



Industrialization and Groundwater Quality in Alwar District, Rajasthan: A Spatial and Environmental Assessment

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ABSTRACT

Groundwater is a major source of domestic, agricultural and industrial water in the semi-arid region of Rajasthan. Rapid industrialization and urban expansion can place additional pressure on ground water quality. The present study assesses ground water-quality conditions in Alwar District, with particular emphasis on industrially influenced areas such as Neemrana, Behror and Tijara. Secondary information's from the Central Ground Water Board (CGWB), published research and Bureau of Indian Standards (BIS) drinking water criteria was examined. Parameters including pH, electrical conductivity, total dissolved solids, hardness, sulphate, chloride, nitrate, fluoride and selected metals were considered. Available evidence indicates spatial variation in ground water quality, with fluoride and nitrate exceeding desirable/permmissible levels in several parts of the district. The findings emphasize the need for regular monitoring, improved industrial waste water management and integrated ground water resource planning.

Keywords: *Ground water quality, Industrialization, Alwar, Neemrana, Fluoride, Nitrate, Ground water pollution, Rajasthan.*

1. Introduction

Ground water is one of the most important fresh water resources in India and plays a particularly important role in arid and semi arid regions. Rajasthan has a high dependence on ground water because rainfall is spatially and temporally variable and surface water resources are limited. Ground water supports domestic requirements, livestock, irrigation and industrial activities [1, 2]. The quality of ground water is controlled by both natural hydro geo chemical processes and human activities. Geological formations influence the concentration of dissolved minerals, calcium, fluoride, magnesium and other ions. At the same time, agriculture, urbanization, industrial waste water, domestic sewage and improper waste disposal can introduce additional contaminant into ground water [3–6].

Alwar District in north eastern Rajasthan has under gone considerable industrial and urban development. Industrial areas such as Behror, Neemrana, Bhiwadi and other RIICO-associated area have contributed to economic developments but have also increased environmental pressure on land and water resources. Previous research has reported ground water-quality concerns in and around industrial areas of Alwar, including elevated nitrate and fluoride at some locations [7].

The Central Ground Water Board has also undertaken detailed aquifer-mapping work for Alwar District. The official CGWB report covers the district's hydrogeology, ground water resources, and ground water quality and management issues [8]. More recently, CGWB published a dedicated NAQUIM 2.0 study for the Neemrana Industrial Area, highlighting the importance of groundwater management in this industrial region [9]. Groundwater contamination is particularly important because pollutants entering an aquifer may remain undetected for long periods and may be difficult to remove once contamination becomes established. Therefore, assessment of ground water quality is essential for sustainable industrial and regional development.

2. Study Area

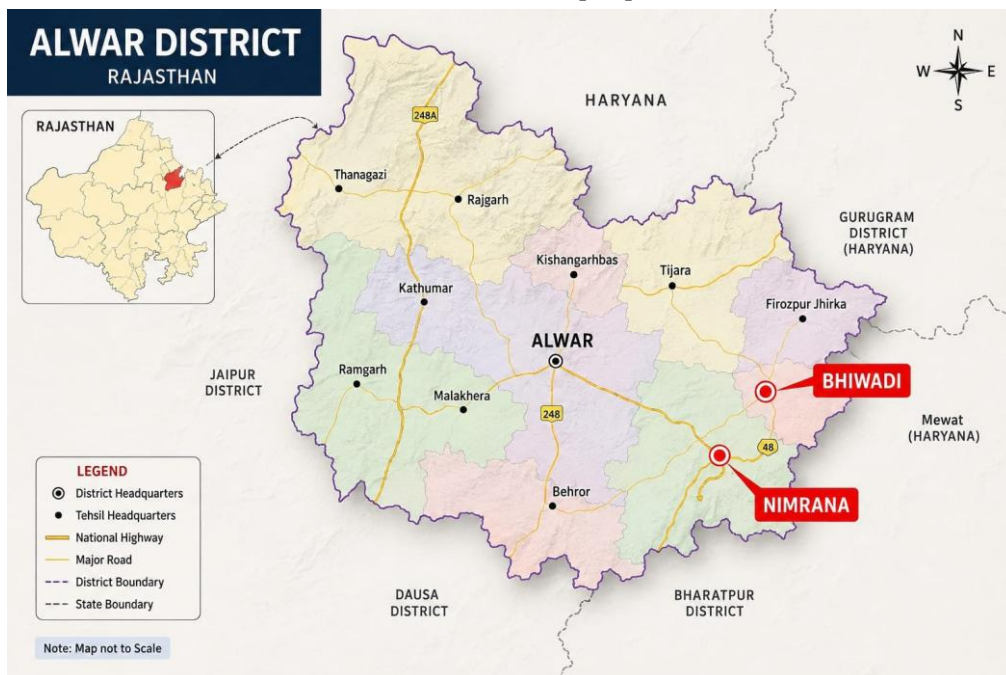
Alwar District is situated in north eastern Rajasthan. According to the Central Ground Water Board, the district extends approximately between 27°03' and 28°14' N latitude and 76°07' and 77°13' E longitude and covers about 8,720 km² [8]. The district has a diverse economic structure comprising agriculture, industry, trade, transport and service activities. Its location near the National Capital Region has encouraged industrial and infrastructural development. Important industrial and urban centres include Neemrana, Behror, Tijara, Kishangarh Bas and adjoining areas. The co-existence of agriculture, settlements and industrial activities creates multiple potential sources of pressure on ground water.

