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An Appraisal of Groundwater resources and its Hydrochemistry in Ladnun Block of Nagaur District, Central part of Rajasthan, India

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Abstract: Groundwater is an important source that provides support to all habitants in the arid to semi-arid regions of Rajasthan. The current study contributes to the rising demand for potable water in Ladnun block in the northern part of Nagaur district; situated in the central part of Rajasthan. This paper concentrates on the Evaluation of the hydrogeological and hydrogeochemical aspects of groundwater in the Ladnun block which encompasses three notable aquifers: Older Alluvium, Bilara Limestone, and Jodhpur sandstone.

An attempt was made to understand the groundwater quality as well as its suitability for drinking and other uses by using the water quality parameters. A comprehensive assessment of water quality parameters in groundwater samples were carried out; collected from 34 different locations in the study area in the year 2018 to 2022. Most of the villages of the study area are affected by more, TDS, and salinity hazards which are harmful to human health. Groundwater quality is slightly hard and brackish to saline in the block due to ancient seawater entrapped in sediments, Halite, and higher-order evaporite mineral deposits.

According to WQI most of the water sample falls into the unsuitable category. Therefore, the study area recommended artificial recharge of groundwater and rainwater harvesting to overcome the water demand for drinking purposes.

Keywords: Groundwater Resources, Hydrochemistry, Fluorosis, Ladnun block, Nagaur District, Rajasthan

I. INTRODUCTION

Rajasthan, located in the western part of India, is the largest state in terms of geographical area, accounting for 10.4% of the country's total which covers 3,42,239 sq. km area. The region experiences unpredictable precipitation patterns and is classified as arid to semi-arid.

The State encompasses a large portion of the Great Indian Thar Desert, constituting approximately two-thirds of its total land area. Nagaur district is located almost in the central part of the state of Rajasthan and extends between North latitudes 26°25’ and 27°40” and East longitudes 73°10” and 75°15”.

It covers an area of 17778 sq. km. The district is surrounded by seven other districts; on the north, it is bounded by Bikaner and Churu districts, on the south Ajmer and Pali districts, on the east by Sikar and Jaipur districts, and in the west Jodhpur district.

The study area of Ladnun block is situated in the northern part of Nagaur district covering about 1448.83 sq. km having co-ordinates 27°39’ to 27°65 North latitude and 74°23’ to 74°38’ East longitude (Figure 1).

The region experiences minimal and brief surface runoff. The primary sources of groundwater in the block are Older Alluvium, Jodhpur Sandstone, Bilara Limestone, and Schists.

The rocks of the Marwar Supergroup are classified into Jodhpur, Bilara, and Nagaur groups, which correspond to sandy, calcareous, and clayey facies, respectively. The Ladnun block having important aquifers namely Jodhpur sandstone, Bilara Limestone, Older Alluvium and Schists.

The quality of groundwater in the Ladnun block exhibits significant variation. The primary quality issues related to groundwater are elevated levels of total dissolved solids (T.D.S.), and salinity.

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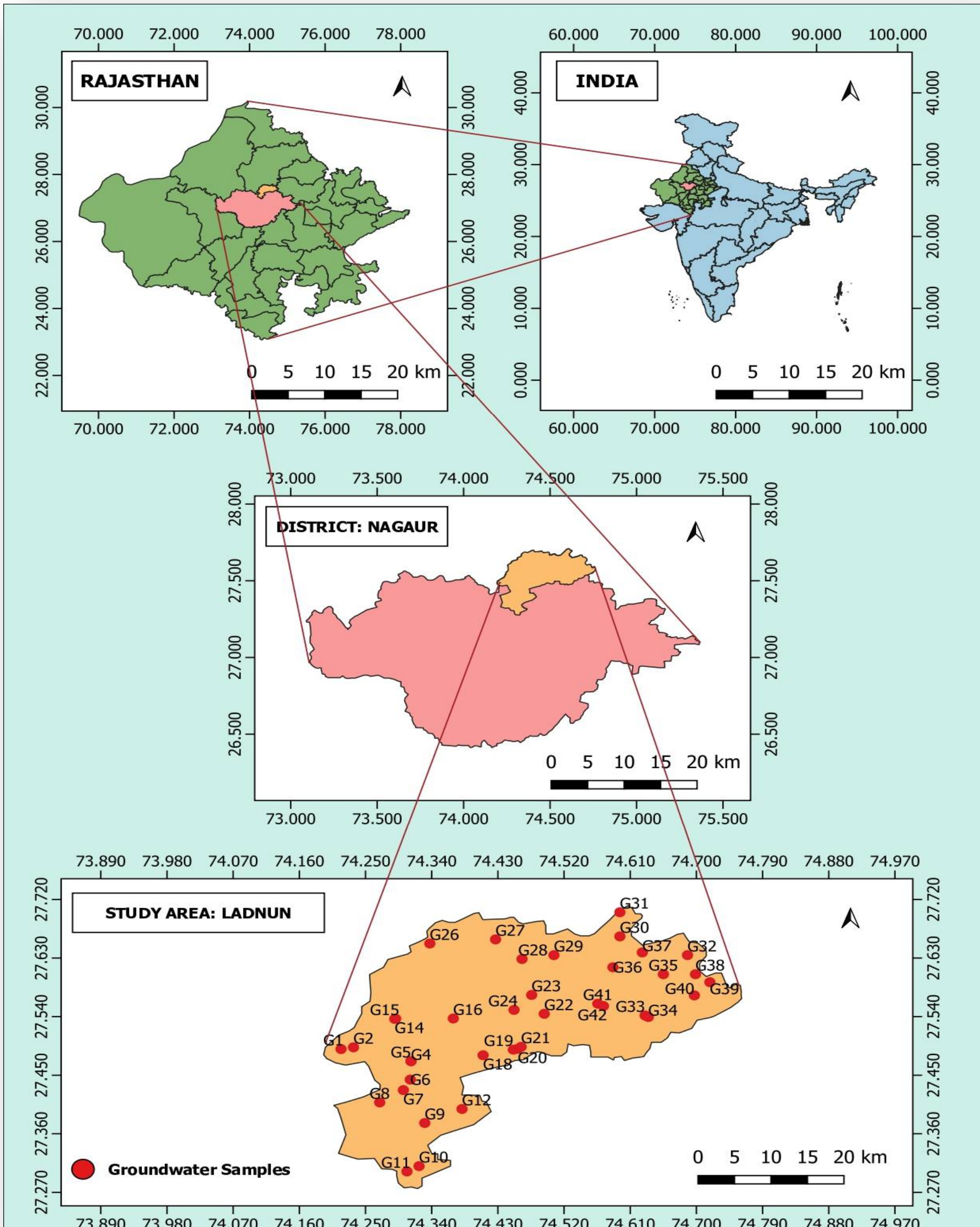

