iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 **Issue:** XII **Month of publication:** December 2023

DOI: https://doi.org/10.22214/ijraset.2023.57740

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue XII Dec 2023- Available at www.ijraset.com

Hydrogeological Studies of Ladnun Block in Nagaur District of Rajasthan, India

Vijay Pal Meena[1], Arun Vyas[2]
[1]*Department of Geology, University of Rajasthan, Jaipur (Rajasthan), INDIA*
[2]*Government Girls College, Soorsagar, Jodhpur (Rajasthan), INDIA*

Abstract: ***The study area of Ladnun block is situated in the northern part of the Nagaur district of Rajasthan State, India covering about 1448.83 sq. kms (excluding 81.25 sq. kms Non potential area) having coordinates 27°39' to 27°65' North latitude and 74°23' to 74°38' East longitude. Older alluvium, Jodhpur Sandstone, Bilara Limestone and Schist are principal sources of groundwater in the study area. Six Potential Zones have been demarcated in different aquifers. Yield of wells and tube wells varies from 90 to 350 M^3/day. Quality of groundwater is potable having EC value less than 4000 micro siemens/cm at 25° C. Depth of groundwater varies from 4.1 to 108 meters in the block. Groundwater quality varies widely in the Ladnun block. High concentration of fluoride and TDS are major quality problems associated with groundwater in the region (Vyas, 1999). Fluoride concentration of groundwater samples from 34 villages of Ladnun block was monitored and thirty villages were found to have a fluoride concentration above 1.5 mg/l. The maximum fluoride concentration (16.1 mg/l) was recorded in groundwater of the Kasumbi village, while minimum (0.90 mg/l) was recorded in Hudas village. The study area is recommended for groundwater management and conservation.***

Keywords: Groundwater, Aquifers, Ladnun, Nagaur and 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. Despite supporting over 5.5% of the human population and 18.70% of the livestock, it only has access to 1.16% of the country's surface water. The state is experiencing a critical shortage of water. The region experiences unpredictable precipitation patterns and is categorized as an arid or semi-arid area. Geographically, approximately two-thirds of the vast Thar Desert in the state comprises a significant portion of the land area. The forest area in the State accounts for 4.19% of the total forest area in the country. The state of the groundwater is highly concerning. It has rapidly deteriorated in the past few decades.

Nagaur is the fifth largest district in Rajasthan (prior to new declaration of new districts in the State), covering a vast area of 17718 sq. km, which accounts for 5.18 percent of the total area of Rajasthan. The study area of Ladnun block (Figure - 1) is located in the northern part of the Nagaur district of Rajasthan. It covers an area of about 1448.83 square kilometers, with coordinates ranging from 27°39' to 27°65 North latitude and 74°23' to 74°38' East longitude.

