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An Appraisal of Hydrogeological Conditions and Fluoride Problem in Makrana Block of Nagaur District in Rajasthan, India

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Abstrct: ***Groundwater is one of the important sources of potable water supply in rural India. The study area of Makrana block is located in the south-eastern part of Nagaur district of Rajasthan covering about 1140 sq. km. area. The marble from the Makrana town gets the GHSR (Global Heritage Stone Resources) status recently from the IUGS. The study area experiences arid to semi-arid type of climate. Older alluvium, Quaternary Alluvium and Schist are important aquifers occur in Makrana block. Groundwater occurs under unconfined to semi-confined conditions. Groundwater quality and depth of water varies widely in Makrana block. High concentration of fluoride and nitrate are major quality problem associated with groundwater and having adverse effects on human health. High concentration of fluoride in a particular belt is so remarkable that the term BANKA PATTI (a strip of land where deformed people reside) has been in used covering parts of Parbatsar, Makrana and Degana blocks of Nagaur district wherein some villages the fluoride concentration in groundwater is over 4 ppm. The concentration of Fluoride mainly comes from Schists, Gneiss and Limestone of Proterozoic age. Higher concentration of fluoride affects metabolic activities of an individual which may cause skeletal and dental fluorosis. The disease fluorosis is non curable but preventable.***

Keywords: Aquifer, Banka Patti, Fluorosis, Marble slurry, Makrana, Nagaur and India.

I. INTRODUCTION

Nagaur district is located almost in the centre 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. It is surrounded by seven districts namely Bikaner, Churu, Sikar, Jaipur, Ajmer, Pali, and Jodhpur in the Western margin of Aravalli residuals. Its geographical spread is a unique combination of plain, hills, sand mounds and it is a part of the great Indian Thar Deserts. Makrana was a part of Jodhpur State in British India. It is home to some of the world's most renowned white marble sites, from which the Taj Mahal, Victoria Memorial of Kolkata, Birla Temple of Jaipur and Jain Temple of Delwara in Mount Abu, Rajasthan were built.

The limited groundwater resources in Rajasthan are being over-exploited for irrigation, industrial and domestic purposes. The impact of overexploitation coupled with non uniform rainfall in the study area is manifested in the long term depletion in water levels and groundwater quality in the State. High fluoride concentration in groundwater in the district has causing fluorosis problem. High concentration of fluoride in a particular belt of this district is so remarkable that people call that particular area as Banka Patti (Banka-distorted, Patti-belt). Nagaur district has been experiencing acute fluorosis problem for many decades.

The study area of Makrana block is located in the south-eastern part of Nagaur district of Rajasthan covering about 1140 sq. km. area (Figure– 1). Surface run off is insignificant and is of short duration in the study area. Older alluvium Schist/Gneisses are principal source of groundwater in Makrana block. Groundwater quality varies widely in Makrana block. Depth of water varies considerably in the block. High concentration of T.D.S. and fluoride are major quality problems associated with ground water (Vyas, 1999).

II. GEOLOGICAL SETTING

The NNE-SSW trending Aravalli Origen (also known as the Aravalli Mountain Range) that extends for about 750 km from Delhi in the north to Gujarat in the south is the most characteristic geologic and geomorphic feature in north-western India. It divides the state of Rajasthan into two unequal parts, viz. the eastern Rajasthan (Mewar Region) and the western Rajasthan (Marwar Region). As reflected in sites of heritage values, each of these regions has a unique historical and socio-cultural lineage (Garg, S. et al., (2019).

