensure precise and accurate location data for each sampling point. Before the actual sampling, all the selected water sources were pumped out to allow the water to stabilize. This step ensures

that the water sampled is representative of the groundwater source, minimizing contamination from stagnant water or initial fluctuations in quality. Groundwater was collected in one liter polyethylene bottles, which are widely used in water quality studies. Polyethylene is chemically inert and resistant to interaction with most substances, making it suitable for preserving the composition of the water samples. After collection, the bottles were sealed properly to prevent any further contamination or evaporation. The samples were then transported to the laboratory in a cool environment and stored at 4°C until analysis, preserving the samples' quality and minimizing any changes in their chemical composition.

### Analysis:

On-site measurements of electrical conductivity (EC) and pH were conducted using digital meters (Systonic Model No.5.956). These parameters provide immediate insights into the general quality of the groundwater. After sample collection and transportation, several physicochemical parameters were analyzed in the laboratory using standard methods. Total Hardness,  $\text{CO}_3^{2-}$  (carbonate), and  $\text{HCO}_3^-$  (bicarbonate) parameters were measured through acidic titration, a common and accurate method to determine hardness and the concentration of carbonate/bicarbonate ions in water. Chloride content was determined by argentometric ( $\text{AgNO}_3$ ) titration, which involves adding a silver nitrate solution to react with chloride ions, allowing quantification based on the volume of titrant used. Calcium ( $\text{Ca}^{2+}$ ) and Magnesium ( $\text{Mg}^{2+}$ ) these two essential ions were analyzed using an iCAP RQ (Inductively Coupled Plasma - Radial Quadrupole). This method is widely used for precise determination of metal ions in water samples. The concentrations of various metal ions (e.g., Mn, Zn, Fe, As, Ni, Cu, Cr, Se, etc.) were also analyzed using iCAP RQ, which provides high sensitivity and accuracy in measuring trace metals in water samples. The analysis followed standard methods for water and wastewater examination outlined by the American Public Health Association (APHA, 1995).

### Results and discussion

Physicochemical parameters of the groundwater in the Manpur block region provide important insights into the overall water quality. The groundwater in the region is alkaline, with a pH range indicating slightly alkaline conditions. The alkalinity of the groundwater ranges from 6.9 to 7.9, which falls within acceptable limits for drinking water (generally around pH 6.5 to 8.5). The TDS levels range between 90 mg/L and 401 mg/L. Since the permissible limit for TDS in drinking water is 500 mg/L, these values fall within the acceptable range. This suggests that the groundwater is not overly saline or contaminated with excessive dissolved solids. Total hardness ranged from 40 to 180 mg/L, with an average of 105.4 mg/L. Hardness is primarily due to the presence of calcium ( $\text{Ca}^{2+}$ ) and magnesium ( $\text{Mg}^{2+}$ ) ions in the groundwater. The average hardness falls within the range typically found in natural water, though values closer to 180 mg/L may be considered moderately hard. The conductivity of the groundwater ranged from 183 to 818  $\mu\text{S}/\text{cm}$ . Electrical conductivity is an indirect measure of the concentration of dissolved ions in water. Higher conductivity generally indicates higher ion concentrations. While the variation in conductivity suggests the presence of dissolved salts, it does not exceed the permissible range for drinking water. A classification of groundwater quality based on these parameters (Sawyer et al. 1994) can help in understanding the overall suitability of the water for drinking and other uses. The water is classified as fresh (below 500 mg/L). The average hardness as shown in Fig. 1(a) 105.4 mg/L suggests that the water is of moderate hardness, which may require softening for some industrial or domestic uses, but is generally acceptable for drinking. From Fig. 1(b) conductivity range 183–818  $\mu\text{S}/\text{cm}$  indicates that the water has a moderate level of dissolved ions, which is typical for groundwater in this region and suggests that it is not excessively contaminated.

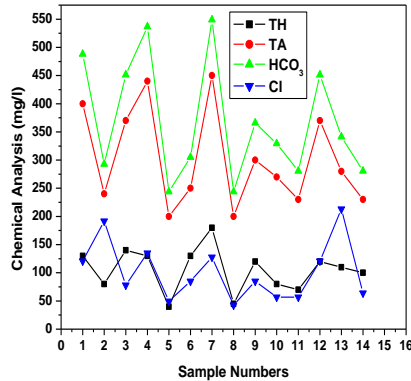


Fig. 1(a) Chemical parameters concentration variation in water samples

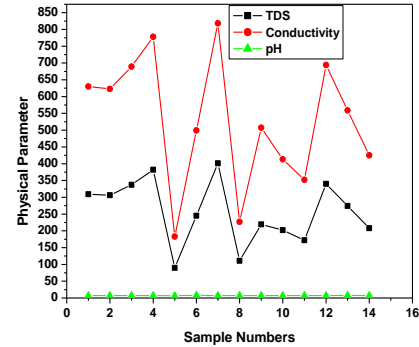


Fig. 1(b) Physical parameter TDS (mg/l), EC (µS/cm), pH variation in water samples

