iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** VI **Month of publication:** June 2025

DOI: https://doi.org/10.22214/ijraset.2025.72601

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

A Review on Water Quality Assessment of Chambal River in Kota, Rajasthan

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Abstract: Water contamination poses a significant global threat, causing over 14,000 fatal diseases daily, with disproportionate impacts in developing nations like India.
This review paper synthesizes existing literature on the pervasive issue of water pollution, detailing its primary sources (industrial, municipal, and agricultural discharges), diverse contaminants (heavy metals, dyes, organic pollutants), and devastating effects on human health and aquatic ecosystems.
It explores various methodologies for water quality assessment, particularly the Water Quality Index (WQI), and highlights established water quality standards. Focusing on the Chambal River in Kota, Rajasthan, as a case study, the paper contextualizes the local challenges within the broader global and national water crisis, drawing upon multiple studies that have investigated water quality parameters, pollution hotspots, and proposed management strategies. The review underscores the urgent need for comprehensive pollution control, continuous monitoring, and sustainable water resource management to safeguard present and future generations.

I. INTRODUCTION

Water is an indispensable resource, yet its contamination remains one of the most pressing global challenges of the 21st century. The World Health Organization (WHO) reports that while 5.2 billion people have access to safely treated water, approximately 1 billion still lack this fundamental necessity.
The consequences are dire, with an estimated 2.2 million individuals succumbing to waterborne diseases annually in developing countries [6]. India, the world's second-most populated country, grapples acutely with this issue, with over 70% of its freshwater rendered unsafe for human consumption.
The primary drivers of water contamination are uncontrolled discharges of industrial and municipal waste, coupled with inadequate wastewater treatment infrastructure [6]. Industry alone contributes nearly two-thirds of the waste dumped into aquatic bodies, with a staggering 80% remaining untreated.
This environmental degradation is anticipated to be a leading threat to life within the next decade, with water pollution directly linked to 1.8 million fatalities worldwide in 2015 [37]. The far-reaching implications extend beyond public health, severely impacting national development, economic stability, and environmental integrity [34]. Factors such as rapid urbanization, burgeoning population growth, increased industrial production, and climate variability further exacerbate the decline in water quality, posing grave dangers to the planet and its inhabitants [34].
The long-lasting effects of water pollution manifest as a multitude of serious ailments across generations. In India, contaminated water has been implicated in numerous detrimental diseases, including cancer, birth defects, and conditions affecting the skin, lungs, brain, kidneys, and liver [15]. A study identified Pune's rivers as among the most contaminated in India, primarily due to the release of raw sewage and poorly treated wastewater [27].
This review specifically examines the challenges faced by Kota city, a significant industrial and educational hub in Rajasthan, where the Chambal River is a vital water source.
The river here faces immense pressure from solid waste dumping, untreated industrial and domestic waste discharge, encroachment, and illegal water diversion [30].

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Figure 1 (refer to original source material) visually depicts the Chambal River near a thermal power plant, underscoring localized pollution concerns.

II. WATER CONTAMINATION AND ITS SOURCES

Clean water is fundamental for the sustenance of individuals and ecosystems worldwide. However, water quality has been steadily declining over recent decades, a direct consequence of rapid urbanization, industrialization, population growth, and the reckless exploitation of natural resources [7]. The variability of contaminants poses a complex challenge, encompassing a wide array of pollutants such as diseases, heavy metals, dyes, radionuclides, plastics, nanoparticles, biocides, organic materials, medications, and excess nutrients [36].

Globally, only 2% of the Earth's water is freshwater, with a mere 0.036% suitable for direct human consumption, the rest being locked in groundwater, wells, and arctic ice [26]. The remaining 98% is saline seawater, unsuitable for potable use.

Water contamination originates from both point and non-point sources [29]:

A. *Point Sources*

These are identifiable, specific locations from which pollutants are discharged.

- Effluent from public and industrialized wastewater treatment plants.
- Overflow and leachate from non-sewer industrial sites, mines, and oil fields.
- Intrusion and runoff from animal feedlots.
- Storm sewer outfalls from large cities (population $\geq$ 100,000).
- Combined sewer overflows during rainstorms and sanitary events.
- Runoff from large construction sites (larger than two hectares).