Figure: 1 Location Map of the Study area.

II. GEOLOGICAL SETTING

The Aravalli Mountain Range in Rajasthan striking northeast to southwest, dividing the state into two unequal parts. Western Rajasthan makes up three-fifths of the state, while eastern Rajasthan makes up two-fifths. The Aravalli Mountain range consists of a series of hills and valleys that stretch from Delhi in the northeast to the plains of north Gujarat in the southwest, covering a distance of approximately 650 km (GSI, 2011). The Proterozoic para-tectonic cover sequences of the Vindhyan and evaporitic Marwar hold promise for defining the Precambrian-Cambrian boundary. The Mesozoic and the Cenozoic sequences are developed only in the western part of Rajasthan.

Geologically, the Nagaur district exhibits a distinctive sequence Stratigraphic, encompassing a diverse range of rock formations spanning from the Precambrian to Recent Alluvium and wind-blown desert sands of the great Thar desert (Paliwal, 1999; Vyas and Paliwal, 2001; Gaur and Vyas, 2007).

The Quaternary and Recent geology is characterized by frequent climatic fluctuations, disorganization of the drainage systems (Lost Saraswati River), and development of the Thar Desert (Tank and Vyas, 2019) The Nagaur district also contains sedimentary rocks from the Marwar Supergroup, as well as Tertiary and Quaternary formations. Tertiary lignite, which is from the Paleocene to the Eocene period, was found at Merta, Indawar, Matasukh, and Igyar-Kasnau. The Quaternary formations in the district consist of Aeolian sand, kankars, clays, etc. are the youngest formations in the area. (Vyas etal., 2015; Chauhan and Vyas, 2021) The region also exhibits effusives and intrusives rocks from the Malani Igneous Suite. The Archaean basement consists of deformed rocks, including metasediments from the Aravalli and Delhi Supergroups, as well as Erinpura age granitic-gneisses (metamorphic rocks). The rocks of the Delhi Supergroup have experienced intrusion by the Erinpura igneous suite, which consists of porphyritic granite, biotite granite, pink granite, leucogranite, and pegmatite (Tank and Vyas, 2019).

A major part of the study area is mostly composed of blown sand, which forms the Thar Desert. The region comprising Gunpaliya, Chappara, and Baklia indicates the existence of serpentinite, pyroxenite, plagiogranite, gabbro-diorite, sheeted dykes, pillow basalt, chlorite schist, and mica schist. The lithological associations closely resemble those found in the Ophiolite Suite. (Meena and Vyas, 2023)

The study area is occupied by various rocks, including the Punagarh group of the Delhi Supergroup, the intrusive Erinpura Granite and Gneiss, as well as the sedimentary rocks of the Jodhpur, Bilara, and Nagaur groups of the Marwar Supergroup. The Sandstone of Sonia Formation, which belongs to the Jodhpur Group within the Marwar Supergroup, is found in the mine sections of Manpura, Benetha, and Swami ki Dhani areas, as well as in the Baklia, Bader, Dojar, and Ladnun areas of the study area (Table - 1) (Meena and Vyas, 2023).

Table:1. General Stratigraphic Succession of the area

Supregroup	Group	Formation	Lithology
		The Desert	Fine aeolian sabd and silt with kankar / alluvium and blown sand
		Erinpura Granite and Gneiss	Granite and gneiss
		Intrusive	Amphibolite / meta basic rock
Marwar Supergroup	Jodhpur	Sonia Formation	Purple sandstone
……………………….Unconfromity (?)…………………………………………..			
Bidasar Ophiolite Suite			chlorite schist with chert band
			Pillow basalt
			Sheeted dyke
			Gabbro-diorite
			Pyroxenite
			Serpentinite
Delhi Supergroup	Punagarh	Bombolai	Basic metavolcanic, phyllites, quartzite, schist
	Ajabgarh	Ajmer	Quartzite, limestone, marble