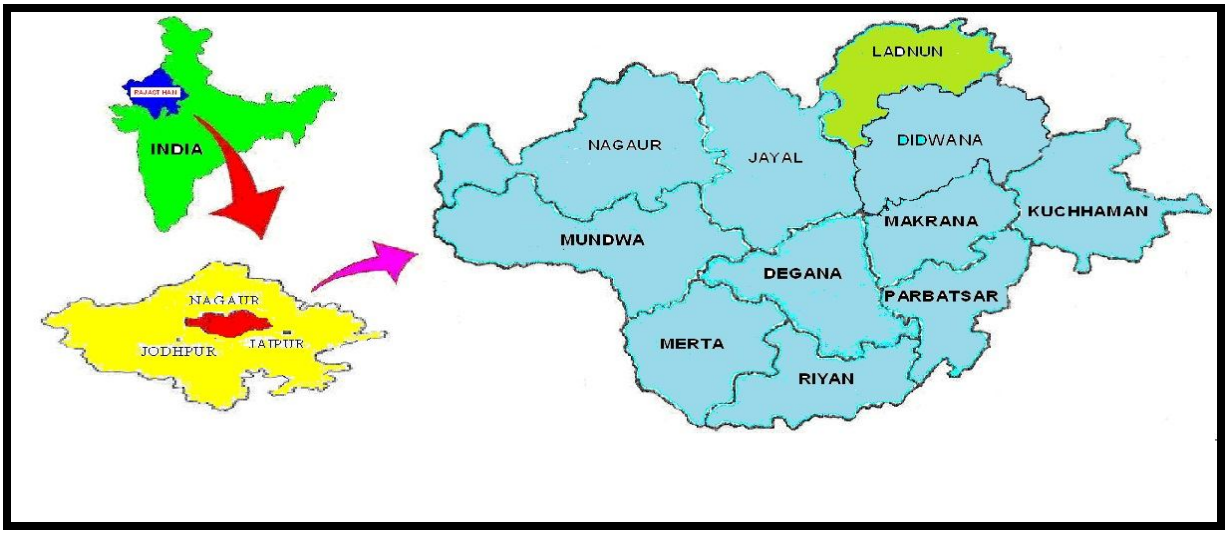


Figure - 1. Location map of the study area

II. PHYSIOGRAPHY, CLIMATE AND REGIONAL GEOLOGY

Geographically, the district is defined by hills that are moderately high and degraded, ranging from 300 to 500 meters above sea level. The landscape is characterized by a distinctive blend of flat plains, rolling hills, and sand mounds. The region lacks perennial rivers and a well-established drainage system, instead relying on an internal drainage system. The Luni River is the only river that flows in the southernmost part of the district. Mean annual rainfall in Nagaur district is 415 mm. In the month of May, Nagaur experiences the highest number of daily hours of sunshine, with an average of 12.08 hours per day and a total of 374.4 hours throughout the month. Additionally, the average wind speed during May-June is 37 km per hour. The district experiences a significant annual maximum potential evapotranspiration, reaching its peak at 255.1mm in May and dropping to its lowest point at 76.5mm in December (source: IMD).

Geologically, Rajasthan State constitutes the northwestern part of the Peninsular India comprising one of the oldest mountain chains of the earth, 'The Aravalli Mountain Range'. The Proterozoic paratectonic 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.

The Quaternary and Recent geology is characterized by the frequent climatic fluctuations, disorganization of the drainage systems (Lost Saraswati River) and development of the Thar Desert (Tank and Vyas, 2019).

Geologically, Nagaur district showing a unique Stratigraphic sequence; comprises a wide spectrum of rock formations ranging from the Precambrian to Recent Alluvium and wind blown desert sands of the great Thar dessert (Paliwal, 1999; Vyas and Paliwal, 2001; Gaur and Vyas, 2007).

The area also displaying effusives and intrusives of Malani Igneous Suite. Rocks of the Archaean basement, deformed metasediments of the Aravalli and Delhi Supergroups, Granitic-gneisses of Erinpura age (Metamorphics) along with the sedimentary rocks of the Marwar Supergroup, Tertiary and Quaternary lying in Nagaur district. Tertiary lignite (Paleocene to Eocene) occurred at Merta, Indawar, Matasukh and Igyar-Kasnau. The Aeolian sand, kankars, clays etc. of Quaternary age are the youngest formations of the district (Vyas etal., 2015; Chauhan and Vyas, 2021) (Table - 1).

III. GEOLOGICAL SETTINGS OF THE STUDY AREA

The boundary between the gneissic terrain and the Delhi Supergroup is indicated by the Phulad Ophiolite Zone (Reddy and Ramakrishna, 1988). Mukhopadhyay (1976) classified the meta-sedimentary rocks in the region as part of the Ajabgarh Group of the Delhi Supergroup.

Additionally, the volcanic rocks in the area were categorized as part of the Malani Igneous Suite. Rao et al. (1982) determined the geological characteristics of the region and the sequence of rock layers (Table - 2). The earliest rock unit in the stratigraphic sequence is the basement rock of the Delhi Supergroup, which consists of schist, quartzite, granite-gneiss, and altered ultramafic rocks intruded by quartz/aplite and micro granite. 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).

The majority of the study area is predominantly composed of blown sand, which forms the Thar Desert. The area encompassing Gunpaliya, Chappara and Baklia indicate the existence of serpentinite, pyroxenite, plagiogranite, gabbro-diorite, sheeted dykes, pillow basalt, chlorite schist, and mica schist (Table - 3). The lithological associations closely resemble those found in the Ophiolite Suite.

This suite consists of various rock types arranged in a specific order, starting from the bottom with mantle peridotites, followed by layered ultramafic rocks and gabbros, isotropic gabbros, a sheeted dike complex, and finally an extrusive sequence comprising pillowed and massive lavas. This sequence is then overlain by radiolarian chert and/or pelagic sediment. These associations were documented by Anon (1972) and further studied by Dilek and Robinson (2003). The Sonia Formation, which belongs to the Jodhpur Group of the Marwar Supergroup, can be observed in the mine sections located in the Manpura, Benetha, Swami ki Dhani, Baklia, Bader, and Ladnun areas.

