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# Identification of Suitable Site for Possible Ground Water Recharge in South-West District of Delhi

Jagriti Kundu[a], Amarjeet Kaur[a], Darshan Malik[b*], Raj Kishore Singh[a], D. K. Chadha[c], Shashi Nijhawan[b]

[a] *University School of Environment Management, GGS Indraprastha University, Dwarka, New Delhi, India*
[b] *Department of Biochemistry, Shivaji College, University of Delhi, New Delhi, India*
[c]*Global Hydrogeological Solutions, G-66, Ground Floor, Vikas Puri, New Delhi – 110058*

***Abstract: India is endowed with a rich and vast diversity of natural resources, water being one of them. The Average Annual Runoff available in India is 1869 BCM (Billion Cubic Meter) of which only 1123 BCM is estimated as utilizable Water Resource. The National capital of Delhi belongs to one of the most populous cities of the world. The growth of the township in the last few decades from 9.4 million in 1991 to 14 million in 2001 has surpassed all comparisons with the other mega cities. The development in terms of infrastructure facilities to match the international standards and to accommodate the changing socio-economic conditions has resulted into a phenomenal growth in overall perspective of Delhi. In today's scenario, the most complex issue is to ensure sustainable water supply. The South-West district of NCT, Delhi covers 420 Sq. Km area characterized by unconsolidated quaternary alluvium deposits out of which 18 Sq Km area is covered by denudation hills specially in the Eastern part of the district. The rate of decline is highly variable in space (1-2 m/yr) depicting the variations in excessive pumpage over natural recharge. This is mainly a result of faulty water supply system (all water treatment plants are located in North Delhi only) coupled with high rate of economic growth in South Delhi which has resulted in ground water depletion in South and South Western districts of NCT, Delhi. Unplanned development of groundwater has disturbed the hydrological balance, leading to decline in productivity of wells, increasing pumping cost, more energy requirement, brackish water upcoming etc. The line of fresh-saline interface also varies greatly in the entire area.***

***Key Words: Ground water recharge, Water Demand; Water bodies; Rainfall; Water Quality.***

## I. INTRODUCTION

The Earth has a finite supply of water resources stored in aquifers (30.1%), surface waters (0.27%) and the atmosphere. Ground water is seriously vulnerable to pollution and depletion and becomes polluted when toxic substances become dissolved in water at the land surface and are carried down, or leached, to the aquifer with the percolating water. Sometimes ground water contamination occurs naturally, but serious contamination is usually the result of human activities on the land surface (PSEP, 2012). Contaminants are expensive to remove and they make the water virtually unusable for years. Contamination is often widespread before being detected because ground water moves slowly and many years pass before a pollutant released on the land surface is detected in water surrounding the aquifer. The hydrological cycle involves the cycling of water in biosphere in different phases as solid, liquid and gas. The cycle starts with the Evaporation from ocean and evapotranspiration from plants. This water reaches the atmosphere, condenses and collects for enough time to precipitate. The precipitation falling on the surface goes directly into lake and streams as runoff while the part of this precipitation seeps down the ground as infiltration. This infiltrated water is constituted in the vadose zone which is accessible to plants while the water moving further is the recharge water which augments the groundwater level by raising the water table.

The National Capital Territory of Delhi is stretched over an area of 1483 sq Km of which 783 $km^2$ urban. Bordered by the Indian states of Uttar Pradesh on East across the river Yamuna, and Haryana on West, North and South, Delhi is located approximately 213 to 314 m above the sea

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level (Sett, 1964) and between latitude 28°24′15″ and 28°53′00″ North and longitudes 76°50′24″ and 77°20′30″ East.

