iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** V **Month of publication:** May 2018

DOI: http://doi.org/10.22214/ijraset.2018.5065

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

Assessment of Groundwater Potential Using Water Balance Approach in Sarojini Nagar Block of Lucknow District

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Abstract: Estimation of groundwater recharge and capacities of aquifer are essential issues in water resource investigation. In this study groundwater potential and stage of groundwater development of Sarojininagar block in Lucknow district was estimated using water balance approach during monsoon and non monsoon season. Groundwater balance equation from (Kumar, 2012) was used for the present study. Inflow parameters like recharge from rainfall, recharge from field irrigation, recharge from canal seepage, recharge from ponds and sub-surface inflow from other block where as outflow parameters like groundwater discharge from tube wells, change in groundwater storage and sub-surface outflow to other blocks were estimated by collecting various data from viable sources. The results obtained from the study reveals that various inflow parameters that is recharge from rainfall, recharge from field irrigation, recharge from canal seepage, recharge from ponds and sub-surface inflow from other block in monsoon season were calculated 36.36 Mm^3 (million cubic metre), 11.76 Mm^3, 339.77 Mm^3, 0.05793 Mm^3 and 0.04032 Mm^3 respectively where as during non monsoon period these inflow parameters were estimated 2.13 Mm^3, 30.85 Mm^3, 261.36 Mm^3, 0.0408 Mm^3 and 0.03924 Mm^3 respectively. Various outflow parameters that are groundwater discharge from tube wells and sub-surface outflow to other blocks in monsoon season were calculated 122.85 Mm^3 and 0.8193 Mm^3 respectively where as during non monsoon season these outflow parameters were calculated 292.70 Mm^3 and 1.1046 Mm^3 respectively. Change in ground water storage in monsoon and non monsoon season was calculated 0.199 Mm^3 and 0.0319 Mm^3 respectively. Stage of ground water development was estimated by using annual groundwater discharge and annual groundwater recharge (Kumar and Srinivas, 2009) and it is estimated 61.17 % which is coming under safe condition.
Keywords: Groundwater recharge, groundwater potential, water balance, groundwater development, groundwater discharge.

I. INTRODUCTION

In the present time the demand for groundwater is increasing due to rapid growth in population, industrial development, urbanization and increase in agricultural activities. It is necessary to maintain the groundwater reservoir in a state of dynamic equilibrium over a period of time and the water level fluctuations have to be kept within a particular range over the monsoon and non-monsoon seasons (Kumar, 2012). Therefore it is important to assess groundwater potential time to time for judicial use of ground water resource However, assessment of groundwater or aquifer potential is one of the most difficult factors to measure in the evaluation of groundwater resources. Estimation of recharge, by whatever method, is normally subject to large uncertainties and errors (Bansode and Patil, 2016). The most extensively used method to assess groundwater potential is groundwater balance equation. By using this method a quantitative estimation of recharge to the groundwater and discharge from the groundwater can be accomplished. It is essential to evolve all the components of groundwater balance equation through which recharge to the groundwater or discharge from the groundwater is occurring. In this study all the inflow and outflow components of water balance equation, annual recharge and discharge, change in groundwater storage and stage of groundwater development of Sarojininagar block of Lucknow district was estimated.

II. MATERIAL AND METHOD

A. Study Area

The study was conducted in Sarojininagar block of Lucknow district the capital of Uttar Pradesh which lies approximately at latitude 26°45´02´´ North and longitude 80°51´35´´ East covering an area of 311.20 km^2. Study area indicates that plains are mid land, old alluvial, nearly level to gently slopy, moderately well to well drained type. Texture of the soil upto 6 ft depth varies from silty loam to clay. Sarojininagar block is divided into 68 Gram Panchayat and 92 villages with a total population of 224045.

Sarojininagar block is 18 km from State capital Lucknow towards North. Sarojaninagar is bounded by Lucknow Tehsil towards North, Kakori Tehsil towards North, Asoha Tehsil towards South, Mohanlalganj Tehsil towards East. It is at 126 m elevation.