CGWB's aquifer-mapping report identifies several groundwater-related issues across Alwar, while the more recent dedicated Neemrana Industrial Area study provides an additional basis for assessing groundwater conditions in an important industrial cluster [8,9].

Table 1. General Characteristics of the Study Area

Parameter	Description
District	Alwar, Rajasthan
Approximate area	8,720 km ²
Region	Northeastern Rajasthan
Major activities	Agriculture, industry, trade and services
Important industrial areas	Neemrana, Behror and adjoining industrial areas
Major groundwater uses	Domestic, agricultural and industrial
Important quality concerns	Fluoride, nitrate, salinity and localized iron contamination

Source: CGWB [8,9].



3. Industrialization and Groundwater Quality

Industrial development is an important component of regional economic growth. However, industrial activities generate waste water containing dissolved salts, organic matter and, depending on the industrial process, potentially hazardous chemical constituents.

If industrial waste water is in adequately treated or improperly disposed of, contaminants may migrate through soil and eventually reach ground water. The potential impact depends upon aquifer characteristics, depth of ground water, soil permeability, recharge conditions and the quantity and composition of wastewater [4,7].

Research conducted in industrial areas of Alwar, including Bhiwadi, Matsya Nagar, Neemrana and Behror, reported variations in ground water chemistry and identified anthropogenic activities as important factors affecting groundwater quality. The study reported elevated nitrate at some location and an exceptional fluoride concentration at Majri Kalan in the Neemrana industrial area [7]. It is therefore important to recognize that industrialization is one of several possible sources of groundwater-quality deterioration. Agriculture, domestic wastewater, urbanization and natural geological processes may also contribute significantly.

4. Materials and Methods

The present study is based primarily on secondary data analysis. Information was compiled from government reports, published scientific studies and drinking-water standards.

The major source of district-level ground water information was the Central Ground Water Board's aquifer-mapping report for Alwar District [8]. Recent information concerning the Neemrana Industrial Area was obtained from the CGWB NAQUIM 2.0 publication [9]. Published research concerning groundwater quality in industrial areas of Alwar was also considered [7,10]. The study further uses the Bureau of Indian Standards specification IS 10500:2012 for comparison of important drinking-water-quality parameters [11].

The major parameters considered were:

- pH
- Electrical Conductivity (EC)
- Total Dissolved Solids (TDS)
- Total Hardness
- Chloride
- Sulphate
- Nitrate
- Fluoride
- Iron
- Calcium
- Magnesium
- Selected heavy metals

The interpretation emphasizes the spatial relationship between groundwater quality and industrial, agricultural and urban activities.

5. Groundwater Quality Parameters

5.1 pH

pH indicates the acidic or alkaline nature of groundwater. BIS IS 10500:2012 specifies an acceptable pH range of approximately 6.5–8.5 for drinking water [11].

pH also affects the mobility and chemical behaviours of several dissolved constituents. Industrial wastewater and natural mineral-water interactions can influence groundwater pH.

5.2 Electrical Conductivity

Electrical conductivity is an important indicator of the concentration of dissolved ionic substances in water. Higher EC generally indicates greater mineralization.