## II. STATUS OF WATER SUPPLY IN DELHI

According to Central Ground Water Board net annual water availability of nine districts of NCT sub-region is 0.28 BCM (Billion Cubic Meter) while the total annual estimated ground water extraction is of the order of 0.48 BCM. Thus, the stage of ground water development is 170%. With the population of Delhi increasing from 0.4 million to 1991 to more than 16 million now, there has been an ever-increasing pressure on the water resources. As a consequence of rapid urban development, much due to unplanned and uncontrolled growth of unauthorized colonies and annual influx of migrants, water supply infrastructure has come under severe pressure. The city, at the moment, requires 990 MGD (Million Gallon per day) of water what it gets stands closer to 805 MGD. Average water consumption in Delhi is estimated at being 63.36 Gallons/capita per day. Also, surface water supply is under Riparian Distribution which again increases the pressure on groundwater resources. Thus, the Government has made it mandatory to practice Rainwater Harvesting techniques under the Urban Building Bye-Laws (20 June 2001, Delhi) according to which "Water harvesting through storing of rain water runoff in all new buildings of residential character, group housing societies & plots of about 1000 $m^2$ and above". All along the Najafgarh Drain the depressions (Gumanhera Village, Pindwalan Kalan, Kakrola) have somewhat deep fresh water layer and can be used as potential recharge sites due to easy availability of runoff water. So the study area is selected in the vicinity of Najafgarh Drain. Also, the surrounding areas are highly saline, so water management and recharge to groundwater is necessary to prevent salinity ingress, maintain sustainable water supply, and improve water quality of the area.

Due to the Widened gap between the demand and supply of water there has been large-scale extraction of groundwater. Rapidly changing hydro geological conditions are leading to a water stress condition in Delhi with acute water scarcity in South and South-West blocks and the groundwater development status being above 200% (Figure-1). This has led to increased salinity ingress in these areas. Thus Artificial Recharge through Rain Water Harvesting is a necessary solution to this problem.

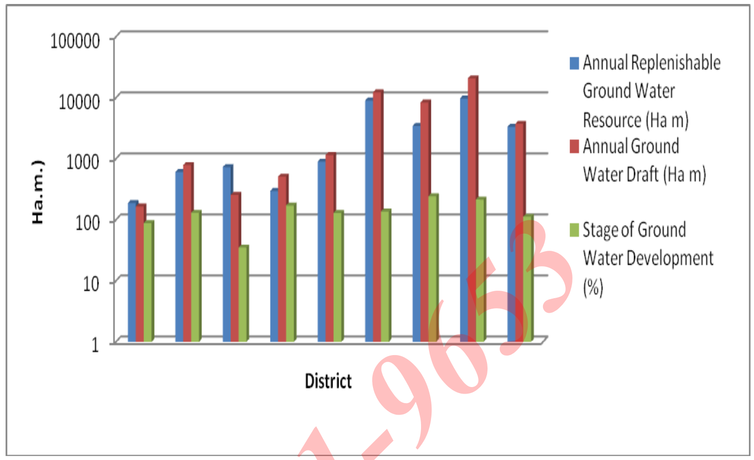


Figure-1. Status of Ground water development of NCT, Delhi (Source: CGWB, 2009)

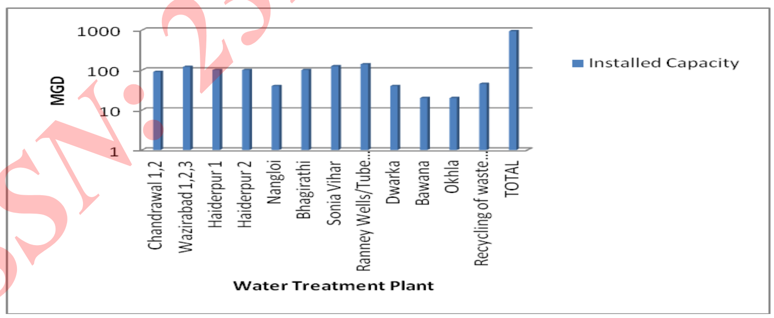


Figure-2. Water Supply Scenario of Delhi in 2011 (Source: Master plan for Delhi, 2021)

As presented in figure-2, Delhi Jal Board will be able to increase its treatment capacity of MGD at present to 940 MGD by the Year 2011 against the projected demand of 1140 MGD by the year 2011. The source available is not be sufficient to meet the demand and still there is shortfall of 200 MGD in 2011. Owing to this situation of escalating population without a commensurate increase in the availability of raw water, the ground water in Delhi has been over exploited. This has disturbed the hydrological balance leading to decline in the productivity of wells, increasing pumping costs and more energy requirement. So it's clear that the nation's capital is perpetually in the grip of a water crisis, more so during the dry season, when the situation gets particularly worse.