B. Study Period

It is desirable to conduct water balance study on part of year basis, that is, for monsoon period and non-monsoon period because generally, the periods for study in such situations will be from the time of maximum water table elevation to the time of minimum water table elevation as the non-monsoon period and from the time of minimum water table to the time of maximum water table elevation as monsoon period. The monsoon periods can be taken as June to October and non monsoon periods can be taken as November to May.

C. Data Required

The data required for carrying out the groundwater balance study is given below-

1) *Climatological Data:* Climatological data consists of rainfall data, maximum and minimum temperature, relative humidity, wind speed and maximum sun shine hours which is used in this study was collected from "GLOBAL WEATHER". Daily rainfall data of last 10 years was collected and examine for the study.
2) *Land Use Data and Cropping Patterns:* Land use data and cropping pattern data of the study area is collected from "Sankhyikiya Patrika".
3) *Tank Data/Pond Data:* A number of ponds along with their storage capacity of pond data were required. In this study the number of ponds and their storage capacity was obtained by survey.
4) *Canal Data:* Month wise water releases into the canal and its distributaries along with running days during each month are required to calculate seepage losses from canal and its distributaries. Canal data was collected from "Lucknow khand – 2 Sharda Nahar Lucknow Sichai Vibhag".
5) *Groundwater Data:* Monsoon and non monsoon groundwater level data, specific yield, transmissivity of aquifers of the block is needed to estimate various parameters. Groundwater data was collected from "Regional Groundwater Board Bhujal Bhawan, Lucknow".
6) *Discharge from Wells:* For estimating groundwater withdrawals, the number of each type of wells operating in the area, their corresponding running hours of each month and discharge is required. This data is collected from "SANKHYIKIYA PATRIKA". Running hours and discharge was taken from personal survey of the block.

D. Groundwater Balance Equation

Inflow to the system – outflow from the system = change in storage of the system (over a period of time)

A groundwater balance equation is proposed by (Kumar, 2012) adopted for the assessment of groundwater resources.

$$R_r + R_c + R_i + R_t + I_g = E_t + T_p + O_g + \Delta S \qquad (1)$$

Where,

R_r = recharge from rainfall

R_c = recharge from canal seepage

R_i = recharge from field irrigation

R_t = recharge from tanks/ponds

I_g = inflow from other blocks

E_t = evapotranspiration

T_p = discharge from groundwater

O_g = outflow to other blocks

ΔS = change in groundwater storage.

Influent and Effluent seepage from rivers was deleted from the main equation as its effect is negligible in the Sarojininagar block as no river is passing through the block area.

E. Estimation of Groundwater Balance Components

1) Recharge from Rainfall (R_r): Recharge from rainfall was calculated using (Chaturvedi, 1936), which was modified by further work at the Irrigation Research Institute, Roorkee (Kumar, 2012).

$$R_r = 1.35\,(P - 14)^{0.5} \qquad (2)$$

Where,
R_r = net recharge due to precipitation during the year (inches)
P = annual precipitation (inches)
Recharge from rainfall in study area = Rechargable area A × R_r (Maurya and Sherring, 2015).

2) Recharge from Canal Seepage (R_c): Recharge from canal seepage was estimated using a formula from (Kumar, 2012).

$$R_c \text{ (cumecs/km)} = \frac{c}{200} (B+D)^{2/3} \quad (3)$$

Where, B and D are the bed width and depth of the channel in meters. C is a constant, being 1.0 for intermittent running channels and 0.75 for constant running channels. In this study the value of c is taken as 1. Further R_c (cumecs/km) is multiplied with average canal length in (km).

3) Recharge from Tanks/Ponds (R_t): Seepage from tanks varies from 9 to 20 percent of their live storage capacity. However, as data on live storage capacity of large number of tanks may not be available, seepage from tanks may be taken as 44 to 60 cm per year over the total water spread, taking into account the agro-climatic conditions in the area (Kumar, 2012). In this study seepage from tanks is taken as 16 % of their live storage capacity.