The Sandstone of Sonia Formation, which belongs to the Jodhpur Group of the Marwar Supergroup observed in the mine sections located at Manpura, Benetha, and Swami ki Dhani areas, as well as in the Baklia, Bader, Dojar and Ladnun areas of the study area. Different rocks of Punagarh group of Delhi Supergroup, intrusive Erinpura Granite and Gneiss along with sedimentary rocks of Jodhpur, Bilara and Nagaur groups (Marwar Supergroup) occupying in the study area.

Table- 1. Geological Succession Of Nagaur District (after Vyas et al., 2015)

Pleistocene and Recent Sediments		Older and younger alluvium and desert sand.
Tertiary rocks		Merta,Indawar, Mokala, Matasukh and Igyar- Kasnau Lignite
	Boulder spread	
	Nagaur Group	Sandstones, shales and evaporites.
Marwar Supergroup	Bilara/Hanseran Group	Limestones and dolomites.
	Jodhpur Group	Conglomerate, sandstones and shales.
Malani Igneous Suite		Rhyolites, tuffs, pyroclastics, and granites.
Erinpura Granite		Granitic gneisses.
	Ajabgarh Group	Phyllites, biotite schists.
Delhi Supergroup	Alwar Group	Conglomerate, arkose, quartzites and amphibolite
	Raialo Group	Quartzites, limestones, marbles and conglomerates
Aravalli Supergroup		Phyllite, schists, greywackes, carbonaceous- phyllites and mylonites.
Archaean Basement		Granitic gneisses, schists and amphibolites.

Table – 2. Regional stratigraphy of the area (after rao et al., 1982)

Age	Supergroup	Group	Formation	Lithology
Recent				Blown sand
Quarternary				Fine grained calcareous sand.
Lower Paleocene		Post Nagaur	Palana	Purple, brown and yellow sandstone with clay and carbonaceous matter.
---------- Contact not exposed ----------				
Cambrian		Nagaur	Nagaur	Red, yellow, brown sandstone.
Cambrian	Marwar Supergroup			Purple, brown sandstone with claystone, brecciated limestone and conglomerate.
----------Unconformity----------				
	Marwar Supergroup	Bilara	Pondlo	Dolomitic limestone, chert, limestone.
----------Contact not exposed ----------				
	Marwar Supergroup	Jodhpur	Sonia	Purple, dark brown and red colored medium to fine grained sandstone.
----------Non conformity/ faulted contact----------				
		Malani Igneous Suite	Jalore/ Siwana Granite Malani Rhyolite	Grey to brownish grey, medium to coarse grained biotite granite. Aphanitic to fine pophyritic rhyolite.
----------Unconformity----------				
Proterozoic	Delhi Supergroup	Ajabgarh	Bambolai	Quartz actinolite schist, chlorite schist, amphibole schist, quartzite, amphibolite, slates and phyllites.

Table - 3. Local Stratigraphical Succession Of The Study Area

Suite/Supergroup	Group	Formation	Lithology
Marwar Supergroup	Jodhpur Group	Sonia Formation	Purple Sandstone
----------Unconformity (?)----------			
Ophiolite Suite			Chlorite schist with Chert band
			Pillow basalt
			Sheeted Dyke
			Gabbro-diorite
			Pyroxenite
			Serpentinite
---------- Sand cover (?) ----------			