B. *Non-point Sources*

These are diffuse sources where pollutants originate from a broad area and cannot be traced to a single discharge point.

- Discharge from range and pasture lands.
- Runoff from non-sewer and sewer urban areas with populations under 100,000.
- Leachate from septic tanks and overflow from failed septic systems.
- Runoff from abandoned mines.
- Contaminants generated by land-related activities such as logging, wetland conversion, building, and canal or land development.

III. WATER QUALITY INDEX (WQI)

The Water Quality Index (WQI) serves as a critical numerical scale that condenses multiple water feature characteristics into a single, comprehensive score, facilitating easy communication of water quality status [27]. This score is instrumental in guiding water resource management decisions and assessing the health of freshwater ecosystems. The WQI is widely employed to detect and evaluate water contamination and overall quality [35][24].

The concept of the WQI was first introduced by Horton in the United States in 1965, utilizing ten common water quality metrics, including Dissolved Oxygen (DO), pH, coliforms, Electrical Conductivity (EC), alkalinity, and chlorides [4]. Subsequently, this index underwent modifications by various experts, leading to the development of new WQI models, such as the one created by Brown in 1970 [2]. Common methods for evaluating WQI include:

1) NSF-WQI (National Sanitation Foundation Method – Water Quality Index)
2) O-WQI (Oregon Water Quality Index)
3) WA-WQI (Weighted Arithmetic Water Quality Index)
4) CCME-WQI (The Canadian Council of Ministers the Environment Index)

IV. EFFECTS OF WATER POLLUTION

The impacts of water contamination are pervasive and severe, affecting various facets of life and the environment:

1) Aquatic Ecosystems: Industrial discharges introduce harmful chemicals that can alter water color, increase mineral content, change temperature, and directly endanger aquatic life [7].
2) Human Health: Domestic sewage water, containing infections, dangerous bacteria, and harmful chemicals, leads to serious health issues and diseases. Contaminated subterranean water from sewer line leaks is unsafe for consumption, and stagnant surface water from unaddressed leaks can become breeding grounds for disease vectors like mosquitoes [23].
3) Chemical Hazards: Hazardous chemicals from underground coal and mineral extraction can react with water, releasing toxic elements that cause major health problems [12].
4) Marine Life: The dumping of domestic waste (paper, plastic, food, rubber, aluminium, glass) into oceans, along with oil spills that do not dissolve in water, poses a serious risk to marine animals, including fish, birds, and sea otters [22].
5) Atmospheric and Terrestrial Impacts: Hazardous chemicals reacting with water vapour contribute to acid rain, which threatens both aquatic and terrestrial life.
6) Agricultural and Climatic Linkages: Chemical pesticides and fertilizers used in agriculture to protect crops can pollute water bodies. Additionally, global warming, by raising Earth and water temperatures, leads to the death of aquatic animals and marine species, further exacerbating water pollution [8].

V. WATER QUALITY STANDARD PARAMETERS

To ensure water safety, various parameters are monitored and compared against established standards. The Indian Standard (IS 10500:2012) and WHO specifications for drinking water [33] provide acceptable and permitted limits for physical, chemical, and bacteriological parameters.

A. Physical Parameters (AS PER BIS 10500:2012)

Table 1: Physical Parameters of Drinking Water (BIS 10500:2012)

S.No.	Specific (mg/l)	Acceptable limit	Permitted limit
1	Odor	<5 hzn	<5 hzn
2	Taste	unobjectionable	unobjectionable
3	Color	5	15
4	Turbidity (NTU)	1	5
5	PH	>6.5 &<8.5	NR
6	TDS	500	2000
7	EC (mhos/cm)	300	750

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B. Chemical Parameters (AS PER IS 10500:2012)

Table 2: Chemical Parameters of Drinking Water (BIS 10500:2012)