The objective of the study is to find the positive impact on the flora, groundwater level, groundwater quality, energy saving, mitigating domestic water requirement, reduction in soil

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erosion. The main goal is to improve the availability of water and maintain sustainable levels of groundwater.

## III. MATERIALS AND METHODS

Land utilization of Delhi has changed drastically over the years due to rapid urbanization. The agricultural lands are repeatedly modified and more and more areas are shifted from cultivation and being used for other purposes (Sharma, 2009). The study area falls in South-West district/Najafgarh Block, Najafgarh Sub-Division of Delhi, is spread in 282 Sq Km. The area broadly falls in the categories of built up area, open area and agricultural land.

The South-West district of NCT Delhi (Figure- 3) covers 420 sq. km. with a population density of 4,166 persons per $Km^2$. Administratively; the district is divided into three Subdivisions: Delhi Cantonment, Najafgarh, and Vasant Vihar.


Figure-3. Map of south-west district of NCT Delhi.

The area is characterized by unconsolidated quaternary alluvium deposits out of which 18 Sq. Km area is covered by denudation hills especially in the eastern part of the district. Thickness of alluvium layer in this area is around 300 m depth which has been encountered at many places i.e. in Dhansa (297 m), Pindwala Kalan (300m), Togham pur (298m) and Jhul-jhuli (251 m). Thick pile of alluvium over the basement rock possesses various natures of sediment strata in an alternate fashion of geological setting. Nearly fine to medium and silt grade of sediment are frequent up to the depth of 50 m along with buff colored clayey bed admixed with coarse kankar. On the other hand after the depth of 50 m, silty-clay and clay (light yellow) beds with kankar increases with depth. The granular zone (Fine sand and silty-sand) at deeper depth are not as frequent as in the shallower depth. The large part of the district experiencing depth to water level in the range of 5 to 28mbgl. The line of Fresh-Saline water interface also varies greatly in entire area (Shekhar *et al.* 2005). In few pockets in the district, the rate of decline has been recorded to be 3 to 4m per annum, which is very alarming (Bhatnagar and Gupta, 1989).

A small part of the district lies in urban limits while major part remains in rural area of Delhi. It has the maximum over draft indicating high quantity of ground water extraction and low water supply coverage. As per the Geological Survey of India the Najafgarh block already have over drafts and new developments in these areas is only going to increase the pressure on the ground water resource. The water table varies from 0 to 30 m. b. g. l. Also the water is saline over the area and confined aquifers occur at great depth and the thickness of unsaturated zone is about 15 to 20 m except in areas adjoining Najafgarh drain where it is around 5-8m only.

*Characteristics of the study area*

Various aquifer properties related to storage and transmission of water and its sub surface disposition, occurrence and distribution of groundwater in space and time needs to be clearly understood before taking up any groundwater development and management plan. Thus hydro geological characteristics of the underlying rock formations need to be studies.

The NCT of Delhi represents a complex hydro geological set up which can be grouped under four distinct units viz. New Alluvium-represented by Yamuna flood plain deposits, Older represented as NNE-SSW trending Quartzitic Ridge. Major part of the SW district is characterized by the unconsolidated sediments of the Quaternary age.

*Rainfall and runoff calculations:*

Rainfall is a form of precipitation that generates runoff on the surface and infiltration of which constitute the major source of water for artificial recharge of groundwater. It is pertinent to study the monthly, annual variation of the rainfall intensity over the years for ground water conservation and recharge studies.

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The entire NCR area including Delhi falls under the semi arid climatic region and its climate is influenced by its inland position and the prevalence of air of continental type during the major part of the year. Extreme dryness with intensely hot summer and cold winter are the characteristics of this climate. Only during the three monsoon months i.e. July, August and September the precipitation occurs. Records of rainfall is 611.8mm. The rainfall increases from southwest to northwest. About 81% of the annual rainfall is received during the monsoon months. The rest of the annual rainfall is received as winter rain and as thunderstorm rain in pre and post monsoon months (Sharma, 2009). The variation of rainfall from year to year is large. In Delhi, the rainfall shows variation from 400 mm to > 700 mm, the lowest being in the western region of the Delhi and highest in the ridge area.