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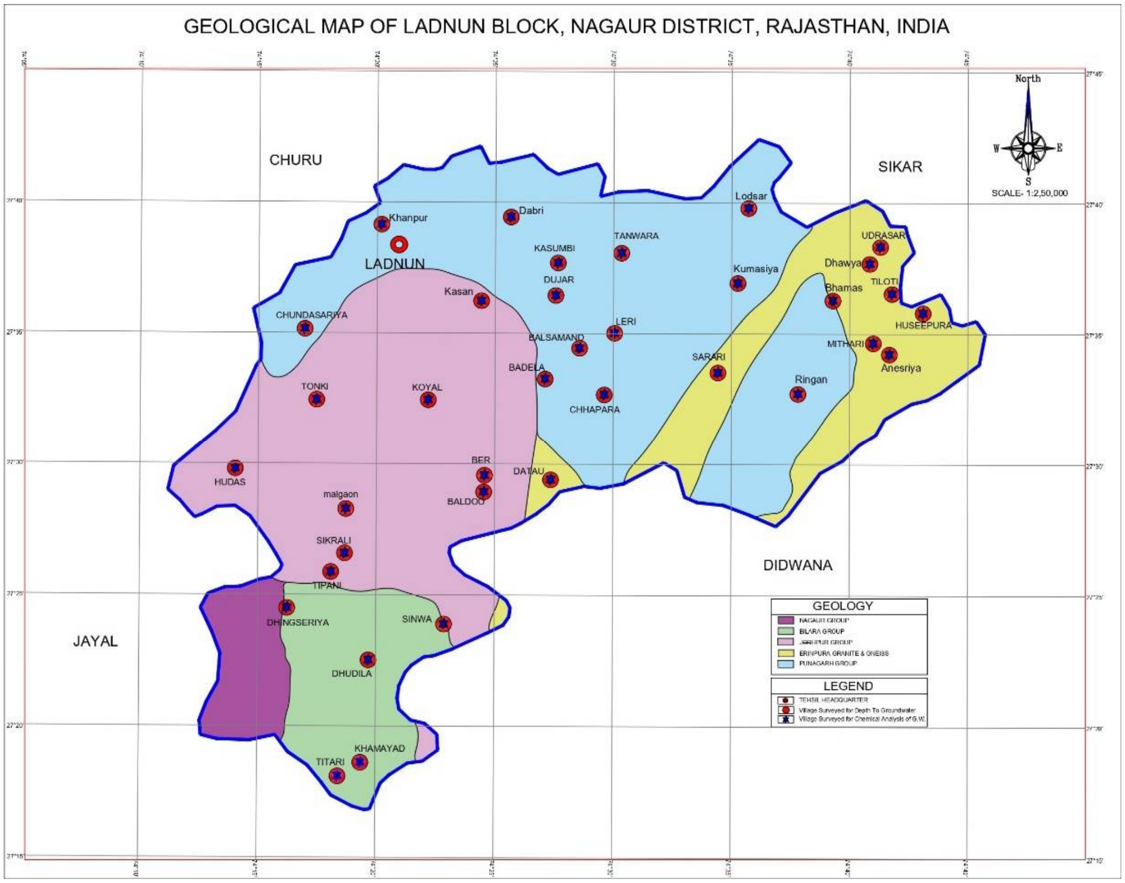

Figure: 2. Geological Map of Ladnun block, Nagaur District, Rajasthan.

III. HYDROGEOLOGY

The state contains three primary hydrogeological units: unconsolidated sediments, semi-consolidated sediments, and consolidated rocks. The state contains two primary types of water-bearing rock formations: soft rocks, which cover approximately 60% of the state's area, and hard rocks, which cover approximately 40%. (Paliwal and Paliwal, 2010; Vyas and Vyas, 2023). The entire Nagaur district can be hydrogeologically categorized into three formations: consolidated, semi-consolidated, and unconsolidated formations, which are characterized by six prominent aquifers: Tertiary Sandstone, Nagaur Sandstone, Bilara Limestone,Jodhpur Sandstone, Granite Gneisses, and Schist. (Vyas, 1999; Vyas and Paliwal, 2001; Vyas, 2010; Chauhan and Vyas, 2021). Depth of groundwater from 3 to 80 meters range is recorded in these aquifers and the direction of the groundwater migration in the district is from southeast to northwest (Chauhan and Vyas, 2022). The average depth to groundwater level in the Pre-monsoon 2021 period of the state is recorded as 23.73 mbgl (G.W.D. Rajasthan, 2022).

The Ladnun block contains both consolidated and unconsolidated formations. The consolidated formations consist of Precambrian metamorphic rocks, especially schists, gneisses, quartzites, and phyllites, as well as sedimentary rocks from the Marwar Supergroup, including limestone and sandstone. The Quaternary Alluvium aquifer is composed of loosely consolidated fine- to coarse-grained sand.

The hydrogeological formations recognized in the Ladnun block consist of Older Alluvium, Jodhpur Sandstone, Bilara Limestone, and Schists which consist of Purple and brown sandstone with claystone, brecciated limestone, conglomerate, Granites, and Gneiss. These are further divided into six Aquifer and Potential Zone named “ALO3a” (Older Alluvium), “STO6a” (Jodhpur Sandstone), “LSO3a” (Bilara Limestone), “SCO1a” (Schists), “SCO1b” (Schists), and “LSO3(S)” (saline Non– Potential) (Table - 2 and Figure -3) (GWD, 2022)

The groundwater is typically found beneath the water table in the alluvium, sandstone, limestone, and schist formations. However, sandstones, exist under semi-confined to confined conditions due to the presence of argillaceous beds above it. (Vyas, 1999; Vyas and Paliwal, 2001; Vyas, 2010; Chauhan and Vyas, 2021)

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Table: 2. Groundwater Potential Zone and Aquifer with Hydrogeological parameters (G.W.D. 2022)