S.No.	Specific (mg/l)	Acceptable limit	Permitted limit
1	Aluminium	.03	.2
2	Ammonia	<.2	<.2
3	Barium	.7	NR
4	Boron	.5	1
5	BOD	NIL	NIL
6	COD	<10	<10
7	Calcium	75	200
8	Chloride	250	1000
9	Copper	.05	1.5
10	DO	3-5	3-5
11	Fluoride	1	1.5
12	Free residual chlorine	0.2	1.0
13	Fe	.3	NR
14	Mg	030	0100
15	Mn	.1	.3
16	Nitrate	45	NR
17	Phenol compound	.001	.002
18	Selenium	.01	NR
19	Silver	.1	NR
20	Sulphate	200	400
21	Total alkalinity	200	600
22	Total hardness	300	600
23	Zinc	5	15
24	Mercury	.001	NR
25	Cadmium	.01	NR
26	Arsenic	.05	NR
27	Cyanide	.05	NR
28	Chromium	.05	NR
29	Lead	.05	NR

C. Bacteriological Quality Of Drinking Water (AS PER IS 10500:2012)

Table 3: Bacteriological Quality of Drinking Water (BIS 10500:2012)

S.No.	Specific	Acceptable limit	Permitted limit
1	E-Coli organism MPN/100ML	It cannot be found in any 100 ml sample.	NIL
2	Coliform organism MPN/100ML	It cannot be found in any 100 ml sample.	500

VI. STUDY AREA: CHAMBAL RIVER, KOTA

The Chambal River in Kota, Rajasthan, India, serves as the specific study area for assessing water quality. Located approximately 240 kilometres from Jaipur, Kota is a prominent city with over 1.5 million residents (as of 2024), known for its industrial activities, educational coaching centres, unique paintings, Kota stone, and textile industries [14]. The city's geographical coordinates are 75.833 E longitude and 25.18 N latitude.

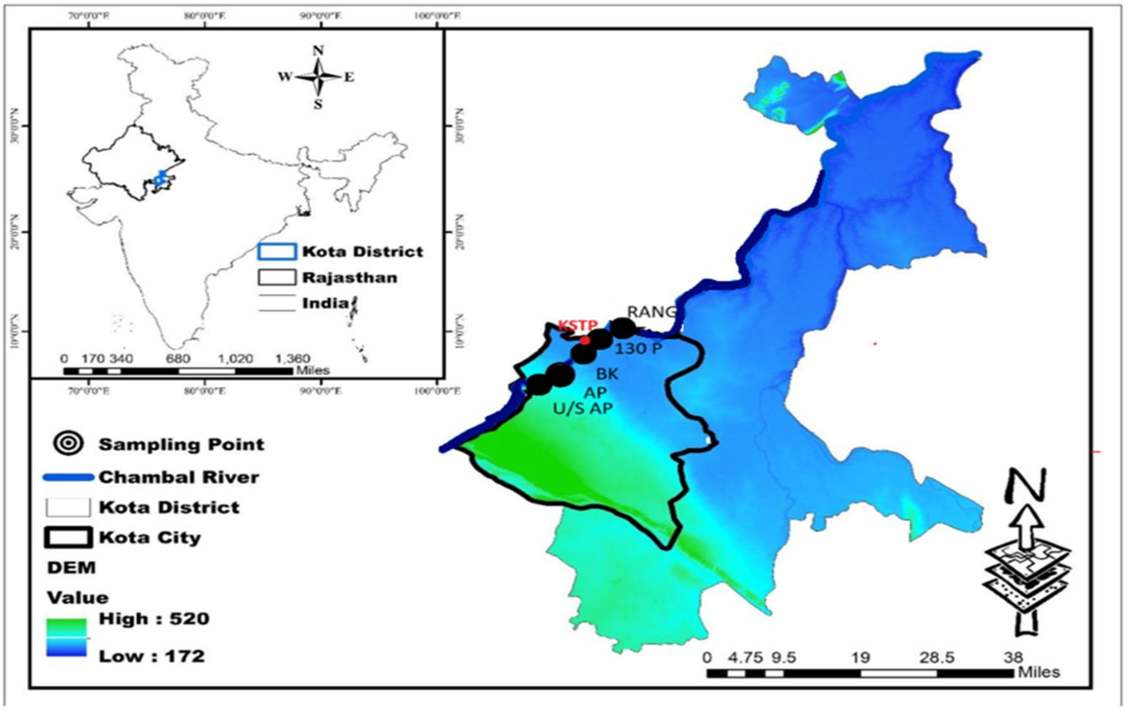

Figure 2 provides a detailed map of the Chambal River in Kota District. The map delineates the Chambal River, Kota District, and Kota City boundaries. Key elements on the map include:

- Sampling Points: Marked with black circles, indicating the specific locations where water samples are to be collected. These include RANG (Rangpur), 130 P (130 MLD plant), BK(Bhitriya Kund), AP(Akhelgarh plant), and U/S AP (Upstream of Akhelgarh plant), suggesting a distribution of monitoring sites around potential pollution sources.
- DEM (Digital Elevation Model): The map also indicates DEM values, ranging from a low of 172 to a high of 520, which provides insights into the topography of the study area and can influence water flow and pollutant dispersion.