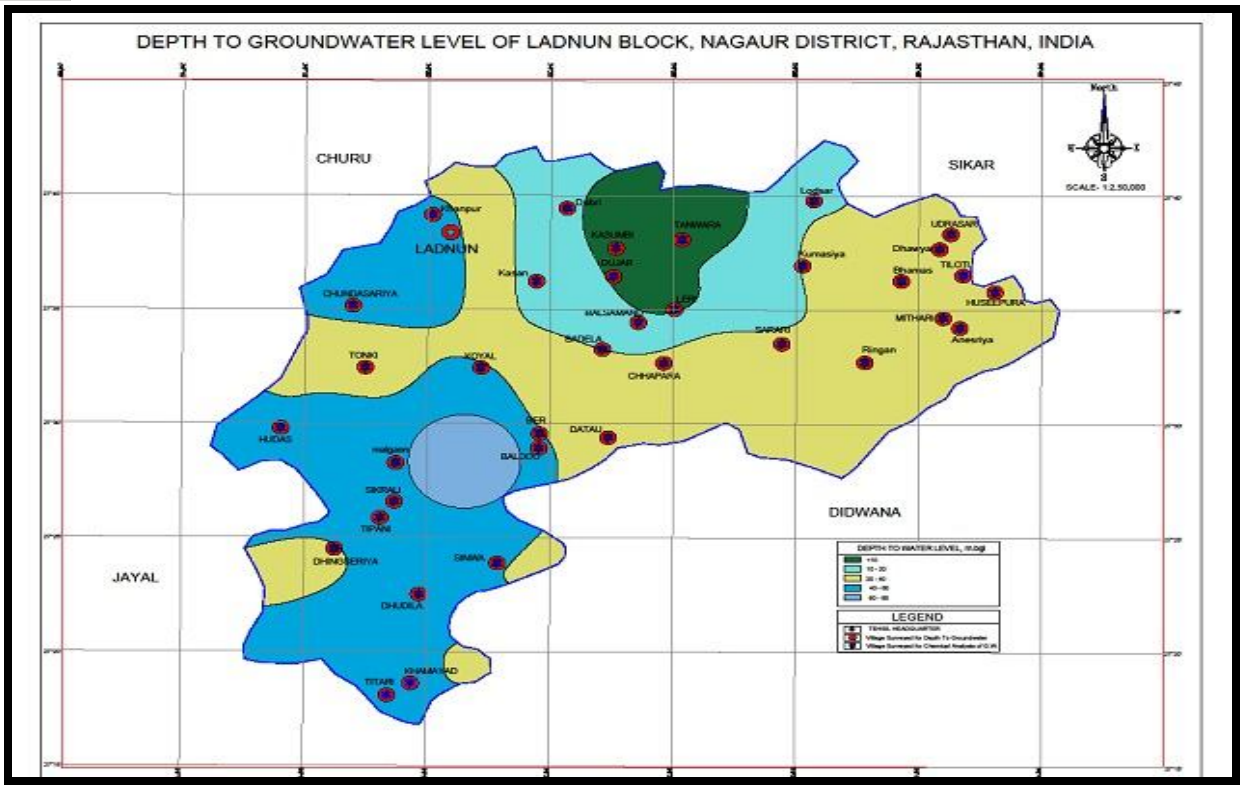
IV. HYDROGEOLOGY

Within the state, three existing main hydrogeological units include: consolidated rocks, semi-consolidated sediments, and unconsolidated sediments. According to Paliwal and Paliwal (2010) and Vyas and Vyas (2023), the predominant water-bearing rock formations in the state can be classified into two main types: soft rocks and hard rocks. Soft rocks account for approximately 60% of the total area, while hard rocks make up about 40%. The Nagaur district boasts a diverse array of rock formations, spanning from the Holocene to the Archaean basement rocks. The district has six major aquifers, namely Tertiary Sandstone, Jodhpur Sandstone, Nagaur Sandstone, Bilara Limestone, Granite Gneisses, and Schist. The aquifers exhibit groundwater depths ranging from 3 to 80 meters. Additionally, the district's groundwater movement is predominantly directed from the southeast to the northwest (Chauhan and Vyas, 2022). The groundwater depth in the majority of the district varied between 20 and 40 meters. Recorded depths exceeding 40 meters have been observed in the northwestern, northeastern, western, southwestern, and central regions of the district (C.G.W.B., 2017; Chauhan and Vyas, 2021). The average depth to groundwater level in the state during the pre-monsoon period of 2021 is recorded as 23.73 meters below ground level (G.W.D., Rajasthan, 2022). The Ladnun block comprises both consolidated and unconsolidated formations. The consolidated formations encompass Precambrian metamorphic rocks, including schists, gneisses, quartzites, and phyllites, as well as sedimentary rocks from the Marwar Super Group, such as limestone and sandstone. The Quaternary Alluvium aquifer is composed of loosely consolidated fine- to coarse-grained sand, which contains intercalations and is mixed with silt and clay. Tank and Vyas (2019) state that groundwater is present in environments ranging from unconfined to semi-confined conditions. The groundwater depth in the Ladnun block ranged from 4.1 (Khanpur) to108 (Dujar) meters recorded during the Pre to Post-monsoon periods in years 2018 and 2022. Fluctuations recorded in Groundwater level in Ladnun block of Nagaur district for Pre to Post Monsoon season in different years 2018 and 2022 is shown in Table - 4. Four villages showing abnormal trends of groundwater level fluctuation for both recording years for pre to post monsoon periods (Figure - 2 and 3).