Elevated EC may be associated with natural geological processes, irrigation return flow, industrial waste water and urban influences. Consequently, EC is useful for identifying areas experiencing increasing salinity pressure.

5.3 Total Dissolved Solids

Total dissolved solids represent the combined concentration of dissolved substances in water. High TDS may affect taste and indicate increased mineralization.

The BIS drinking-water standard includes TDS among the important parameters used for assessing potable water [11].

In industrial regions, increased TDS may result from industrial waste water, while agricultural regions may experience increasing dissolved salts because of irrigation return flow and evaporation.

5.4 Total Hardness

Hardness is primarily associated with calcium and magnesium ions. Ground water in areas containing carbonate-bearing formations may naturally exhibit elevated hardness.

High hardness may create scaling problems in domestic and industrial water systems. Therefore, hardness is an important parameter for assessing ground water suitability.

5.5 Chloride

Chloride occurs naturally in ground water but elevated concentrations may indicate salinity or anthropogenic influence.

Domestic sewage, industrial waste water and irrigation return flow may increase chloride concentrations. Chloride therefore becomes particularly useful when interpreted together with EC and TDS.

5.6 Sulphate

Sulphate is naturally derived from mineral dissolution but can also enter ground water through industrial and agricultural activities.

High sulphate concentration may affect taste and, at sufficiently high concentrations, may cause gastrointestinal discomfort. BIS includes sulphate among the important chemical parameters for drinking-water assessment [11].

5.7 Nitrate

Nitrate is one of the most important indicators of anthropogenic ground water contamination.

Major sources include:

- nitrogen fertilizers,
- animal waste,
- domestic sewage,
- septic-system leakage, and
- waste water infiltration.

The BIS drinking-water specification gives 45 mg/L as the acceptable limit for nitrate [11]. The CGWB assessment of Alwar found nitrate concentrations above 45 mg/L in parts of Umren, Neemrana, Tijara, Thanagazi, Kishangarh Bas, Laxmangarh and Ramgarh [8]. This spatial pattern suggests that nitrate contamination is not restricted to a single industrial location and may reflect a combination of agricultural, domestic and industrial influences.



5.8 Fluoride

Fluoride is a major groundwater-quality concern in several parts of Rajasthan. Its presence can be associated with natural geological processes and groundwater-rock interaction.

According to the CGWB assessment, fluoride in Alwar groundwater ranged from 0.672 mg/L at Tapukara in Tijara block to 3.42 mg/L at Ramgarh. Excess fluoride was particularly reported from Ramgarh, Neemrana, and Kathumar, with contamination also reported in parts of several other blocks [8]. The presence of fluoride therefore represents an important issue for drinking-water management in Alwar.

5.9 Iron

Iron can occur naturally in groundwater because of geological conditions. However, excessive iron may cause undesirable taste, colour and staining.

CGWB reported that iron concentration was within the permissible level in most parts of Alwar, although isolated higher concentrations occurred in parts of Umren, Rajgarh Laxmangarh, Rajgarh and Reni [8].

6. Spatial Pattern of Groundwater Quality

The available evidence indicates that groundwater quality varies considerably across Alwar District.

The pattern is particularly important in industrial and urban areas. Neemrana, Behror and Tijara represent areas where industrial development and urban expansion coexist with agricultural activity.

The CGWB findings demonstrate that both fluoride and nitrate contamination have a spatially variable distribution. Fluoride exceeds the permissible level in parts of Neemrana, Ramgarh and Kathumar, while nitrate above 45 mg/L occurs in several blocks including Neemrana and Tijara [8]. Published research from Alwar industrial areas similarly found variations in groundwater chemistry and reported nitrate concentrations reaching 337 mg/L at one investigated location, while an exceptionally high fluoride concentration was reported at Majri Kalan in the Neemrana industrial area [7].

Table 2. Major Potential Sources of Groundwater Contamination

Source	Major potential contaminants	Possible groundwater effect
Industrial wastewater	Dissolved salts, chemicals, metals	Increased EC/TDS and chemical contamination
Domestic sewage	Nitrate, chloride, pathogens	Chemical and microbial contamination
Agricultural runoff	Nitrate, phosphate, pesticides	Nutrient contamination
Solid-waste disposal	Organic matter, salts, metals	Localized contamination
Irrigation return flow	Dissolved salts	Increasing salinity
Natural geological processes	Fluoride, minerals	Geogenic contamination

Source: Compiled from [4,7,8,10].