Potential Zone	Area in sq. km	Aquifer	Depth to water in Meter	Type of Well	Proposed depth in Meter	Expected yield of wells in M^3/day	E.C. Micro-Siemens / cm at 25°c	Category
1	2	3	4	5	6	7	8	9
“ALO3a”	125.25	Older Alluvium	25 to 30	TW	140 to 150	100 to 250	<4000	Over Exploited
“STO6a”	773.58	Jodhpur Sandstone	21 to 135	TW	180 to 200	100 to 300	<4000	Over Exploited
“LSO3a”	168.75	Bilara Limestone	35 to 65	TW	180 to 200	100 to 300	<4000	Over Exploited
“SCO1a”	231.25	Schists	8 to 20	TW	75 to 108	75 to 100	<4000	Over Exploited
“SCO1b”	150	Schists	32 to 34	TW	75 to 108	75 to 100	4000-8000	Over Exploited
“LSO3(S)”	81.25	NON – POTENTIAL	43 to 53	TW	180 to 200	100 to 150	>8000	Safe

In the Ladnun block, Older alluvium's average depth to groundwater is 27 meters below ground level. The yield of wells and tube wells from these aquifers varies from 100 to 250m3/day and groundwater has electrical conductivity less than 4000 micro-siemens /cm. at 25° c. The average depth of water in Jodhpur Sandstone is 80 meters below ground level and the yield from these resources varies from 100 to 300 m3/day, The average depth of water level in Bilara Limestone is 45 mbgl, and yield from the groundwater resources varies from 100 to 300 m3/day. Other water-bearing formation schist located in the northeast part of the Ladnun block; (Figure: 3) in these aquifers’ groundwater is available only in weathered zones and yield varies from 75 to 108 m3/day (low to moderate yield) (Gouran and Vyas, 1998; Vyas, 2010; Chauhan and Vyas, 2021).

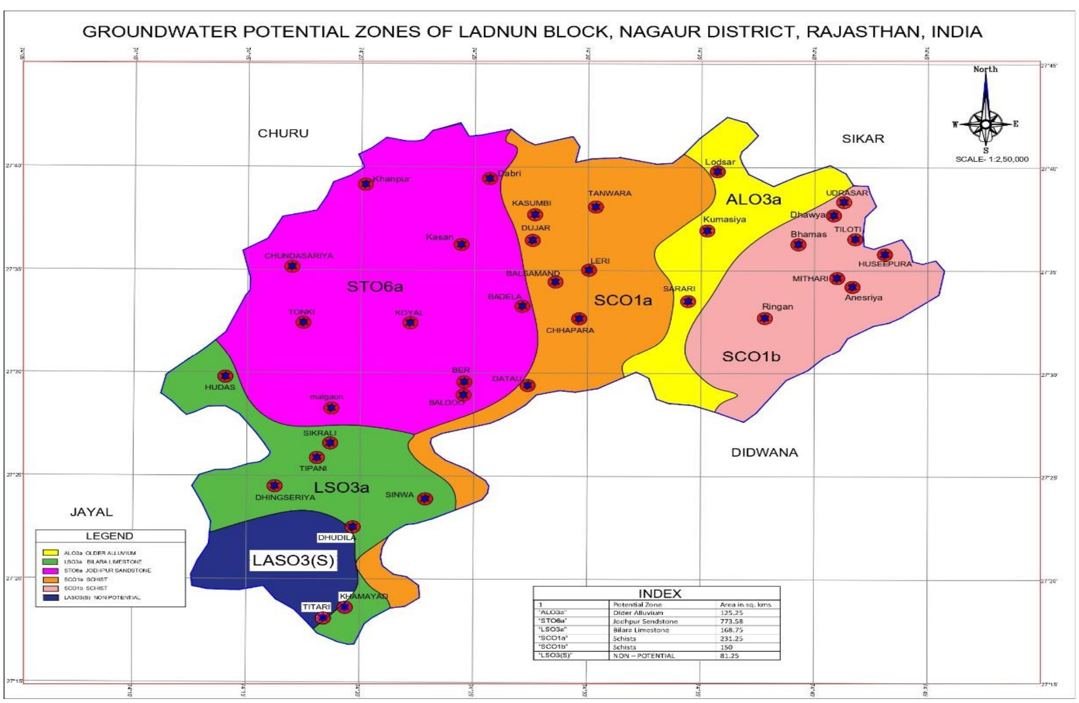

Figure: 3. Groundwater Potential Zones Map of Ladnun block, Nagaur District, Rajasthan. India.

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IV. HYDROCHEMISTRY

To assess the quality of groundwater in Ladnun Block, samples were collected from 34 different villages during the Pre-monsoon season of 2018 through the post-monsoon season of 2022. The chemical analysis indicates that the groundwater quality in the Ladnun block exhibits high levels of fluoride, nitrate, chlorides, and total dissolved solids, surpassing the limit set by the Bureau of Indian Standards (1992).

A. Nitrate (NO3)

The presence of nitrate in groundwater is a crucial determinant of water potability. A large amount of nitrate in groundwater indicates contamination from external sources, making it unsuitable for drinking purposes due to its poor quality. The excessive application of nitrogenous fertilizers, haphazard sewage disposal practices, and the decomposition of organic material in surface water bodies are major contributors to the presence of nitrates in groundwater. 20.58% of the Groundwater sources in the Ladnun block fall in the desirable limit of Nitrate (i.e. <45 mg/l), 26.47% of groundwater sources have high values of Nitrate (i.e. 46-100 mg/l) while the remaining 52.95% of the groundwater showing very high values of Nitrate (i.e. >100 mg/l). Chhapara and Anesriya villages in the Ladnun block reported high Nitrate values of up to 326 mg/l and 330 mg/l respectively. Nitrate concentration in groundwater within desirable limits lies only in seven villages. All other samples show nitrate in the groundwater samples exceeding 45 mg /liters. Over of samples (09 villages) in the block have nitrates exceeding the emergency limit i.e.100 mg /Liter. The rest of the 18 samples are unsuitable for drinking as well as domestic purposes Nitrate concentration ranges from 04 Mg/l (minimum) in the Balddoo villages and 330 Mg/l (maximum) in the Anesriya village. (Table : 3 and Table : 5)

Table: 3. Nitrates Distributions with BIS water standards index; villages wise in the Ladnun.