Table - 4. Fluctuations In Groundwater Level In Ladnun Block Of Nagaur District For Pre To Post Monsoon Season In Different Years

S_No	Village	Potential Zone	Pre Monsoon (Mts)	Post Monsoon (Mts)	Fluctuation (Mts)	Pre Monsoon (Mts)	Post Monsoon (Mts)	Fluctuation (Mts)
			2018			2022		
1	Hudas	LS1	79	78.2	0.8	74	73.5	0.5
2	Malgaon	SS1	78.00	80.00	-2	84.00	87.50	-3.5
3	Sikrali	LS1	58	56.9	1.1	53	52.8	0.2

4	Tipani	LS1	86	84.6	1.4	90	87.5	2.5
5	Dhingseriya	LS1	50	51.1	-1.1	54	56	-2
6	Dhudila	SC2	49	48	1	43	41.5	1.5
7	Khamiyad	LS1	76.2	75	1.2	77	75	2
8	Titari	SC2	54.5	56	-1.5	59	61	-2
9	Sinwa	LS1	56.5	57	-0.5	60	63.65	-3.65
10	Chundasriya	SS1	88	86	2	85	83	2
11	Tonki	SS1	99	98.6	0.4	99	98	1
12	Koyal	SS1	75	73	2	78	79	-1
13	Bed	SS1	65	63.5	1.5	67	65.1	1.9
14	Baldoo	SS1	60.00	59.00	1	58.00	59	-1
15	Datau	SS1	45.5	43.15	2.35	46.3	44	2.3
16	Chhapara	SC1	25	22	3	28	25.9	2.1
17	Balsamand	SC1	20	19	1	20.65	19	1.65
18	Badela	SS1	67.5	66.1	1.4	65	64.55	0.45
19	Dujar	SS1	104.90	105.2	-0.3	106.00	108	-2
20	Kasan	SS1	30	29.6	0.4	32	31	1
21	Khanpur	SC1	5	4.1	0.9	7	5.2	1.8
22	Dabri	SC1	14.5	13.9	0.6	16	14.25	1.75
23	Kasumbi	SC1	8	7.5	0.5	6	5.6	0.4
24	Tanwara	SC1	23.7	22.4	1.3	22	22.4	-0.4
25	Lodsar	AO1	20	19.1	0.9	22	20.1	1.9
26	Udrasar	SC2	29	28	1	30	28.5	1.5
27	Dhawya	SC2	70	68	2	73	69	4
28	Ringan	SC2	40	42	-2	41	43	-2
29	Bhamas	AO1	17.5	16	1.5	19	18.3	0.7
30	Kumasiya	AO1	18.5	19	-0.5	18.9	18.2	0.7
31	Tiloti	SC2	45.7	45	0.7	47	46	1
32	Huseepura	SC2	24.38	24	0.38	25.35	25	0.35
33	Mithari	SC2	33.5	32.6	0.9	35	34	1
34	Anesriya	AO1	25	27	-2	27	27	0



.Figure - 2. Fluctuations In Groundwater Level In Ladnun Block Of Nagaur District

V. GROUNDWATER QUALITY OF LADNUN BLOCK

The pH of the groundwater in the study area falls within the range of 7.4 (Balsamand and Dhingseriya) to 8.8 (Udrasar), indicating an alkaline nature based on its chemical composition. The Total Dissolved Solids (TDS) which represents the overall amount of dissolved substances in the groundwater fall within the range of brackish water. The concentration of TH (Total Hardness) in the groundwater of the study area falls within the range of moderately hard (75 to 150 mg/L) to very hard (> 300 mg/L) categories. The concentrations of TDS, TH, Ca, Mg, NO_3, and Cl^- indicate a salinity hazard. The groundwater in the area exhibits a substantial presence of chlorides, resulting in hard water.

Figure - 3. Monitoring Of Groundwater Level In Open Well In The Study Area.