*Chemical quality:*

Chemical quality of groundwater in NCT, Delhi varies with depth and space. In alluvial formations, the quality of groundwater deteriorates with depth which is variable in different areas. As such the chemical quality of groundwater is dependent particularly on the chemical composition of soil and surrounding conditions through which surface water percolates to recharge an aquifer and upon the chemical composition of rocks within which the water is or has been in contact. The source and volume of the water recharging the aquifer and the rate of flow of water through the aquifer (which determines the length of time the water is in contact with various rock media) are equally important. The ion concentration of the groundwater tends to increase with distance the water travels through the ground. Rising temperatures and pressures with increasing depth are other factors contributing in the rise of ionic concentration. Generally, the assessment of groundwater quality is accomplished through sampling at pre defined locations and then samples are subjected to laboratory analysis for the major and trace elements as per the objective of the study. Groundwater quality is the major concern as the depth of fresh-saline water interface varies greatly. Based on stage of groundwater development and significant decline in groundwater level in pre and post monsoon period, the entire south west district has been categorized as 'Overexploited'. The interface of saline/fresh aquifer exists at shallow depths particularly in the northern and north eastern parts and becoming slightly deeper towards south western direction along Najafgarh drain. The granular zone with thickness of 20 to 30 m bearing potable water is expected in areas lying adjacent to Najafgarh and Palam drain.

*Water level fluctuations:*

Monitoring of groundwater levels and its quality at pre determined locations with respect to time provides basic idea of groundwater regime changes as a result of various stresses acting on groundwater system. The important attributes of the groundwater regime monitoring are groundwater level, groundwater quality and temperature. Water level is the manifestation of resultant changes in groundwater storage in space and time. Seasonal fluctuation in groundwater levels are indicator of input and output to groundwater reservoir. The long term decline in groundwater level points towards excess withdrawal with respect to recharge. In South-West district, steep decline in the range of 1-2 m/yr have been observed, in the rest of the areas the long term decline is mostly within 1m/yr. About 10 sq Km low lying areas along the Najafgarh and Palam drains has shallow ground water levels and there is no temporal variations in water levels observed in these areas.

*Two dimensional models*

To know the sub-surface configuration, 3 lithologoical section have been prepared using the data obtained from Geophysical Survey for Determination and Aquifer Geometry in Delhi (Report), Volume-II Data Base, GHS for the surrounding area. The 2 dimensional sections of the study area were prepared using the drawing software- AutoCAD. It is drawing software that finds its utilization in various fields like engineering drawings, maps, sections etc. In the present project, the given software is used for preparing the 2 Dimensional sections of the lithology of the given area.

## IV. METHODOLOGY

1. The lithology of the three given sites was first plotted on the graph paper, taking into account the distance between the given sites and their RL.
2. The inferred lithology of the area is then plotted on the graph paper which was then scanned and stored in the computer as a JPEG image.
3. Then the raster image was opened in Auto CAD.
4. Suitable layers were made (like overburden, saline aquifer, clay and rock/compacted formation) by clicking on the Layer tab on the menu bar and different colours were given to these layers.

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5. Polyline was selected and the respective lithologies (as in Raster image) were digitized.
6. Then hatching was done for each layer by filling each layer using specific symbol and color.
7. The Raster layer was then turned off by clicking on layer tab.
8. Then the section was saved as pdf file.

## V. RESULTS AND DISCUSSIONS

Based on the studies carried out, the sites suitable for Artificial Recharge have be identified which are decided on basis of potential permeable aquifer zones. Artificial Recharge of Groundwater is an important management strategy the overall objective of which is to provide water security through recharging depleting aquifer. The artificial recharge to groundwater aims at augmentation of groundwater reservoir by modifying the natural movement of surface water utilizing suitable civil construction techniques. It mainly depends on the runoff, geomorphology and presence of aquifer zones.