Nitrates (as NO3) Mg/l	Water Standards Index for uses	Percentage of Area (%)	Name of Village
0-45	Desirable limit	20.58	Malgaon, Khanpur , Chundasriya, Tonki, Koyal, Ber, Baldoo
45-100	Permissible Limit	26.47	Hudas, Sikrali, Tipani, Dhingseriya, Titari, Badela, Dujar, Tanwara, Mithari
100-<	Unsuitable	52.95	Dhudila, Khamiyad, Sinwa, Datau, Chhapara, Balsamand, Kasan, Dabri, Kasumbi, Lodsar, Udrasar, Dhawya, Ringan, Bhamas, Kumasiya, Tiloti, Huseepura, Anesriya

B. Chloride (Cl)

Chloride is present in small amounts in the earth's crust, but it is a significant component of most natural waters when dissolved. The most prevalent chloride found in natural waters is sodium chloride (NaCl), commonly known as table salt. Common chlorides present in water include calcium chloride, magnesium chloride, and iron chloride. Groundwater containing a chloride concentration exceeding 200 mg/l will have a noticeable salty taste. According to the Bureau of Indian Standards (1992), it is recommended that the chloride levels in drinking water should be around 250 mg/l in normal circumstances and can be increased to 1000 mg/l in emergencies for optimal human health. Increased consumption can lead to a substantial rise in the prevalence of hypertension, stroke risk, left ventricular hypertension, osteoporosis, renal stones, and asthma in humans (Ramesh and Soorya, 2012). Chloride is naturally present in all types of water. The chloride content of groundwater is attributed to minerals such as apatite, mica, and hornblende, as well as the liquid inclusions found in igneous rocks (Das and Malik, 1988). The elevated chloride concentration in the Ladnun Block indicates that the groundwater in the area is characterized by high levels of hardness and salinity, specifically of the chloride type. Only 2.95% of the Groundwater sources in the Ladnun Block fall in the desirable limit of Chloride (i.e. <250 mg/l), 38.23% of groundwater sources have high values of Chloride (i.e. 251-1000 mg/l), and the remaining 58.8.2% of the groundwater showing very high values of Chloride (i.e. >1000 mg/l). Mithari Khanpur and Kusumbi village in Ladnun block reported a high Chloride value of up to 2800 mg/l and 10900 mg/l. Chemical analysis of samples of 34 villages has shown that about 97.05% of villages in the block have Chlorides in the groundwater more than 250 mg/l. (Table: 4) Chloride concentration ranges from 70 ppm (Baldoo) to 10900 ppm (Kusumbi).

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The primary origin of chlorides in groundwater is the entrapment of ancient seawater within sedimentary layers. Halite and other complex evaporite minerals are found in deposits formed through the process of evaporation. Through the process of evaporation, the water content from precipitation becomes more concentrated, and the deposition of particulate matter from the atmosphere, especially in arid to semi-arid regions

Table: 4. Chloride Distributions with BIS water standards index villages wise in the Ladnun

Chloride (as Cl) Mg/l	Water Standards Index	Percentage of Area (%)	Name of Village
0-250	Desirable limit	2.95	Baldoo,
251-1000	Permissible Limit	38.23	Titari, Huseepura, Dhawya, Ringan, Bhamas, Kasan, Tonki, Koyal, Ber, Datau, Chhapara, Balsamand, Chundasriya
1000 <	Unsuitable	58.82	Hudas, Malgaon, Sikrali, Tipani, Dhingseriya, Dhudila, Khamiyad, Sinwa, Badela, Dujar, Khanpur, Dabri, Tanwara, Lodsar, Udrasar, Kumasiya, Tiloti, Mithari, Anesriya, Kasumbi

C. *Total dissolved solids (TDS)*

Total dissolved solids (TDS) are used as a measure of the water's salinity. Water containing more than 500 mg/l of total dissolved solids (TDS) is deemed unfit for consumption (WHO, 1971). A high Total Dissolved Solids (TDS) level that surpasses the permissible limit can be ascribed to different pollutants seeping into the groundwater. This can reduce the water's ability to move, cause irritation in the human gastrointestinal tract, and lead to laxative effects. High levels of Total Dissolved Solids (TDS) can make water unattractive for bathing and washing. Only 2.95% of the Groundwater sources in the Ladnun Block fall in the desirable limit of the TDS (i.e. <500 mg/l), 5.88% of groundwater sources having high values of TDS (i.e. 501-2000 mg/l), and remaining 91.17% of the groundwater showing very high values of TDS (i.e. >2000 mg/l) (Table: 5.). Over 91.17% of samples (31 out of 34 villages) in the block have T.D.S. in the groundwater exceeding the emergency limit i.e. 2000 mg /liter. Values of T.D.S. range between 366 ppm (Baldoo) to 24500 ppm (Kusumbi) (Figure: 4).