The Piper trilinear diagram is a widely used method to represent the hydrochemical facies and classify water types based on the relative concentrations of major cations and anions. The diagram divides water types into distinct groups based on the chemical composition of the water, providing insights into the hydrogeochemical processes that govern water quality. The study reveals that the groundwater in Manpur block is dominated by the cations Calcium ( $\text{Ca}^{2+}$ ) and Magnesium ( $\text{Mg}^{2+}$ ), as well as the anions Bicarbonate ( $\text{HCO}_3^-$ ) and Chloride ( $\text{Cl}^-$ ) as shown in Fig.2. The Ca-Mg- $\text{HCO}_3$  water type is typical of groundwater that has undergone rock-water interaction, particularly with silicate minerals such as feldspars, which are commonly present in the local geology (Kaur et al. 2019). The interaction between groundwater and silicate rocks leads to the release of calcium and magnesium ions, which contribute to the overall water chemistry. Chloride ( $\text{Cl}^-$ ) ions, while present in the groundwater, are primarily attributed to anthropogenic influences, since there are no natural sources of chloride, such as halite (rock salt) deposits, in the study area. The presence of chloride points to human-induced contamination. The likely sources of chloride in the groundwater include industrial effluents, particularly those discharged untreated by local industries. These effluents often contain saline water, which can contribute to elevated chloride levels. This aligns with the fact that the study area hosts several industries that are likely discharging untreated saline waste into the environment. Domestic sewage and irrigation return flows may also contribute to the chloride levels, as they can introduce organic and inorganic contaminants, including chloride, into the groundwater system. The Piper diagram and the observed chemical composition of the groundwater indicate that while the overall water chemistry is influenced by natural processes like rock-water interactions (specifically with silicate minerals), anthropogenic activities such as industrial effluent disposal and domestic waste contribute significantly to the contamination of groundwater, particularly in terms of chloride and nitrogen compounds. Ca-Mg- $\text{HCO}_3$  suggests that the dominant geological processes shaping groundwater chemistry are the weathering of silicate minerals and the dissolution of calcium and magnesium carbonates. The presence of chloride beyond natural levels suggests human activities, particularly the discharge of industrial and domestic waste, are likely influencing the quality of the groundwater. It is also important to note that chloride can serve as an indicator of saline contamination, which, if left unchecked, can degrade groundwater quality over time.

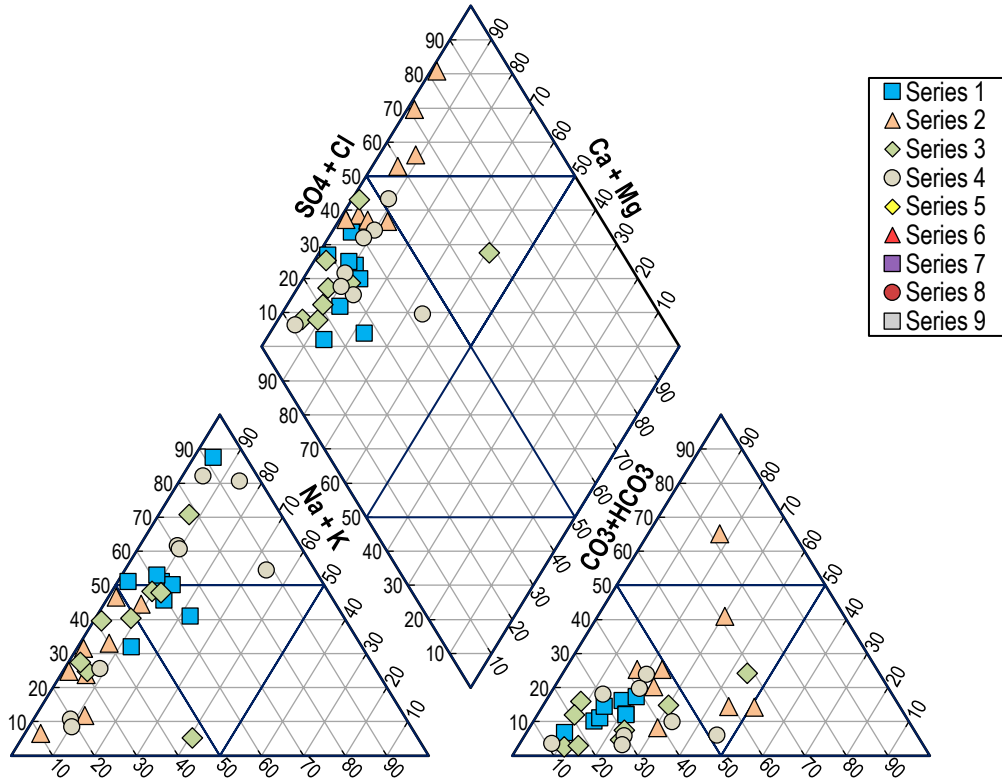


Fig. 2 Piper diagram of the investigated groundwater samples.