VI. FLUORIDE PROBLEM IN THE REGION

Groundwater in all aquifers in Nagaur district exhibits a significant presence of fluoride, as reported by Vyas (2015). The presence of elevated levels of fluoride in groundwater has emerged as a significant health-related geoenvironmental concern in the area. The fluoride concentration in the Ladnun block varies from 0.91 to 16.1 mg/l. The village of Kasumbi had the highest recorded concentration of 16.1 mg/l, while the village of Hudas village had the lowest concentration. Only four samples were found to be within the maximum desirable limit set by BIS IS 10500: 2012 (ranging from a minimum of 0.6 mg/l to a maximum of 1.5 mg/l in the absence of an alternate source). However, 30 samples were recorded to be outside the acceptable limit. The range of fluoride concentration in the study area is displayed in the Figure - 4 and 5. The presence of fluoride in natural water is a result of the dissolution of fluorite and apatite, which commonly occurs due to the solution of fluoride-bearing micas and amphiboles. Kaolinite serves as a primary receptor for fluoride, with the highest absorption occurring at pH 6. However, absorption is minimal when the pH falls below 4 or rises above 7. Desorption of fluoride from kaolinite causes slightly alkaline waters to contain more than 1mg/L of fluoride (Hounslow and Back, 1985). Long time intake of high concentration fluoride groundwater causes Fluorosis problems in habitants of the study area.