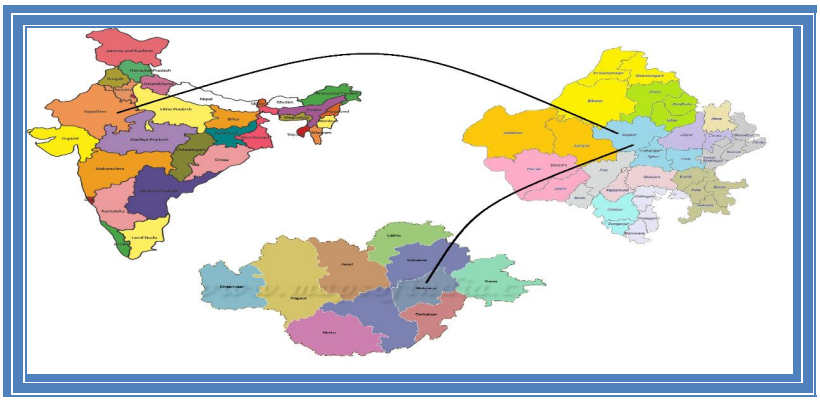

Figure- 1. Location map of the study area

Makrana marble deposits belongs to the Ajmer Formation of Kumbhalgarh Group of the Delhi Supergroup. Delhi Supergroup comprises of Raialo Group (Ras Formation locally), Alwar and Ajabgarh Groups. The rocks of Raialo Group are exposed near Ras and Makrana (Paliwal et al., 1997, Paliwal and Vyas, 1999). Makrana is famous world over for the marble. The marble deposit is 15 Km in length and 1.6 Km in width trending NNE-SSW. There are several parallel to sub parallel bands of 2 to 12 meters width. Total reserves are estimated to be around 50 MT. In Nagaur district at Makrana, the marble is fine grained crystalline and calcareous in nature containing more than 98% CaCO3 (Vyas et al., 2010). The Alwar Group of rocks towards east are overlain by the Ajmer Formation (Ajabgarh Group) comprising of medium to coarse grained, cherty, ferruginous and/or micaceous quartzite . The Ras Formation of the Kumbhalgarh Group, considered coeval with the Ajmer Formation, comprises greyish white to pink marble and dolomitic marble and is exposed west of Makrana. Marble occurs as thin parallel bands associated with calc-silicate rocks and calcareous quartzite having NNE-SSW strike and steep easterly dips. Rocks of the Delhi Supergroup have been intruded by the Erinpura Igneous suite comprising porphyritic granite, biotite granite, pink granite, leucogranite and pegmatite (Tank and Vyas, 2019). Geological map of the Makrana area is shown in Figure- 2. Stratigraphic succession of Makrana area is given in Table - 1.

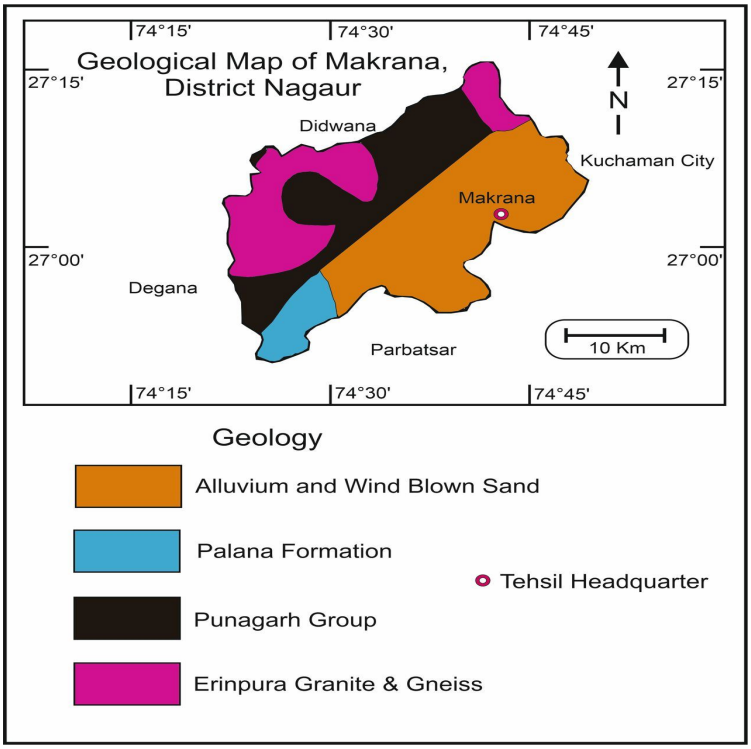

Figure- 2. Geological map of Makrana area of Nagaur district, Rajasthan

In Makrana area there are various mines in the Aravallis range, popularly known as Doongri, Devi, Ulodi, Saabwali, Gulabi, Kumari, Neharkhan, Matabhar, Matabhar Kumari, Chuck Doongri, Chosira and Pahar Kua. The Pahar Kua range is thought to be the actual mine from which the marble for the Taj Mahal was extracted. The Doongri, Devi, Sahabwali, Ulodi, Chosira and Neharkhan mines are famous for white marble, whereas Ulodi is famous for albeta marble (white marble with dark patterning). The Gulabi mine produces pink plain and pink adana marble, whereas almost all mines produce adana marble with brown and grey shades. There are about 800 factories in the study area for marble cutting and processing.