### Metal Ions

Manganese (Mn) and Zinc (Zn) are essential trace metals for human health, but elevated levels of these metals in groundwater can pose serious risks to both human well-being and the environment. Manganese is an essential nutrient for humans, required in small amounts for various physiological functions such as enzyme activation and bone formation. However, excessive manganese in drinking water can lead to significant health issues. Elevated manganese levels have been linked to a range of behavioral and developmental disorders in children, including cognitive impairments and attention problems. Long-term exposure can also cause neurological damage, leading to symptoms similar to Parkinson's disease (Agarwal et al., 2020). According to the World Health Organization (WHO), the maximum permissible limit for manganese in drinking water is 400 ppb (parts per billion). Levels above this threshold indicate the potential for metal contamination that could adversely affect human health, particularly in regions with elevated concentrations of manganese. While manganese is a naturally occurring mineral, high concentrations in groundwater are relatively rare. When present in excess, it often results from industrial activities, pollution, or geological factors. Manganese can leach into water sources from mining activities or through the use of certain fertilizers and pesticides. Elevated manganese concentrations pose a potential toxic risk to the environment, especially in areas where contaminated groundwater interacts with natural water systems, potentially affecting aquatic ecosystems. The average concentration was found 687.121357 ppb with maximum concentration of 8,698.50 ppb.

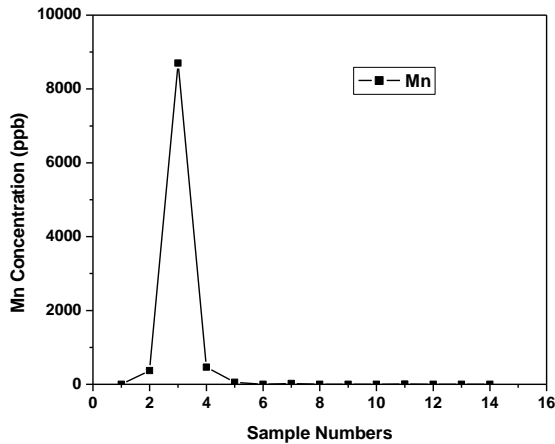


Fig.3(a) Mn concentration variation in water samples

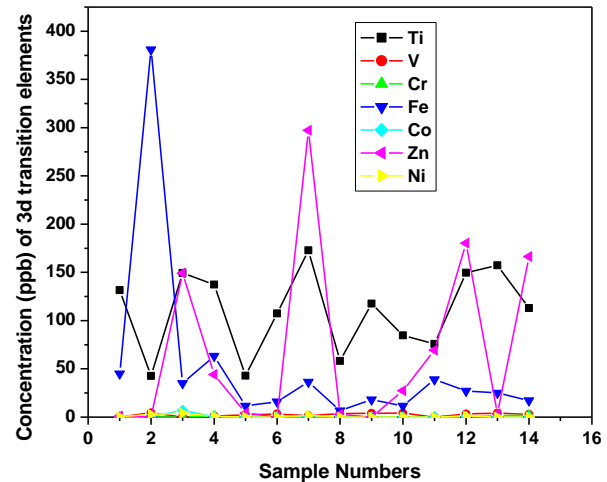


Fig.3(b) Transition metals concentration variation in water samples

Zinc is another essential trace metal that plays a vital role in immune function, wound healing, and DNA synthesis. However, excessive levels of zinc in drinking water can lead to toxic effects on both humans and the environment. The maximum permissible level of zinc in drinking water is set at 30 ppb (parts per billion). When zinc concentrations exceed this limit, it signals the potential presence of heavy metal pollution, which can be detrimental to aquatic ecosystems and human health. Toxicity to Aquatic Life: Zinc toxicity affects aquatic organisms, such as algae, invertebrates, and fish, and can disrupt aquatic ecosystems. The toxicity of zinc to aquatic organisms varies, but it has been reported to affect algae at concentrations as low as 100 ppb with more severe effects occurring at higher concentrations (Duraisamy et al., 2021). For humans, while the body requires small amounts of zinc, prolonged exposure to elevated zinc levels in drinking water can cause gastrointestinal issues, nausea, and vomiting. Chronic exposure to very high levels can result in kidney damage and other health complications. From Fig. 3(b) the average concentration is 67.547429 with maximum and minimum concentration 297.137 to 3.55 ppb of zinc.