Table: 5. Total Dissolved Solids Distributions with BIS & WHO water standards index villages wise in Ladnun

Total Dissolved Soiids in Mg/l	Water Standards Index	Percentage of Area (%)	Name of Village
0-500	Desirable limit	2.95	Baldoo
501-2000	Permissible Limit	5.88	Koyal, Chundasriya
2000- <	Unsuitable	91.17	Ber, Datau, Tanwara, Bhamas, Balsamand, Badela, Sinwa, Sikrali, Tipani, Dhingseriya, Khamiyad, Dujar, Kasan, Khanpur , Dabri, Kasumbi, Udrasar, Dhawya, Ringan, Kumasiya, Tiloti, Huseepura, Mithari, Anesriya, Hudas, Malgaon, Dhudila, Tonki, Lodsar, Titari, Chhapara

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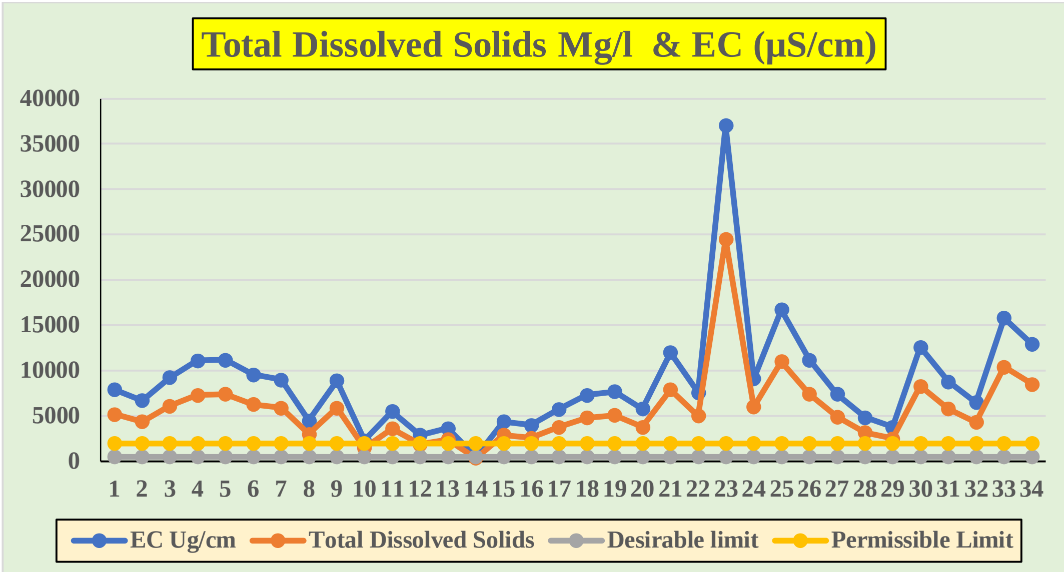

Figure: 4. Spatial Distributions of TDS and EC with BIS water standards index sample-wise

Nearly 2.95% of the Groundwater sources in the Ladnun Block fall in the fresh to slightly brackish (i.e. E.C.< 2000 µS/cm), 14.7% of groundwater sources are moderately saline (i.e. E.C. 2000-4000 µS/cm), 38.23% of groundwater sources are highly saline (i.e. E.C. 4000-8000 µS/cm) and the remaining 44.12% of the groundwater are very highly saline (i.e. E.C.>8000 µS/cm). Kusumbi village in Ladnun Block reported the highest E.C. value up to 3700 µS/cm (G.W.D. Report,2018).
Groundwater in Ladnun Block is alkaline. pH value of groundwater samples ranges from 7.4 (Balsamand) to 8.8 (Dhyawa and Udrasar).The results of analyzed groundwater samples are presented in Table - 6.

1) Fluoride Problem in the Region

The presence of fluoride in groundwater has garnered societal attention due to its influence on human physiology. A lack of fluoride (<0.6 mg/lit) leads to dental cavities, while an excessive amount (>1.5 mg/lit) results in skeletal fluorosis and other symptoms. (W.H.O.,1971, Bureau of Indian Standards. 1992). higher values of fluoride have a direct impact on an individual's metabolic functions, potentially leading to skeletal fluorosis, dental fluorosis, non-ulcer dyspepsia, and polyuria (increased frequency of urination). Polydipsia, muscle weakness, recurrent abortions/stillbirths resulting from impaired blood flow to the fetus due to arteriosclerosis and calcification of blood vessels, oligospermia, azoospermia, decreased testosterone levels, and tooth enamel discoloration. (Underwood, 1977; W.H.O., 1984; Singh and Seimbi, 1988; Machoy et.al.,1991; Susheela, 1999; Maanju et.al. 2003).
As a result of the arid to semi-arid climate and limited availability of surface water resources, the people living in Rajasthan rely heavily on groundwater for drinking and agricultural needs. The fluoride issue is affecting most of the districts in the state. India is home to approximately 20% of the villages worldwide that are affected by fluoride contamination. Rajasthan has more than 50% of the total number of fluoride-affected villages in the country, with 16,560 out of 33,211 villages (UNICEF, 2001). Approximately 64% of the villages in the Nagaur district suffer from endemic fluoride-related issues.
Hussain et al. (2007) conducted a study on the distribution of fluoride contamination in groundwater. The study was carried out in 750 villages in the Nagaur district of Rajasthan, where a total of 871 water samples were collected. The fluoride concentration in the district ranged from 0.1 to 19.0 mg/lit. A total of 510 villages, accounting for 68% of the sample, exhibited a fluoride concentration exceeding 1.5 mg/lit. A total of 142 villages, accounting for 18.93% of the sample, fell into category I. In this category, the fluoride concentration in the water was below the maximum desirable limit of 1.0 mg/lit, as per the drinking water standards. Among the 750 villages in Nagaur districts, 98 villages (13.06%) had a fluoride concentration ranging from 1.0 to 1.5 mg/lit, which classified them as category II. The maximum allowable concentration of fluoride in the drinking water standard is 1.5 mg/Liter. Approximately 44% of the population residing in 322 villages (equivalent to 42.93%) consumes water that contains a fluoride concentration ranging from 1.5 to 3.0 mg/lit.