4) Recharge from Field Irrigation (R_i): Potential evapotranspiration ET_o is calculated by using Penman Monteith equation (FAO 56) on daily basis for last ten years of the study area.

$$ET_o = \frac{0.408\Delta(Rn-G) + \gamma\frac{900}{T+273}u2(es-ea)}{\Delta + \gamma(1+0.34\,u2)} \quad (4)$$

Where,
ET_o = potential evapotranspiration [mm day^{-1}]
R_n = net radiation at the crop surface [MJ m^{-2} day^{-1}]
G = soil heat flux density [MJ m^{-2} day^{-1}]
T = air temperature at 2 m height [°C]
u_2 = wind speed at 2 m height [m s^{-1}]
e_s = saturation vapour pressure [kPa]
e_a = actual vapour pressure [kPa]
e_s-e_a = saturationvapour pressure deficit [kPa]
Δ = slope of vapour pressure curve [kPa °C^{-1}]
γ = psychrometric constant [kPa °C^{-1}].

Crop water requirement is the amount of water needed by the various crops to grow optimally it can also be defined as the depth or amount of water needed to meet the water loss through evapotranspiration. In this study for calculating crop water requirement on daily basis, following formula was used:

$$ET_c = ET_o \times K_c \quad (5)$$

Where,
ET_c = Crop evapotranspiration [mm day^{-1}]
ET_o = Potential evapotranspiration [mm day^{-1}]
K_c = Crop coefficient

Net irrigation requirement and Gross water requirement was calculated by using following formula:

Net irrigation requirement = Crop water requirement – Effective rainfall (6)

Effective rainfall is the amount of rainfall that is actually added and stored in the soil.

$$\text{Gross water requirement} = \frac{Net\ irrigation\ depth}{Ea\ (Application\ efficiency)} \quad (7)$$

In 2009 Groundwater Estimation Committee has recommended the following norms for return seepage from irrigation fields:

Table1: Percentage of water delivered at the outlet contributing for return seepage from field irrigation

Irrigation Sources	Paddy Crop	Non-Paddy Crop
Surface water	40%	35%
Groundwater	35%	30%

5) Evapotranspiration from Groundwater (E_t): Evapotranspiration from groundwater occurs in waterlogged areas. During well inventory, investigation should be specifically oriented towards accurately delineating water table depth for depths less than 2 meters (Kumar, 2012). As in the study area depth of water level is found to be in between 7-14 meters below ground level therefore evapotranspiration from groundwater in the study area was found to be negligible as evapotranspiration effectively occurs at water level depth till 2 meters below ground level only.

6) Inflow from and Outflow to Other Basins (I_g and O_g): Subsurface inflow-outflow was estimated by using water table elevation which is calculated by using water level data for monsoon and non monsoon period of the study area, elevation of the study area, which is calculated from Google Earth. The flow into the block or out of the block is governed mainly by the hydraulic gradient and transmissivity of the aquifer. In this study Darcy's law was used for the calculation of subsurface inflow-outflow which is based on the equation from (Kumar, 2012).

$$Q = T\, I\, L \qquad (8)$$

Where,

Q = Flow across the boundary (m^3/day)

T = Transmissivity of the aquifer (m^2/day)

I = Hydraulic gradient (m/km)

L = Average length of contour line (km).

7) Groundwater Discharge from Tube Wells (T_p): Groundwater discharge or Draft is the amount of water lifted from the aquifer by means of various lifting devices. The withdrawal can be made by means of state tube wells, private tube wells and open wells. Following equation was used in this study to compute the ground water discharge from tube wells (Maurya and Sherring, 2015).

$$T_{w1} = \text{Number of annual average running days} \times \text{Average number of running hours} \times \text{Discharge from well } (m^3/hr) \qquad (9)$$

$$T_{p1} = T_{w1} \times n \qquad (10)$$

Where,

T_{w1} = Discharge of a well in block during monsoon and non monsoon period

n = Number of wells in the block

T_{p1} = Total groundwater discharge from tube wells in study area.