The focus of the planned study is to assess the water quality of the Chambal River in Kota city using the CCME method of the Water Quality Index. This involves a comparative analysis of water quality at different locations upstream and downstream of a thermal power plant, correlating with the sampling points shown in Figure 2. Water samples will be collected monthly from March 2024 to Feb 2025, covering pre-monsoon, monsoon, and post-monsoon periods, to analyze 17 key water quality parameters.

VII. LITERATURE REVIEW

A comprehensive literature review is essential for understanding the existing body of knowledge, identifying research gaps, and informing future methodologies. This section summarizes relevant studies on water quality assessment and pollution.

Earlier studies on river pollution highlighted significant concerns: Sunil Kumar Karn et al. (2001) found high BOD and coliform levels in the Yamuna, Buriganga, and Baghmati rivers, indicating severe organic pollution [1]. Bordalo A. et al. (2001) attributed pollution in the Bangpakong River to urban wastewater, industrial discharges, and agricultural runoff, threatening aquatic ecosystems and human consumption [2]. V. Simeonov et al. (2003) emphasized the need for long-term monitoring, biological data, and health risk assessment in Northern Greece's surface waters [3]. Y. Ouyang et al. (2006) noted seasonal variations in water quality and suggested broader evaluations including biological assessments and climate change impacts [4].

Several studies have specifically investigated the Chambal River. D.N. Saksena et al. (2008) observed generally good water quality in the National Chambal Reserve (Madhya Pradesh segment) from 2003-2004, characterizing it as oligosaprobic (pollution-free), with high DO and low BOD/COD, supporting diverse aquatic species [5].

Naresh Singh et al. (2014) also reported excellent water quality in the Chambal River, suitable for bathing, irrigation, and aquaculture, and potable with minor treatment [12]. AMIT KUMAR et al. (2014) used NSF-WQI to assess the Chambal River in Madhya Pradesh, confirming its suitability for various uses and aquatic life conservation [13]. However, PARVEEN KUMAR et al. (2018) investigated heavy metal concentrations around the Kota Super Thermal Power Plant, examining the impact of coal burning and fly ash on both surface and groundwater, indicating localized concerns [25].

Beyond the Chambal, broader issues of water contamination are evident. A. Agrawal, R. S et al. (2010) explored widespread pesticide contamination in Indian water supplies due to agricultural practices, warning of their persistent nature and harmful effects on aquatic life and human health [6]. Oladele Osibanjo et al. (2011) found substantial organic contamination in River Alaro and River Ona from industrial discharges, impacting residential and agricultural uses [7]. Singh Jaspal et al. (2012) observed mild contamination in a river from domestic sewage, agricultural runoff, and industrial discharges, making it unfit for agriculture due to high alkalinity and industrial pollutants [8].

The application of Water Quality Index methods is a recurrent theme. V. Calmuc et al. (2018) compared various WQI determination techniques (British Columbia, CCME, NSF), emphasizing that local conditions and water use should guide the choice of approach, and advocating for generic WQI models that account for new pollutants and regional variances [27]. Chandra D. S. et al. (2017) utilized the Weighted Arithmetic Water Quality Index method to classify water quality from good to unfit based on parameters like pH, DO, BOD, NO3, and TDS [24]. Venkatramanan S et al. (2016) used CCME-WQI with GIS to map groundwater quality in a research area, identifying impacts from salty water intrusion, localized pollution, and agricultural runoff [20]. Similarly, V. M. Wagh et al. (2017) applied CCME WQI to categorize groundwater quality in a basin, noting changes due to natural and anthropogenic causes like waste management, industrial discharge, and agricultural runoff [21]. Ruth Olubukola Ajoke Adelagun et al. (2021) also employed WQI to assess water quality in Nigeria, emphasizing the need for better management and policy implementation [35].