This concentration exceeds the maximum permissible limit as advised by the Bureau of Indian Standards (BIS). The fluoride concentration in the groundwater exceeded 5.0 mg/lit in 22 villages, which accounts for 2.93% of the total. The fluoride concentration in the Nagaur district is non-uniform due to disparities in the occurrence and availability of fluoride-bearing minerals in water, as well as the process of weathering and leaching.

The groundwater in the Nagaur district exhibits a significant presence of fluoride across all aquifer types (Vyas, 2015). Fluoride in groundwater originates from minerals such as Fluorite, Apatite, Topaz, Fluorspars, Metamorphic, and Sedimentary rocks. The presence of elevated levels of fluoride in certain areas of the study region (specifically in the Banka Patti belt) leads to the occurrence of Dental and Skeletal Fluorosis, as well as other ailments such as tooth discoloration, spinal abnormalities, bone deformities, and impaired growth in both humans and livestock

2) Fluoride contamination Problem in Ladnun Block

The principal sources of fluoride are the minerals fluorite and apatite. Most fluorides are low in solubility, and the amounts present in ordinary waters are therefore limited. Typically, the concentration of fluoride in natural water ranges between 0.01 to 10 mg/L. In the study area, fluoride is a crucial determinant of drinking water quality. The concentrations of fluoride vary between 0.5 and 7.1 mg/L, with an average concentration of approximately 2.7 mg/L (Arif et al., 2013). Elevated fluoride levels beyond the recommended limit can lead to harmful consequences such as dental and skeletal fluorosis. Based on fluoride concentration in the groundwater, the study area is classified into five categories as follows:

Category I: Fluoride concentration is less than 1.0 mg/L – 5.0% of the total samples

Category II: Fluoride concentration ranging from 1.0 to 1.5 mg/L – 15.0% of the total samples

Category III: Fluoride concentration ranging from 1.5 to 3.0 mg/L – 45.0% of the total samples

Category IV: Fluoride concentration ranging from 3.0 to 5.0 mg/L – 22.5% of the total samples

Category V: Fluoride concentration exceeding 5.0 mg/L – 12.5% of the total samples

The distribution of fluoride in groundwater in the study area is given in Table: 6.

Table: 6. Fluoride Distributions with BIS & WHO water standards index villages wise in the Ladnun block (based on Arif et al., 2013).

Fluoride (as F) in Mg/l	Water Standards Index	Percentage of Area (%)	Name of Village
0-1	Desirable limit	12.5	Manu, Hudas, Dujar, Nimbijodhan, Bankaliya
1-1.5	Permissible Limit	15.0	Odeet, Simla, Sandas, Sikarali, Bhidasari, Dhurila
1.5-3	Extreme Conditions	45.0	Hirawati, Vishwanathpura, Jaswantgarh, KasumbiUpadara, Lodsar, Chhapara, Malgaon, Dhingasari, Silanwati, Titi, Khamiyad, Seewa, Ratau, Baldoo, Sanwrad
3-5	Unsuitable	22.5	Sunari, Reengan, Rodo, Sardi, Tanwara, Roja, Khokhari, KasumbiAlipur, Koyal
5 <	Unsuitable	12.5	Bhamas, Udrasar, Dholiya, Kasan, Dhawya

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12.5% of the groundwater sources in the Ladnun block fall within the desirable limit of fluoride (i.e., <1.0 mg/L), while 15.0% of the sources fall within the permissible limit (i.e., 1.0–1.5 mg/L). The remaining 72.5% of groundwater sources have high fluoride concentrations (i.e., >1.5 mg/L), making the water unsuitable for long-term human consumption without treatment. The Roja village in the Ladnun block reported the highest fluoride concentration of 7.1 mg/L, whereas the lowest concentration of 0.5 mg/L was observed in Hudas village (Arif et al., 2013).

The presence of elevated fluoride levels in groundwater is likely linked to regional sedimentation processes. The Quaternary sediments in the Ladnun block are enriched with micaceous minerals, which can release fluoride into groundwater through weathering and leaching. Notably, the eastern regions of the Ladnun block tend to exhibit significantly higher fluoride concentrations, indicating spatial variability in geochemical influences.The map displaying the Fluoride area in the Ladnun block is shown in Figure: 5.