F. Change in Groundwater Storage (ΔS)

Water levels are highest immediately after monsoon in the month of October or November and lowest just before rainfall in the month of May or June. During the monsoon season, the recharge is more than the extraction; therefore the change in groundwater storage between the beginning and end of monsoon season indicates the total volume of water added to the groundwater reservoir. While the change in groundwater storage between the beginning and end of the non-monsoon season indicates the total quantity of water withdrawn from groundwater storage. In this study the change in storage (ΔS) was calculated by using the following formula (Kumar, 2012).

$$\Delta S = \Delta h \times A \times S_y \qquad (11)$$

where,

Δh = change in water level (m)

A = rechargeable area of the block (m^2)

S_y = specific yield.

G. Estimation of Stage Groundwater Development

The groundwater assessment unit is categorized into different categories – Safe, Semi Critical, Critical and Over Exploited based on groundwater resource available and groundwater discharge. It is calculated using the following equation (Kumar and Srinivas, 2009).

$$\text{Stage } (\%) = \frac{\text{Annual net groundwater draft}}{\text{Annual net groundwater recharge}} \times 100 \qquad (12)$$

Various stages of groundwater are as follows:

1) Safe – groundwater development is < 70%

2) *Semi Critical – groundwater development is in between 70-90%*
3) *Critical – groundwater development is in between 90-100%*
4) *Over Exploited – groundwater development is > 100%*

III. RESULTS

From Fig. 1 it is clearly visible that in monsoon season maximum recharge in the study area was happened through canal seepage (R_c) that is 339.77 Mm³ which is followed by recharge through rainfall (R_r) that is calculated 36.36 Mm³, which is further followed by recharge through field irrigation (R_i) that is calculated 11.76 Mm³. Minimum recharge in study area is happened through recharge from tanks/ponds (R_t) and groundwater inflow in block (I_g) that is calculated 0.05 Mm³ and 0.04 Mm³ respectively. Recharge from canal seepage is high because length of canal running through the block is 170 km which translates a large area under canal. Whereas due to monsoon season lot of rainfall is received by the study area which results a good amount of recharge from rainfall. Whereas in non monsoon season again maximum recharge is happened in the study area through canal seepage (R_c) that is calculated 261.36 (Mm³) which is followed by recharge through field irrigation (R_i) that is calculated 30.85 (Mm³). Minimum amount of recharge in non monsoon season in the study area is happened through recharge from rainfall (R_r), recharge from tanks/ponds (R_t) and groundwater inflow in block (I_g) that is calculated 2.13 (Mm³), 0.04 (Mm³) and 0.039 (Mm³) respectively. There is a good amount of recharge happening from field irrigation in non monsoon season due to the cropping pattern in the study area. From Fig.1 we can easily compare the recharge happened by different components of groundwater balance equation in monsoon and non monsoon season. Recharge from rainfall (R_r) is greater in monsoon season as compared to non monsoon season because maximum amount of rainfall is received by the study area in monsoon season. Recharge from field irrigation (R_i) is greater in non monsoon season as compared to monsoon season because of the cropping pattern in the study area. Recharge from canal seepage (R_c) is greater in monsoon season as compared to non monsoon season because number of running days of canal in monsoon season is more than the non monsoon season in the study area. As well as due to the rainfall in monsoon season most of the area under canal remains saturated with water for maximum days as compared to the non monsoon season. Recharge from tank/pond (R_t) is greater in monsoon season because of rainfall the depth of water in the ponds increases which further increases the total volume of water stored in ponds which results greater recharge from tank or pond in monsoon season as compared to non monsoon season.