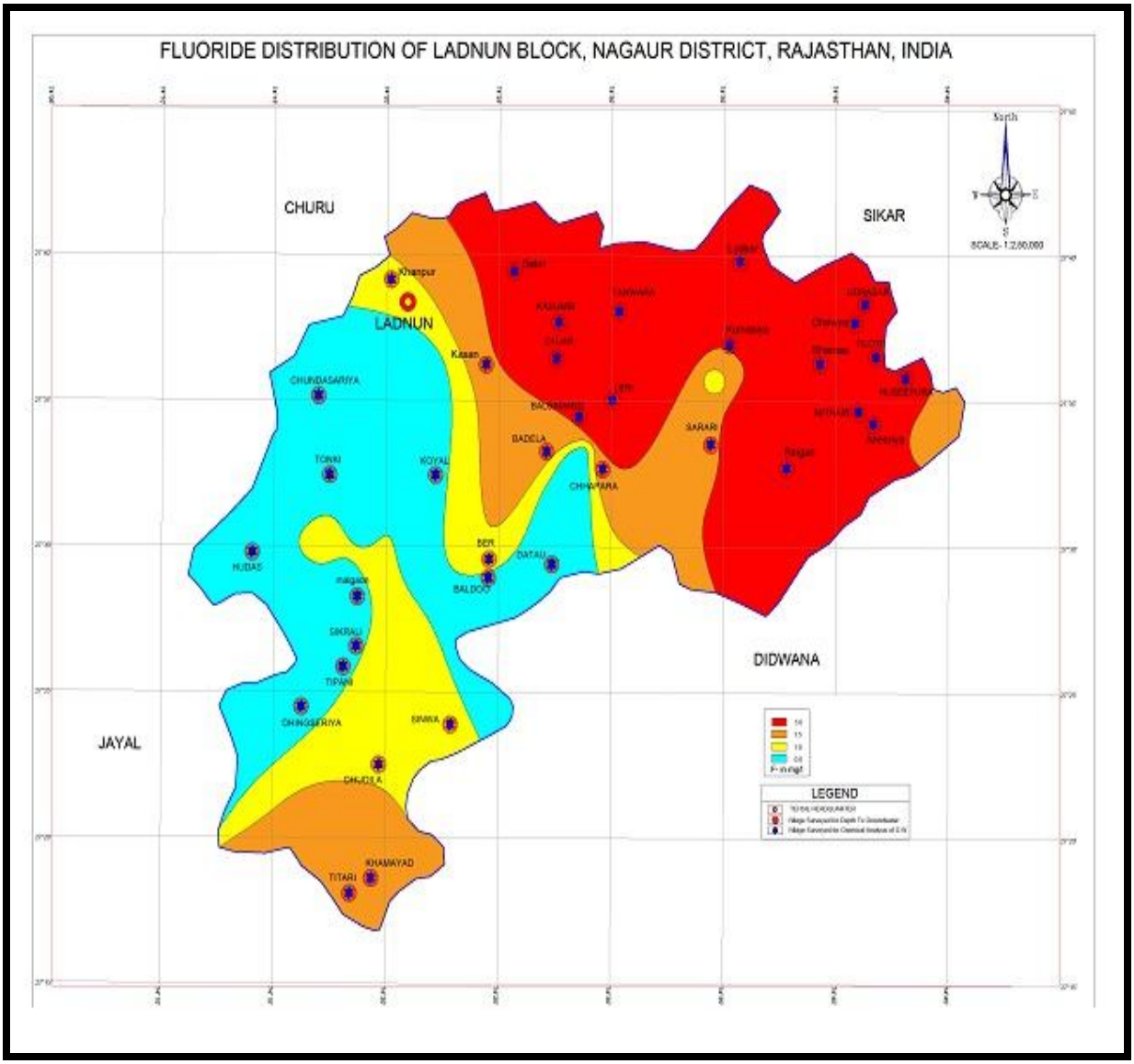


Figure – 4. Map Showing Fluoride Concentration In Groundwater Of Ladnun Block

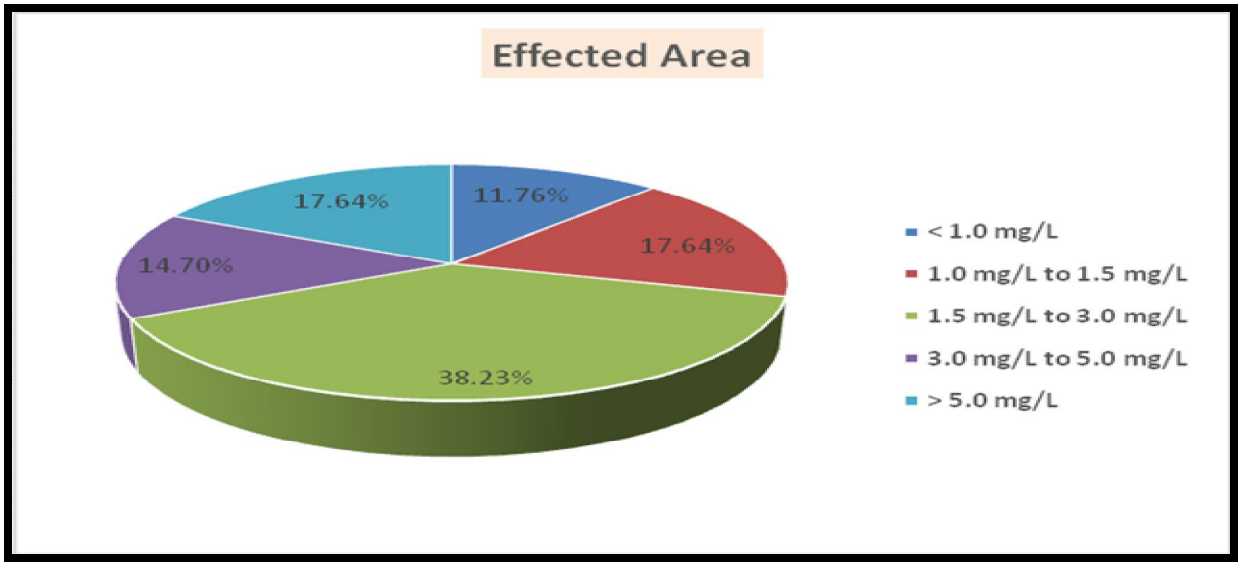


Figure – 5. Classification of The Study Area On The Basis Of Fluoride Concentration

VII. CONCLUSION

The primary sources of groundwater in Ladnun block are older alluvium, Jodhpur Sandstone, Bilara Limestone, and Schists. The quality of groundwater in Ladnun block exhibits significant variation. The water depth exhibits significant variation within the block. The presence of elevated levels of Total Dissolved Solids (T.D.S.) and fluoride is a significant issue affecting the quality of groundwater. The consequences of elevated fluoride concentration in groundwater are extremely severe. The water depth in the district exhibits significant variation. The presence of high levels of Total Dissolved Solids (T.D.S.) and fluoride is a significant issue affecting the quality of groundwater. The elevated concentration of fluoride in the district has been resulting in the occurrence of fluorosis.

The geochemical study of the Ladnun block shows that the groundwater is alkaline, chloride type, brackish and saline in nature. Most of habitations are affected by High salinity, TDS more than 2000 mg/L, Total hardness exceed more than 500mg/L, fluoride high concentrations value (> 1.5mg/L). These hydro chemical parameters of the study area show that groundwater has partially suitable for drinking purpose and public health. Potable groundwater pockets have been recognized in the study area. The fluoride is a major problem and high concentration of Fluoride in Ladnun block mainly comes from Micas Schists, Chlorite schist, Amphiboles, Pyroxenite Gneiss and Dolomitic Limestone of Proterozoic age; and having adverse effects on human health and livestock as well. Roof top rainwater harvesting in the study area offers a good source of drinking water (Quereshi and Vyas, 2017). The study area needs more artificial recharge of groundwater through rainwater harvesting for sustainability of groundwater quality in the wake of excessive withdrawal. Canal will be the next alternative for long term solution of potable drinking water and irrigation in the study area. Application of remote sensing and geographic information system (GIS) can be used for optimum groundwater management scheme.