Table- 1. Startigraphic succession around Makrana, Nagaur district (Bhadra et al. 2007)

Quaternary				Aeolian mobile sand with calcareous clay or silt with polymictic conglomerate and grit
Upper Proterozoic	Erinpura Igneous Suite			Biotite granite, pegmatite, amphibolite
Lower to Middle Proterozoic	Delhi Supergroup	Punagarh Group	Bombolai Formation	Phyllite, impure limestone, calc-silicate rock
		Kumbalgarh/ Ajabgarh Group	Ras Ajmer Formation	Makrana marble and dolomitic limestone / quartzite

III. HYDROGEOLOGY

Three main hydrogeological units namely, unconsolidated sediments, semi-consolidated sediments and consolidated rocks are lying in the state. Two principal categories of water bearing rock formations in the state are soft and hard rocks ; covering about 60% and 40% area of the state respectively (Paliwal and Paliwal, 2010 and Vyas and Vyas, 2023). Diverse range of rock formations from the archaen basement rocks to the Holocene lying in Nagaur district. Major six aquifers namely Older alluvium, Tertiary Sandstone, Nagaur Sandstone, Jodhpur Sandstone, Bilara Limestone and Granite gneisses, Schist have been reported in the district. 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). Groundwater level in most of the part of the district varied in depth from 20 to 40 meters. More than 40 meters depth recorded in northwestern, northeastern, western, southwestern and central part of the district (C.G.W.B., 2017 and Chauhan and Vyas, 2021). Average depth to groundwater level in Pre-monsoon 2021 period of the state is recorded as 23.73 mbgl (G.W.D. Rajasthan, 2022). The Makrana block comprises of Consolidated and Unconsolidated Formations. The consolidated formations include metamorphic rocks like schists, gneisses, quartzites and phyllites of Precambrian age and sedimentary rocks like limestone and sandstone of Marwar Super Group. Metamorphics are normally impervious except in the presence of a few weak planes, joints, weathered zones and kinks which contain moderate and limited quantity of groundwater. Quaternary alluvium is the important aquifer comprised of unconsolidated to loosely consolidated fine to coarse grained sand having intercalations and intermixing with silt, clay with `kankar`. Groundwater occurs under unconfined to semi-confined conditions (Tank and Vyas, 2019). Groundwater level in Makrana block varied in depth from 32 to 113 meters and fluctuation up to 10 meters and 12 meters were recorded for the Pre to Post Monsoon period for year 2018 and 2022 respectively (Table - 2).

IV. FLUORIDE PROBLEM IN THE REGION

About 64% villages of the Nagaur district are endemic to fluoride related problems. The excess amount of fluoride in the groundwater in Makrana block is the major problem. The term BANKA PATTI (a strip of land where deformed people reside) has been in use in Rajasthan since long and refer to a specific belt near Makrana. It is in the South-eastern part of the district covering parts of Parbatsar, Makrana and Degana blocks where in some villages the fluoride concentration in groundwater is much over 4 ppm. All types of aquifer in Nagaur district have shown a high concentration of fluoride in the groundwater (Vyas, 2015). The occurrence of high fluoride concentration in groundwater has now become one of the most important health related geo-environmental issues in the block.

Excess amount of fluoride (>1.5 mg /lit) causes dental and skeletal fluorosis and other manifestations (Figures 3 and 4). Fluoride in groundwater is contributed by minerals like, Fluorite, Apatite, Topaz, Fluorspars, Metamorphic and Sedimentary rocks. Drinking water is considered as the major contribution to fluoride and other sources are food, industrial exposure, drugs and cosmetics etc (Vyas, 2015, Tank and Vyas, 2019). To mitigate the fluoride problem it is essential to popularize economically viable techniques of defluoridation techniques and adequate intake of calcium and vitamin-C diet, prohibition on use of fluoride enriched products. Excessive fluoride ingestion by human beings can be prevented by using the alternate water sources including Canal System (Vyas, 2015).

Table- 2. Fluctuations in Groundwater level in Makrana block of Nagaur district for Pre to Post Monsoon season indifferent years