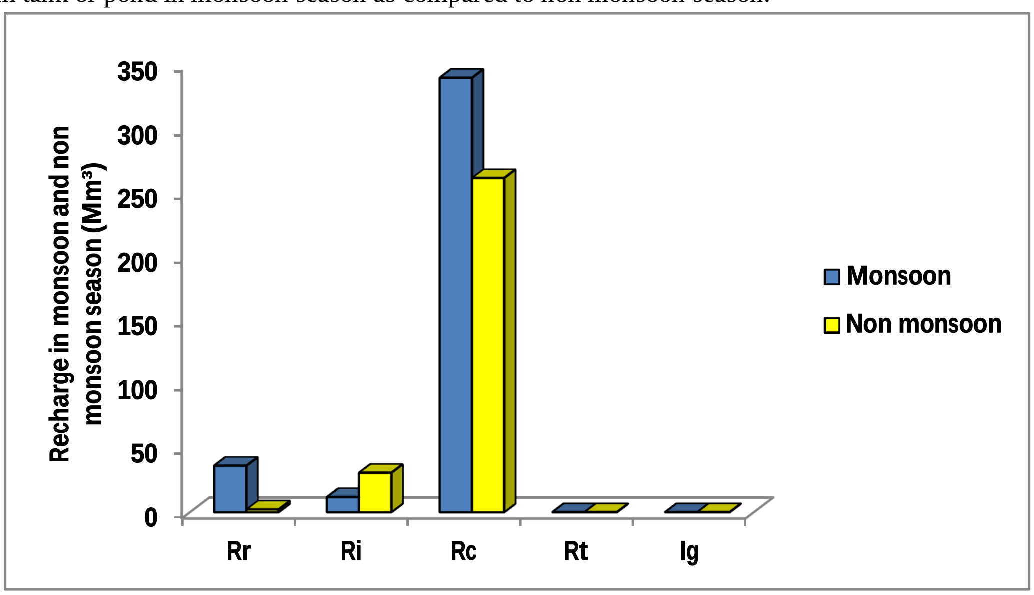

Fig. 1 Recharge in monsoon & non monsoon season through different components

As it is clearly visible from Fig. 2 that maximum discharge happening in monsoon season is through the groundwater discharge from tube wells (T_p) in the study area that is calculated 122.85 Mm³. Minimum discharge from ground water in monsoon season is happening from ground water outflow (O_g) to Kakori and Chinhat Block which is calculated 0.025 Mm³ and 0.794 Mm³ respectively. Whereas in non monsoon season again the maximum discharge is happening through the groundwater discharge from tube wells (T_p) in the study area that is calculated 292.7 Mm³. Minimum discharge from ground water is happening from ground water outflow (O_g) to Kakori and Chinhat Block which is calculated 0.018 Mm³ and 1.085 Mm³ respectively. From Fig. 2 we can easily compare the

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

discharge happened by different components of groundwater balance equation in monsoon and non monsoon season. Discharge from tube wells (T_p) is greater in non monsoon season as compared to monsoon season because due to very less rainfall in non monsoon season dependency on water from tube wells increases for various personal as well as agricultural needs.