Chromium (Cr) is a metal that can naturally occur in groundwater, but its presence at elevated concentrations poses significant risks to both human health and the environment. Chromium is a naturally occurring element found in trace amounts in the Earth's crust. It can leach into water sources from the surrounding rocks and soils. However, while chromium is essential in very small quantities for some biological functions, excessive concentrations in water can have toxic effects on both human health and the environment. Chromium exists in two primary forms in the environment: Chromium (III) ( $Cr^{3+}$ ) is the more stable, less toxic form and is naturally occurring. Chromium (VI) ( $Cr^{6+}$ ), on the other hand, is highly toxic and carcinogenic, often resulting from industrial activities like tanning, metal plating, and the manufacturing of pigments. Elevated chromium levels, especially in the hexavalent form, can contaminate groundwater through industrial effluents, mining activities, or agricultural runoff. Chromium can accumulate in aquatic ecosystems, harming fish, invertebrates, and plants. The toxic effects include damage to cellular functions, disruption of enzymatic activities, and long-term ecological degradation. According to Indian water quality standards, the permissible limit for chromium in drinking water is set at 50 ppb (parts per billion). This limit is intended to safeguard human health from the toxic effects of chromium exposure. Natural chromium levels in marine waters are typically around 50 ppb, as reported by Patterson Edward et al. (2021). These levels are



considered typical in natural water bodies and are not associated with harmful effects. In the study of groundwater quality in the Manpur block, the highest concentration of chromium found in the 14 samples collected was 1.833 ppb Fig. 3(b). This concentration is well below the permissible limit of 50 ppb, indicating that the groundwater in this region does not present a chromium-related health hazard based on the samples collected.

The presence of Cobalt (Co), Nickel (Ni) and Iron (Fe), in groundwater is an important factor to consider for assessing water quality and the potential health risks associated with their consumption. These metals can occur naturally in groundwater, but their concentrations may also be influenced by anthropogenic activities, such as industrial contamination. Cobalt is an essential trace metal that plays a crucial role in human health, particularly in the production of vitamin B12. However, when Cobalt concentrations exceed certain limits, it can have harmful effects on human health (Shahida et al., 2009). In the study, the average concentration of cobalt in the groundwater samples was 0.6671 ppb, with the maximum concentration being 6.861 ppb and the minimum 0.024 ppb. This is well within the permissible limit of 300 ppb set by the World Health Organization (WHO) for drinking water. The Cobalt levels in the study area are considered safe for drinking as they are significantly lower than the WHO's permissible limit.

Nickel is widely used in modern technologies and is found in various industrial products, including batteries, coatings, and electronics. However, exposure to nickel through drinking water and food can have adverse effects on human health, such as skin reactions and respiratory issues (Aleksandra and Urszula, 2008). In the 14 groundwater samples, the nickel concentration ranged from 0.466 ppb to 4.093 ppb, with an average concentration of 0.7911 ppb. This is far below the WHO permissible limit of 20 ppb for nickel in drinking water. The Nickel levels in the groundwater are well within the safe limit for human consumption, indicating that the groundwater is not a significant source of nickel contamination.

Iron is essential for human health as it is vital for oxygen transport in the blood. However, excessive iron in drinking water can cause undesirable effects, such as a metallic taste, staining of clothing, and potential skin issues. It is considered a secondary contaminant, primarily due to its aesthetic impact on water quality (e.g., taste, color). The iron concentration in the study area ranged from 6.618 ppb to 380.967 ppb, with an average concentration of 52.333 ppb. The WHO permissible limit for iron in drinking water is 300 ppb. The iron concentrations in the study area are generally within the permissible limit. However, some locations may exhibit higher levels, which could cause aesthetic issues such as unpleasant taste and staining, though the levels are not high enough to pose significant health risks.

### **Conclusion:**

This research sheds light on the quality and safety of groundwater in the Manpur block region, with a focus on pollution sources, water chemistry, and associated health risks. The overall groundwater quality in the Manpur block is relatively good. Parameters such as total dissolved solids (TDS), hardness, and conductivity are within acceptable or moderate ranges for drinking water. The groundwater is alkaline and has relatively low TDS, indicating its general suitability for consumption. The hydro chemical analysis (using the Piper trilinear diagram) suggests that groundwater composition is primarily influenced by natural rock-water interactions. Elevated chloride levels point to anthropogenic contamination, likely from industrial activities and untreated saline effluent disposal.

Manganese concentrations in the groundwater samples were found an average 687.12 ppb, significantly exceeding the WHO permissible limit of 50 ppb. One sample exhibited Mn levels as high as 8,698.5 ppb, posing severe health risks, including neurological and developmental disorders, particularly in children. Elevated Mn levels may also harm aquatic ecosystems if it accumulates in water sources. Levels of metals such as titanium (Ti), vanadium (V), chromium (Cr), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu) and zinc (Zn), were below WHO permissible limits and are considered safe for drinking.

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