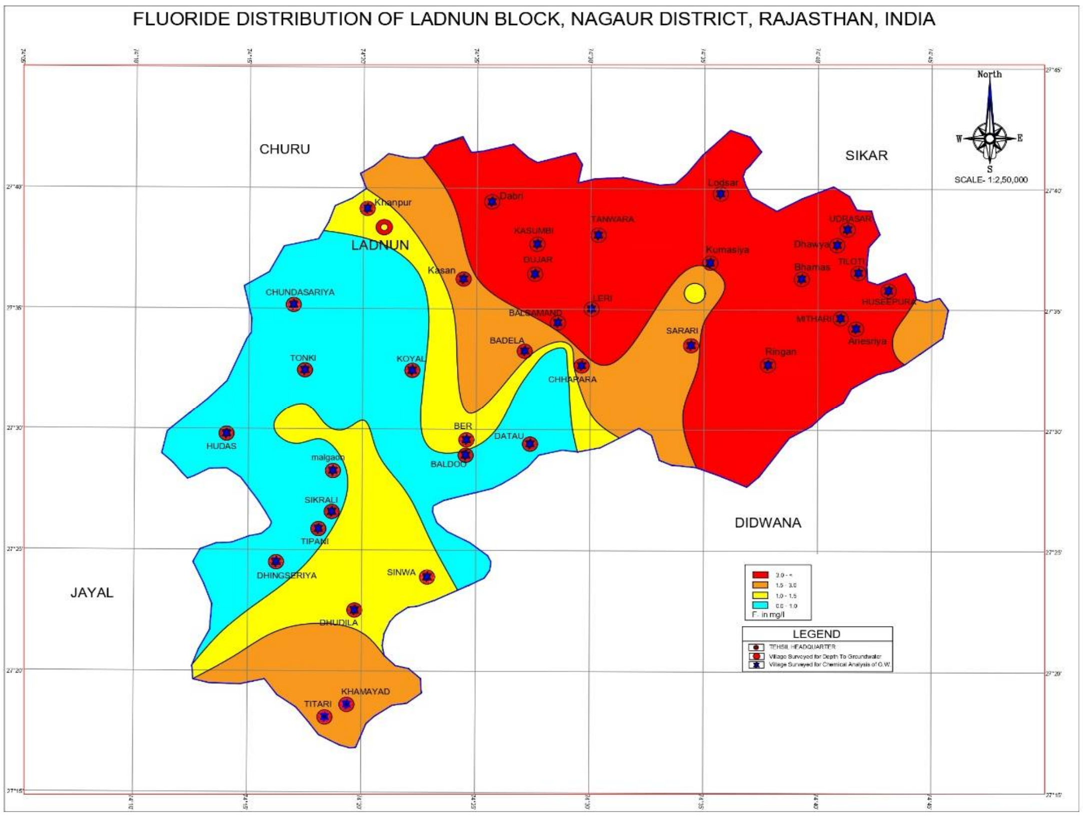

Figure: 5. Fluoride distribution Map of Ladnun block, Nagaur District, Rajasthan. India (modified after Arif et al., 2013).

V. RESULT AND DISCUSSION

The "water" is on the verge of being classified as a scarce commodity. India's per capita annual water supply is 2461 cubic meters. Groundwater, bestowed upon all living beings by nature, is the most precious and frequently utilized resource on our planet. Individuals in all communities must acknowledge groundwater as a precious asset that necessitates careful handling, collection, storage, and administration to ensure its availability during periods of scarcity. The accessibility of subterranean groundwater resources is vital for the sustenance of life. The residents of Rajasthan State heavily rely on groundwater for drinking, agriculture, and industrial needs due to the arid climate and limited availability of surface water resources.

The groundwater in the study area of Ladnun block is experiencing issues with its quality. The study area exhibits significant variability in groundwater quality, with high salinity observed in the northern and central regions of the Ladnun blocks. The water table depth exhibits significant variation within the area. Groundwater quality issues are primarily caused by elevated levels of Total Dissolved Solids (T.D.S.), Nitrate, Chloride, Salinity, and Fluoride (Vyas, 1999). The elevated concentration of fluoride in the groundwater within the study area has resulted in significant and detrimental consequences, leading to the occurrence of fluorosis issues in the region. A significant accumulation of fluoride is found in the northwest flow path of groundwater, where the hydraulic gradient is relatively low, as well as in the vicinity of fluoride-rich rocks. (Chauhan, D. and Vyas, A. 2022) The presence of granites, gneisses, and ophiolitic suite deposits in the Ladnun block area is responsible for the elevated levels of fluoride in the groundwater. The presence of elevated levels of fluoride in the groundwater in this region poses a significant risk to the quality of drinking water, as highlighted by Vyas (2010). The recommended measures for the area involve conducting a comprehensive survey to determine the elevation levels by installing multiple piezometers at various locations within the study area. This should be followed by regular and periodic monitoring of the piezometers. Additionally, it is important to study the variations in fluoride levels about the fluctuations in the water table. Comprehensive investigations will be conducted to determine the precise origin of fluoride in the region. The rural uneducated section of society should receive basic education regarding the detrimental health consequences of elevated fluoride levels (Vyas, 2010). The impact of fluoride on human physiology has garnered significant societal attention, particularly when it is found in groundwater. The hardships faced by the local population are exacerbated by the arid to semi-arid climate, inadequate and irregular precipitation, absence of accessible water sources, recurrent famines, and declining water levels in the underground aquifers.

Hence, it is recommended that the research area implement appropriate strategies for the preservation and prudent administration of groundwater resources. The findings of the epidemiological survey conducted in Nagaur district indicate that a large number of individuals are suffering from Dental Fluorosis and Skeletal Fluorosis. There has been a significant rise in the sales of small packets of Pan Masala, Gutkha, mouthwash, and mouth rinses in recent years, especially in northern India and specifically in Rajasthan. It is worth noting that these products also contain high levels of fluoride (Chauhan, D. and Vyas, A. 2022; Ozha, et al., 2003).

VI. CONCLUSION

The excessive utilization of groundwater in the Ladnun block, combined with insufficient replenishment of groundwater, has led to the decline of the water table, depletion of aquifers, and degradation of groundwater quality. Hence, it is advisable to implement appropriate strategies for preservation and prudent schemes for managing groundwater. Large-scale implementation of artificial recharge methods is necessary to enhance groundwater resources. This can be achieved through practices such as rooftop rainwater harvesting and other viable water harvesting systems commonly used in the region (Figures: 6 and 7), (Quereshi and Vyas, 2017) such as Talab, Nadi, Tanka, Pond, Bawari, Percolation tanks, and other suitable recharge structures. Developing a lift canal from the main Indira Gandhi Canal in the high-fluoride concentrated groundwater area will soon provide an alternative to using surface water for drinking and irrigation purposes. (Chauhan and Vyas, 2021).

Figure: 6. Viable water harvesting structure in Ladnun block, Nagaur District of Rajasthan

Figure: 7. Viable water harvesting structure alongside an Open Well in Ladnun block, Nagaur District of Rajasthan

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