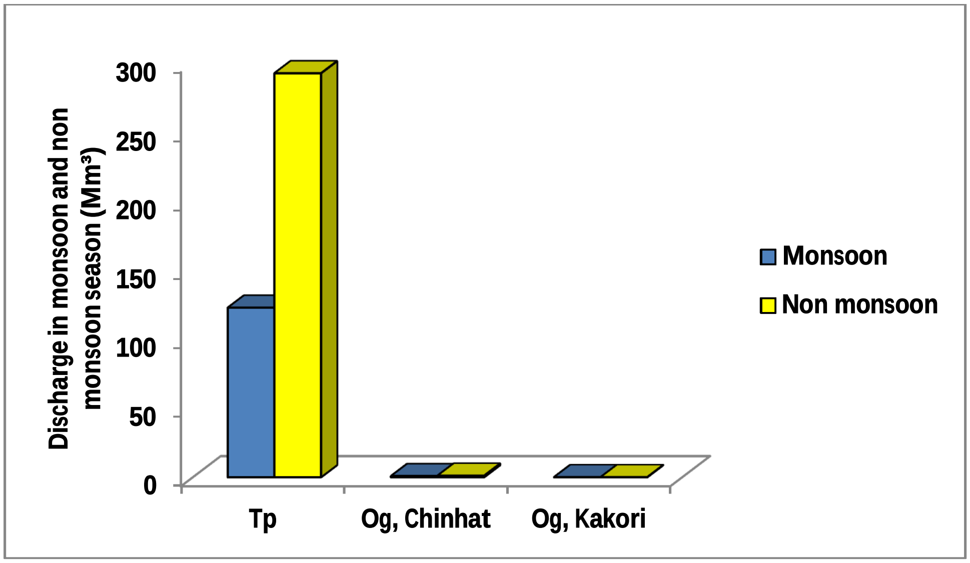

Fig.2Discharge in monsoon & non monsoon season through different components

In monsoon season change in groundwater storage was calculated 0.1999Mm³ and in non monsoon season it is calculated 0.0319 Mm³ for the study area. As it can be seen from Fig. 3 change in storage is higher in monsoon season as compared to non monsoon season. Fig. 4 shows total annual groundwater Recharge was calculated 682.41 Mm³ where as total discharge was calculated 417.48 Mm³ in Sarojininagar block. In this study stage of groundwater development was under Safe condition as it was calculated 61.17 % for Sarojininagar block.

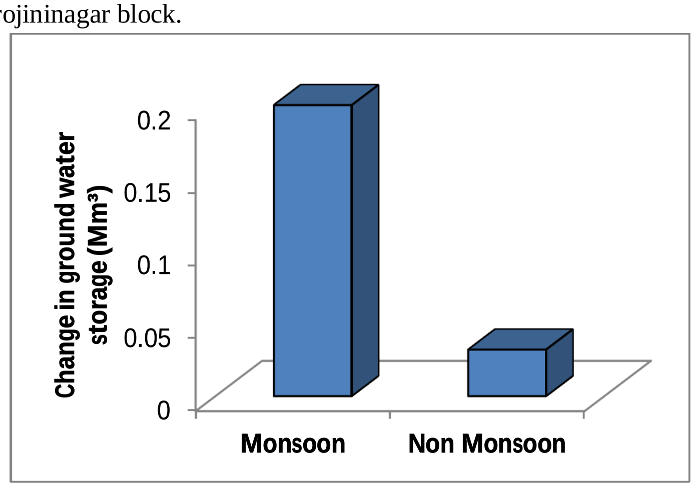

Fig. 3 Change in groundwater storage (ΔS)

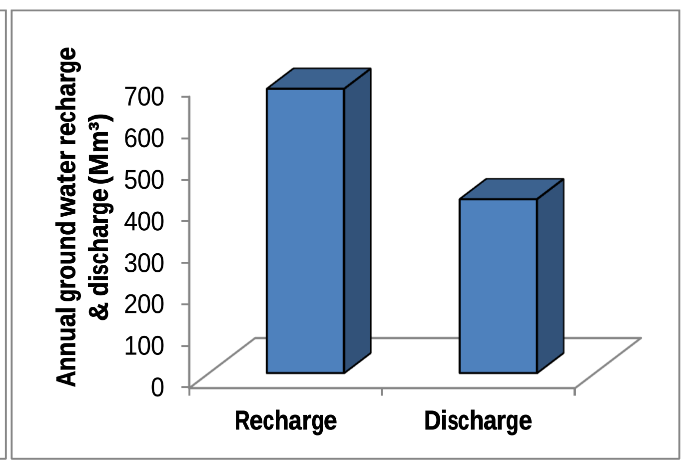

Fig. 4 Annual groundwater recharge and discharge

IV. CONCLUSIONS

The maximum inflow in Sarojininagar block was happened through recharge from canal seepage as that is 339.77 Mm³ and 261.36 Mm³ in monsoon and non monsoon respectively. The maximum outflow in Sarojininagar block was happened through groundwater discharge from tube wells that is 122.85 Mm³ and 292.7 Mm³ in monsoon and non monsoon respectively. In this study, stage of groundwater development was under Safe condition as it was calculated 61.17 % for Sarojininagar block.

V. ACKNOWLEDGEMENT

I would like to thank Prof. (Dr.) i.r. D. M. Denis, Professor and Head, Department of Irrigation & Drainage Engineering, Dr. Alex Thomas, Head Department of Soil & Water Conservation Engineering, Prof. (Dr.) R. K. Pandey, Professor, SIET, Dr. Arpan Sherring, Associate Professor, Department of Irrigation & Drainage Engineering, Vaugh Institute of Agricultural Engineering & Technology, Sam Higginbottom University of Agriculture Technology & Sciences, Allahabad, Uttar Pradesh, India for their esteemed stewardship, guidance & hopeful counseling.