Studies on heavy metal contamination are also prominent. A. Akobundu N. et al. (2012) applied the Heavy Metal Contamination Index to Nigeria's Aba River, revealing high contamination levels, especially near industrial operations, and advocating for urgent pollution control [10]. Soma Giri et al. (2013) found both natural and man-made heavy metal pollution in the Subarnarekha River, with higher levels in industrial and mining areas [11]. Atish Prasad et al. (2020) reported heavy metal concentrations (iron, manganese, zinc, chromium, lead) in the Upper Ganga River often exceeding WHO and BIS standards, linking them to non-carcinogenic health risks from industrial waste and untreated trash [30]. C. Zamora-Ledezma et al. (2021) investigated heavy metals (As, Pb, Cd, Hg, Cr) in water bodies and contrasted traditional remediation methods with novel approaches like nanomaterials and bioremediation [28].

The impacts of pollution on public health and the environment are consistently highlighted. J. Halder et al. (2015) emphasized that drinking tainted water leads to long-term brain problems (from lead and arsenic), skin infections, and gastrointestinal disorders, stressing the importance of waste management, pollution control, and water purification [15]. C. P. Liyanage et al. (2017) linked increasing water pollution (nitrates, phosphates, heavy metals, pathogens) to poor waste management and population growth, suggesting public awareness and urban design solutions [22]. H. R. Bharathi et al. (2017) found many water bodies unfit for human consumption due to domestic sewage, farm runoff, and industrial effluents, with high nitrate and TDS levels contributing to poor water quality [23].

Further research includes Mohd Yawar Ali Khan et al. (2015) who investigated water quality deterioration in the Ramganga River, identifying significant organic contamination and suggesting the need for better management plans [16]. R. Ramya Priya et al. (2016) explored natural and man-made factors affecting the Cauvery River's water quality, noting spatial and temporal variations linked to pollution sources [19]. B.T. P. Jian et al. (2020) used WQI and PAHs to assess river water quality affected by treated landfill leachate, underscoring the necessity of improved monitoring and treatment [34]. J. O. Ighalo et al. (2020) identified water pollution hotspots across Nigeria and analyzed their effects on health, ecology, and water supplies, recommending targeted solutions [32].

The literature consistently points to the complex interplay of various factors contributing to water pollution and the necessity of comprehensive approaches for assessment and mitigation. Anjali Puri et al. (2015) even touched upon an unexpected social impact, highlighting the negative aspects of competitive exam preparation in Kota, leading to student stress and mental health issues [14], though not directly related to water quality, it provides context for the city's overall environmental and social pressures.

VIII. CONCLUSION

Water contamination presents a severe, multifaceted crisis with profound implications for global public health, economic development, and environmental sustainability. The extensive literature reviewed underscores the pervasive nature of this issue, driven by uncontrolled industrial, municipal, and agricultural discharges, leading to a myriad of harmful pollutants in vital water sources. Developing nations, particularly India, bear a disproportionate burden of water-borne diseases and inadequate access to safe drinking water.

The Water Quality Index (WQI) has emerged as an invaluable tool for synthesizing complex water quality data into a digestible format, aiding decision-making and highlighting critical areas of concern. Various WQI methodologies, alongside detailed physical, chemical, and bacteriological parameter assessments, are crucial for effective monitoring.

The case of the Chambal River in Kota, Rajasthan, exemplifies the localized challenges within this global crisis. While some studies historically indicated good water quality in certain segments of the Chambal, more recent investigations point to the increasing pressure from urbanization, industrial activities, and thermal power plants, leading to localized contamination concerns, particularly related to heavy metals and organic pollutants.

The collective findings from the literature emphasize an urgent and continuous need for:

- Effective Pollution Control: Implementing stringent regulations and advanced treatment technologies for industrial and municipal wastewater, and promoting sustainable agricultural practices to reduce runoff.
- Continuous Monitoring: Regular, comprehensive assessment of water quality parameters across diverse locations and seasons to identify pollution trends and hotspots.
- Integrated Water Resource Management: Adopting holistic approaches that consider both point and non-point sources of pollution, taking into account land use, climate change impacts, and the specific needs of aquatic ecosystems and human populations.
- Public Awareness and Education: Engaging communities in water conservation efforts and promoting hygienic practices to minimize contamination.