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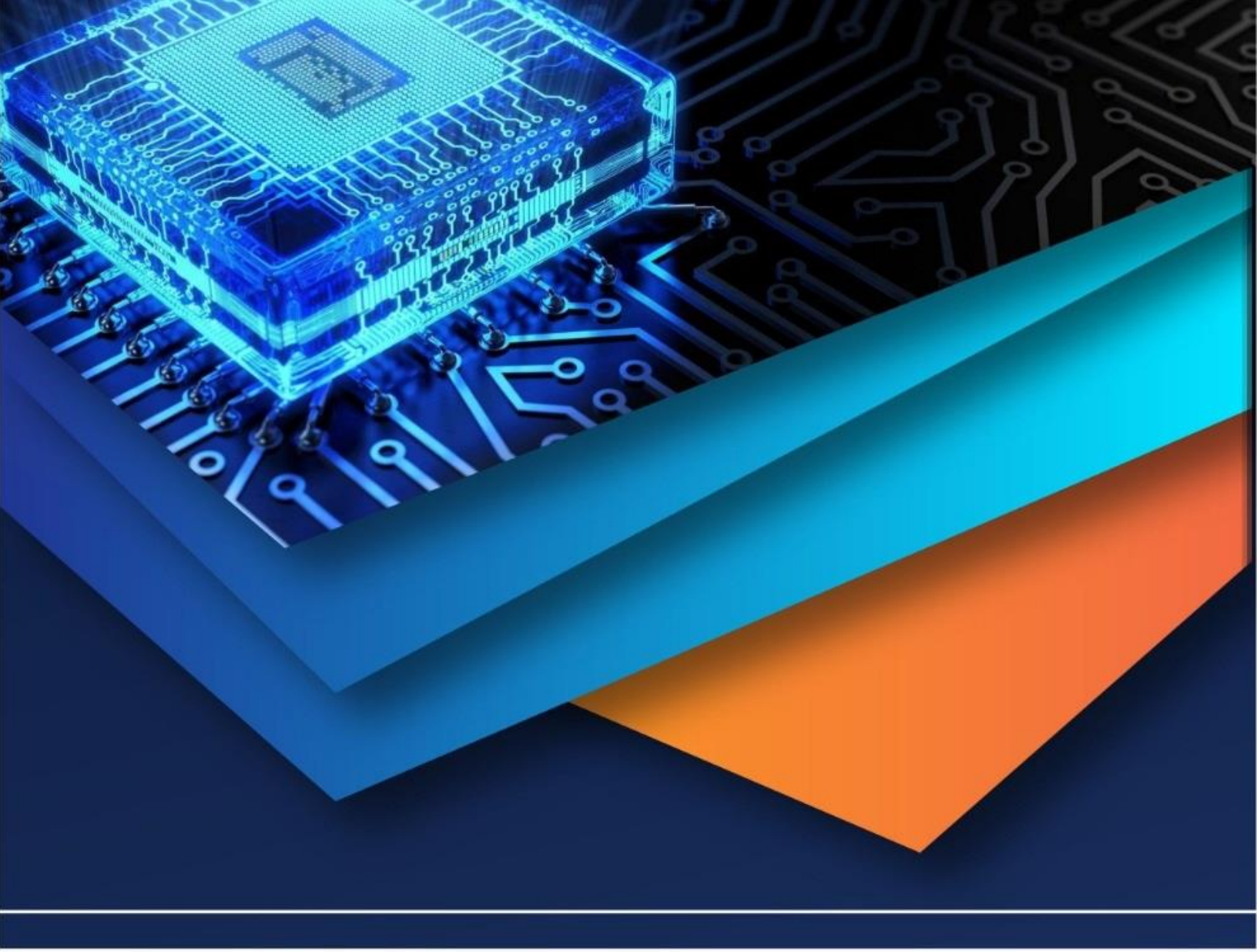

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