7. Industrial Areas of Alwar

Industrial areas require special attention because groundwater is often used for domestic and industrial purposes and because wastewater can become a potential source of contamination.

A previous investigation examined groundwater from four industrial areas—Matsya Nagar, Bhiwadi, Neemrana and Behror—and found that groundwater chemistry was influenced by industrial and human activities [7].

A more recent study published in 2026 assessed groundwater quality at ten industrial locations in Alwar, including areas around Behror, Neemrana, Shahjahanpur, Sotanala and Ramgarh. The study considered parameters such as pH, temperature, alkalinity, hardness, calcium, magnesium, chloride and fluoride and reported that although average values were generally within WHO guidelines, some locations showed higher concentrations than prescribed standards [10].

These studies reinforce the importance of location-specific monitoring rather than assuming uniform groundwater quality across the entire district.

8. Comparison with Drinking-Water Standards

The Bureau of Indian Standards' IS 10500:2012 provides the principal Indian standard for drinking-water quality. It specifies acceptable limits and, where no alternate source exists, permissible limits for several parameters [11].

Table 3. Selected Drinking-Water Quality Criteria

Parameter	BIS acceptable limit	Importance
pH	6.5–8.5	Acidity/alkalinity
TDS	500 mg/L	Dissolved mineral content
Chloride	250 mg/L	Salinity indicator
Sulphate	200mg/L	Chemical quality
Nitrate	45 mg/L	Major anthropogenic contaminant
Iron	0.3 mg/L	Taste/colour and water-quality concern
Fluoride	1.0 mg/L	Important health parameter
Total hardness	200 mg/L	Calcium and magnesium content

Source: BIS IS 10500:2012 [11].

9. Environmental and Health Implications

Ground water contamination has consequences for human health, agriculture and the wider environment. Fluoride is particularly significant because prolonged consumption of ground water containing excessive fluoride can contribute to fluorosis. Nitrate contamination is also important because elevated nitrate in drinking water presents recognized health concerns.

High TDS, hardness and salinity can reduce the acceptability of ground water for domestic use and may create scaling problems. Saline ground water can additionally affect agricultural soils when used continuously for irrigation.

Industrial contamination may also affect surrounding surface-water bodies through drainage and ground water-surface-water interaction. Therefore, ground water management should be integrated with surface water and water shed management.

10. Discussion and Conclusion

The assessment shows that groundwater quality in Alwar District varies from place to place and is affected by a combination of industrial activities, agriculture, urbanization, and natural hydro geochemical processes. Industrial areas such as Neemrana and Behror need special attention because of their high concentration of industrial and urban activities. The findings of CGWB are particularly important in this regard. Fluoride levels above the permissible limit have been found in parts of Neemrana, Ramgarh, and Kathumar, while nitrate concentrations above 45 mg/L have been reported in parts of Neemrana, Tijara, Kishangarh Bas, Laxmangarh, Ramgarh, and other blocks [8]. Earlier studies in Alwar's industrial areas also showed considerable variation in groundwater chemistry, including high nitrate levels and an unusually high fluoride value at one location in the Neemrana industrial area [7]. Recent research has also suggested that groundwater at some locations near industrial areas may exceed the prescribed standards [10]. However, it would not be scientifically correct to link all groundwater-quality problems in Alwar directly to industrialization. Fluoride can naturally occur due to local geological conditions, while nitrate may come from agriculture and domestic wastewater as well as industrial sources. Therefore, a multi-source groundwater assessment is needed to properly understand the situation.

The dedicated CGWB NAQUIM 2.0 study of the Neemrana Industrial Area is an important development because information about aquifer conditions can help identify vulnerable areas and improve groundwater management [9]. Overall,

sustainable groundwater management in Alwar should focus on regular quality monitoring, proper treatment of industrial wastewater, control of untreated sewage, balanced fertilizer use, protection of groundwater recharge areas, and GIS-based spatial monitoring. Drinking-water sources with high nitrate or fluoride levels should be given priority for treatment or alternative water supplies. The study highlights that industrial development and groundwater conservation need to go hand in hand. With proper monitoring and effective pollution-control measures, economic development can continue while reducing the risk of long-term groundwater-quality deterioration in Alwar District.

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