Addressing water contamination demands a concerted global effort, integrating scientific understanding with robust policy frameworks and community engagement to secure safe and clean water for present and future generations.

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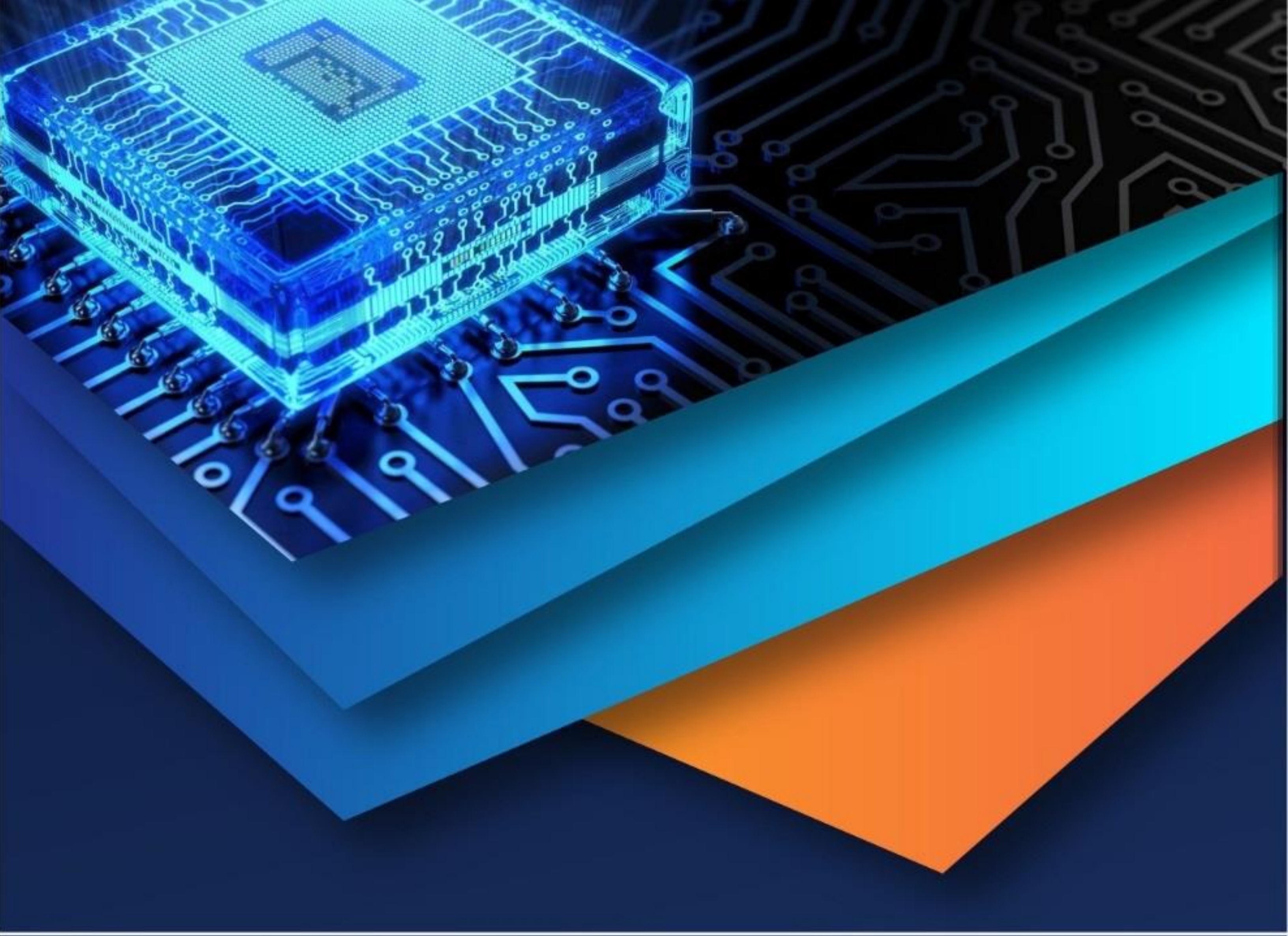

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