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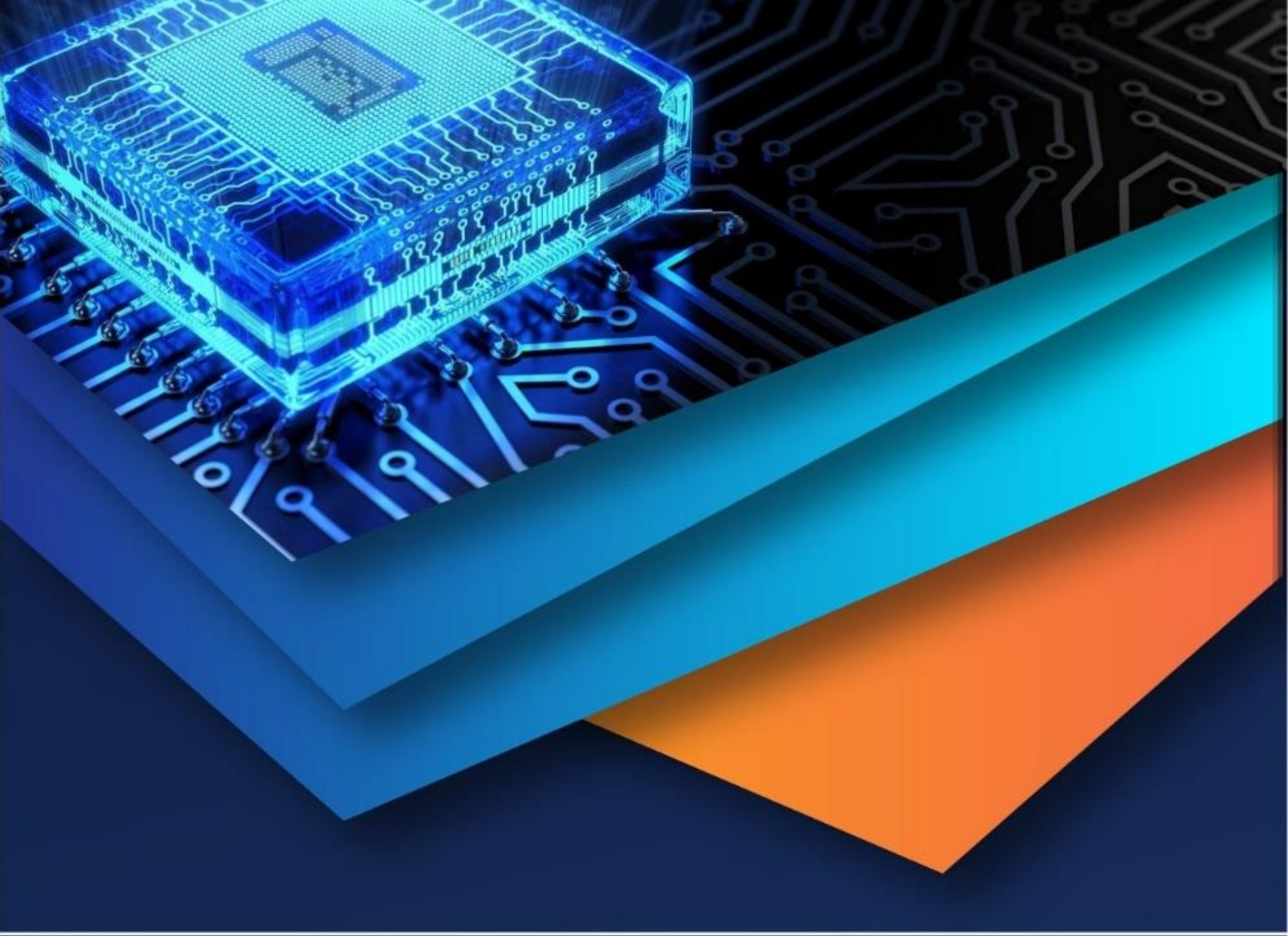

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