S. No.	Village	Hydrological Formation	Water Level Pre-Monsoon in mts	Water Level Post-Monsoon in mts	Water Level Fluctuation in mts	Water Level Pre-Monsoon in mts	Water Level Post-Monsoon in mts	Water Level Fluctuation in mts
			2018			2022		
1.	Amar Pura	Older Alluvium	99	109	-10	101	113	-12
2.	Juseriya	Older Alluvium	85.34	90	-4.66	95	98.55	-3.55
3.	Barwala	Older Alluvium	102.68	100	2.68	103	101	2
4.	Kukrod	Older Alluvium	34	33	1	34	32.9	1.1
5.	Rampura	Older Alluvium	39	38	1	37.2	37	0.2
6.	Chadni	Older Alluvium	45.7	47	-1.3	50	53	-3
7.	Deowla	Older Alluvium	56	55	1	54	51.9	2.1
8.	Bichhawa	Older Alluvium	75.00	85.00	-10	90	95	-5
9.	Laroli	Older Alluvium	55.5	50	5.5	54	52.6	1.4
10.	Ramsiya	Older Alluvium	37.82	38.08	-0.26	40	41	-1
11.	Gera Kalan	Older Alluvium	45	44.1	0.9	43.5	43.1	0.4
12.	Itawa Lakha	Older Alluvium	48	50	-2	49	49	0
13.	Manawa	Older Alluvium	62.5	65	-2.5	70	76	-6
14.	Nimbri	Older Alluvium	90	95	-5	85	84.1	0.9
15.	Morer	Older Alluvium	60	60	0	57	54.1	2.9
16.	Retnas	Older Alluvium	65	62	3	54	53	1
17.	Gudha Kheri	Older Alluvium	47	45	2	41	39.55	1.45
18.	Dheersar	Schist	39.5	40	-0.5	48	45	3
19.	Baladhana	Schist	67	66.55	0.45	65	64.1	0.9
20.	Mamdoli	Schist	80	84	-4	80.5	79	1.5
21.	Sabalpur	Schist	75	74.5	0.5	80	84	-4
22.	Chawndiya	Schist	51	50	1	54	57	-3
23.	Manani	Schist	34	31.5	2.5	35	32	3
24.	Kajana	Schist	46	45	1	45	43.5	1.5
25.	Sarnawara	N.P.	37.57	36.44	1.13	37	36.4	0.6

V. HYDROCHEMISTRY

To study the groundwater quality of Makrana Block groundwater samples were collected from different 27 villages during Pre-monsoon - 2019 season. Chemical analysis reveals that groundwater quality of the Makrana block show high concentration of fluoride, nitrate, chlorides, Magnesium and total dissolved solids much higher than the limit prescribed by the Bureau of Indian Standards (1992). Results of groundwater samples analyzed are given in Table- 3.

Table- 3. Chemical analysis report of samples collected from different villages during Pre-Monsoon season-2019

S.NO	VILLAGE	SOURCE	PH	Total Hardness (as CaCo3)	Magnesium (as Mg)	Chloride (as CT)	Nitrates (as NO3)	Fluoride (as F)	Total Dissolved Solids
1	Amar Pura	GLR	8.8	300	43.2	1450	291	10.6	6500
2	Juseriya	GLR	8.4	280	40.8	380	73	1.26	1674
3	Barwala	T/W	7.6	1020	148.8	1450	201	0.573	4400
4	Kukrod	O/W	8.7	280	40.8	1330	315	4.24	5400
5	Rampura	O/W	8.4	220	31.2	850	55	5	3900
6	Chadi	GLR	7.9	780	115.2	1950	210	1.99	7400
7	Deowla	O/W	8.1	600	86.4	1370	139	2.63	5400
8	Bichhawa	GLR	8.4	250	36	720	65	3.63	2800
9	Laroli	O/W	8.4	380	52.8	880	289	2.83	3900
10	Ramsiya	O/W	8.1	340	50.4	620	336	9.39	3900
11	Gera Kalan	GLR	8.1	370	55.2	1000	181	2.21	3900
12	Itawa Lakha	GLR	8.6	320	48	700	49	2.71	2700
13	Nimbri	T/W	8.5	130	19.2	280	41	1.26	1325
14	Retnas	O/W	8.3	190	28.8	390	23	2.46	1880
15	Gudha Kheri	O/W	8.2	130	19.2	200	16	3.23	1155
16	Dheersar	O/W	8.1	270	38.4	440	288	3.66	2800
17	Baladhana	T/W	8.3	500	72	1500	242	8.86	7300
18	Mamdoli	T/W	8.5	200	28.8	420	126	3.05	1894
19	Sabalpur	T/W	8.3	170	24	100	78	2.28	868
20	Chawndiya	T/W	7.6	340	48	540	209	1.94	2500
21	Manani	O/W	8.4	450	64.8	980	178	5.77	5000
22	Kajana	O/W	8	800	115.2	1220	107	0.893	4100
23	Bhaiya Khurd	O/W	7.8	1180	168	2900	267	2.64	8.80
24	Sarnawara	O/W	8.5	500	72	1500	306	7300	6100

Figure- 3. Dental Fluorosis affected person in Makrana block

Figure- 4. Skeletal Fluorosis affected person in Makrana block

VI. CONCLUSION

In Makrana block, overexploitation of groundwater resources resulting in depletion of groundwater table at alarming rate along with desaturation of aquifers and deterioration in chemical quality of groundwater. The fluoride is a major problem and high concentration of Fluoride in Makrana block mainly comes from Schists , Gneiss and Limestone of Proterozoic age; and. having adverse effects on human health and live stock as well. Roof top rainwater harvesting in the study area offers a good source of drinking water. (Quereshi and Vyas, 2017). 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 schemes.