The basic prerequisites for taking up artificial recharge schemes are:

- Need of Artificial Recharge- The need for artificial recharge also requires to be prioritized according to its importance in the overall development perspective of the nation. Such prioritization will also help indeciding the economic viability of the scheme being comtemplated.
- Availability of source water- It is one of the prime prerequisites for recharge to groundwater and is basically assessed in terms of Non-Committed surplus monsoon runoff that goes unutilized. This component can be analyzed by assessing the rainfall pattern, its frequency, number of rainy days and its relevance in relation to scope for artificial recharge.
- Quality of Water available for recharge- Physical, Chemical, Biological quality of recharge water helps in deciding what kind of treatment, costing of treatment plant is required. If suspended solids are present in recharge water it is more applicable for surface technique rather than sub surface. However induced recharge is the best method in such cases. Also recharge water should be chemically compatible to the aquifer material through which it passes like it should be free of color, turbidity, toxic substances, organic material, algae and bacteria.
- Hydrogeological Conditions- These aspects need to be studied for appropriate selection of recharge site and type of recharge structure. The parameters to be considered are study of hydraulic boundaries, inflow and outflow of waters, storage capacity, hydraulic conductivity, water resources available, natural recharge occurring if any, depth of aquifer, tectonic boundaries and the type of geological formation existing in the area. Thus the aquifers best suited for Artificial Recharge are those which can absorb large quantities of water and release them slowly. That means the vertical hydraulic conductivity should be high.

*Potential of artificial recharge for NCT, Delhi*

The average annual rainfall of Delhi is 611.8mm of which 533.1mm occurs during monsoon period (June to September). Considering a 30% runoff coefficient in urban areas, 12 % in other areas, the runoff availability for Delhi is found to be 162 MCM. Alongwith this surplus monsoon runoff available for Yamuna is 282 MCM which makes a total of 444 MCM runoff available for recharge.

Since the potential recharge areas are at higher elevation than Yamuna, so it is not feasible to drive the water against action of gravity. Thus the only available surface runoff is 70.45 MCM. Out of this 70.45 MCM, 4.45 MCM accumulates in quarries, depressions, bunds while the rest of 66 MCM is available for groundwater recharge.

Available water for
Groundwater Recharge
(66MCM)

Recharge
Structures
(0.4MCM)
(65.6MCM)

Rain water
Harvesting

*Thus net surplus runoff available from recharge areas is 65.6 MCM.*

Conclusion

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Inadequate water supply to meet domestic water requirement and steeply increasing population puts a pressure on groundwater resources. This in turn leads to salinity ingress in freshwater resources. Thus, the aim of recharge to groundwater is to replenish the groundwater resource and to conserve it. Groundwater is a common pool resource, its management and conservation is therefore a responsibility of all of us but due to over exploitation its resource potential is getting reduced. From the available literature, collected data, sections interpretation of Geophysical survey the following conclusions can be drawn out:

- The results obtained from both the methods; Geophysical Survey and AutoCAD sections are in accordance and suggest that the aquifer bearing zones are very narrow and exist at shallow depths. The water bearing strata exists from 20-40 m bgl and from 200-260 m bgl of which the upper zone is the potential aquifer zone as the zones at greater depth are economically not feasible. However the section along Najafgarh Drain has good aquifer zone even at greater depth from 160 to 260 m bgl. This is very important information for planning of groundwater structures and their sustainability.
- The water quality is moderate as EC values ranges from 1000-7000 (uS/cm) with shallow aquifers showing EC values < 2000 and deeper aquifers showing values > 2000 indicating that shallow aquifers have availability of freshwater.
- The cumulative runoff potential of the study area is 0.12 MCM. Considering only 70% of it is available for recharge (0.084 MCM), it needs to be efficiently utilized to improve the ground water level, quality & sustainability of ground water structures.
- The results of geophysical survey have clearly brought out the difference between saline and fresh water region and also occurrence of Saline-Fresh Interface which is interpreted from the resistivity values. The value of low resistivity depicts high conductivity which corresponds to the presence of saline water and vice versa.
- Since the study area is dominated by agricultural fields and shallow aquifer zone exist in the area so recharge to groundwater is necessary and is proposed at different sites according to the site characteristics. The artificial recharge practices can be carried out for agricultural areas where Recharge Well type structures are proposed, for Roads along the Najafgarh Drain and Rooftop Rainwater harvesting can also be practiced. Of all these measures Rooftop Rain Water Harvesting is the best option as the region is marked by extensive impervious layers and also rainwater once stored can be used directly.