Marble mining activities in Makrana have led to a large scale land transformation causing obliteration of slopes, water pounding and flooding, derelict lands. Marble slurry and mining waste disposal dumps and mining below water table (50-60 meters below ground level) pose severe threat to safety and health besides causing soil, water and air pollution. For sustainable development and to check the environmental degradation the mechanized mining, reclamation of the quarried landscape and finding use of marble slurry etc. are corrective measures should be taken up immediately.

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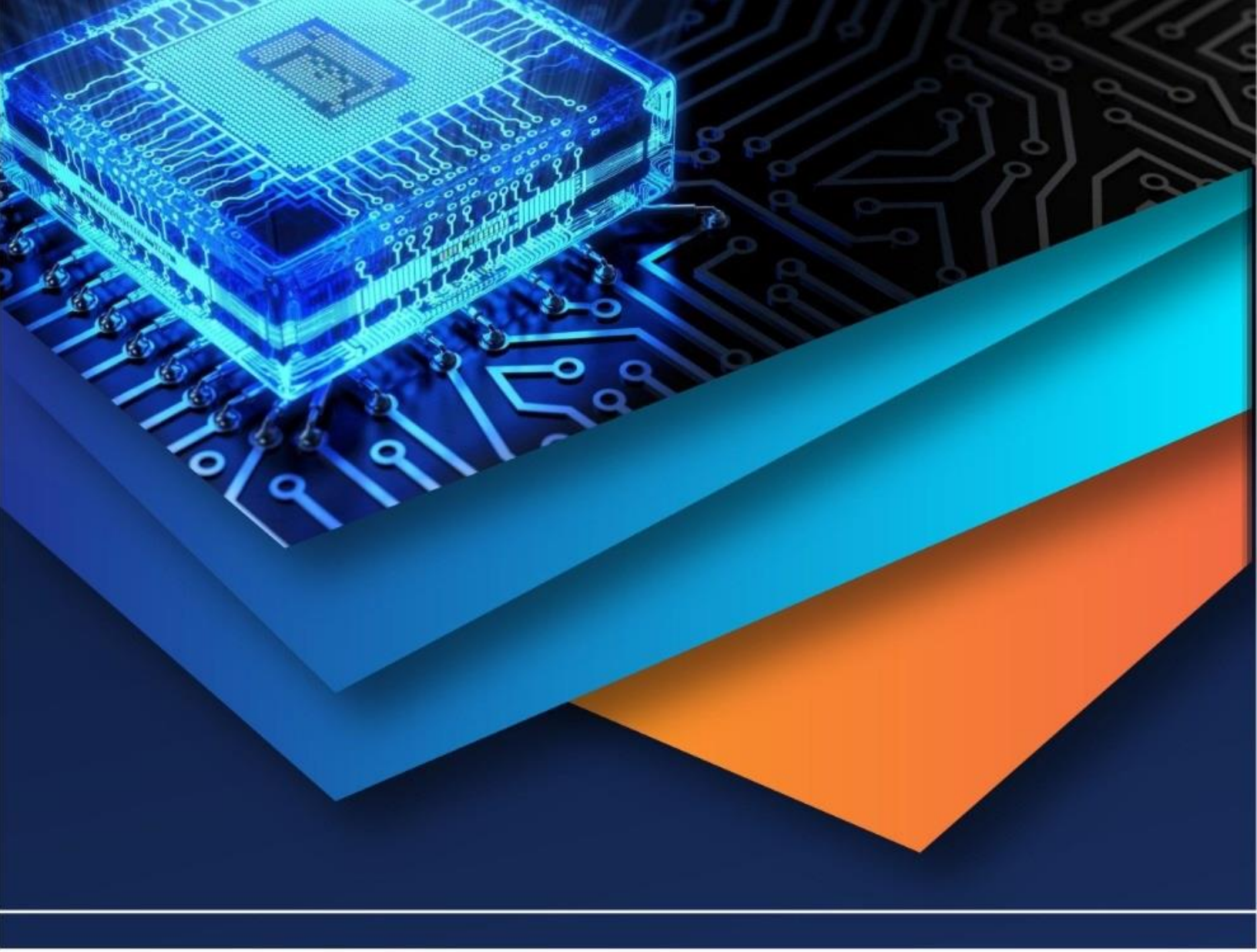

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