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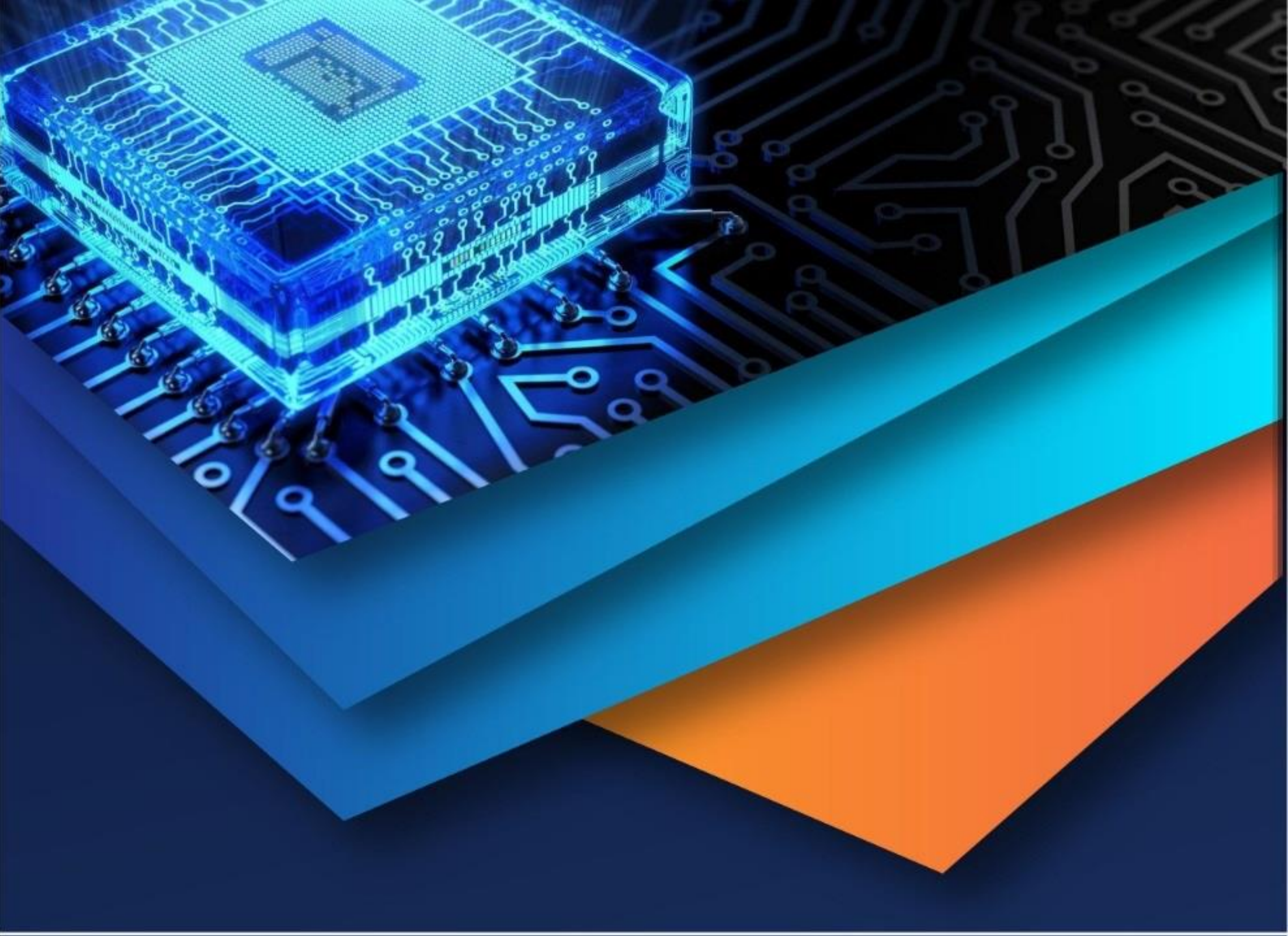


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