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Spatial Analysis of Groundwater Quality of an Industrial District of Punjab (Ludhiana) using Geographic Information System - A Case Study

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Abstract: Groundwater is the main source of water for human-use for drinking, domestic and industrial purposes. Now a days, groundwater is getting more and more contaminated each day due to increase in industrialisation and other human activities like use of fertilizers and pesticides etc. In this study, a total of 13 water quality monitoring stations were identified and water samples were collected from tube wells in various identified sampling locations during the beginning of the month of October, 2018 and the end of the month of March,2019. The obtained groundwater samples were analysed for the parameters which include pH, EC, sulphates, nitrates, chlorides, carbonates, bicarbonates, phosphates, TH, fluorides, Ca(II), Mg(II) using standard methods and the values obtained for both of the months were averaged to generate the data for the year 2018-2019. Also, geographic information system-based groundwater quality mapping in the form of spatial distribution maps for distribution of physico-chemical parameters of the groundwater samples were developed using Arc-GIS software. The final integrated map presents the entire study area divided in the form of three priority classes as Excellent, Good and Poor groundwater quality zones of the study area and provides the locational distribution of water quality and helps in suggesting if the groundwater is suitable for domestic and other purposes.

I. INTRODUCTION

Groundwater is an extremely important source of water for drinking purposes as it is often free from contaminants because it is widely dispensed and adjusts throughout the year. Most of the population in India depends upon groundwater for their daily needs. Groundwater often gets contaminated due to various human activities such as industrialisation, commercialisation and other domestic and agricultural activities.

GIS is a software which is used to capture, store, analyse, manage and showcase all types of geographical data. GIS is a very effective tool which plays a great role in water resource management and groundwater quality mapping and detection of any environmental change. Some studies have shown classification of groundwater quality by the correlation of their total dissolved solids(TDS) values with some aquifer characteristics or land cover. A GIS-based method- groundwater quality index method has been proposed by Babiker et al. which classifies different available water quality data by indexing them numerically to the WHO standards. Other studies has used GIS for the preparation of maps to analyse the quality of the groundwater by using the available physicochemical parameter data.

In such studies, the entire area is divided into various zones according to the quality of their groundwater which can be used for irrigation and domestic purposes. The assessment of various natural resources such as air pollution and groundwater pollution has been greatly simplified by the use of GIS.

Barber et al. carried out a GIS based groundwater study to analyse the effect of urbanisation on groundwater quality in relation to the land-use changes. Rahman et al. determined the groundwater vulnerable zones in shallow aquifers in Aligarh and its surrounding areas using GIS mapping. Krishnaraj et al. used GIS to divide the entire area of the Karur districts into groundwater quality zones using parameters like TDS and WQI. Nas et al. have mapped the groundwater quality if Konya city and central part of Turkey with GIS. A map for groundwater quality is important for any city to understand and evaluate the safety of water for drinking, agricultural and various other uses. It also can be used as an indication for potential environmental health problems.

Muzaffar et al. used GIS based interpolation technique called IDW i.e. Inverse Distance Weight to estimate spatial distribution of groundwater quality parameters. Present study aims to map the spatial distribution of various groundwater quality parameters for Ludhiana district using GIS.

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II. MATERIALS AND METHODS

A. *Study Area*

The Ludhiana district of Punjab, India is located between North latitude $30^0 33'$ and $31^0 01'$ and East longitude $75^0 25'$ and $76^0 27'$. The geographical area of the district is 3790 sq.kms. The normal annual rainfall of the district is 680 mm which is unevenly distributed over the area in 34 days. The Satluj forms the border of the district in the North with Jalandhar and Hoshiarpur districts.

Figure 1. Map showing the study area with sampling locations

Establishment of many small, medium and large scale industries which are mainly textile industries has resulted in the adverse effect on groundwater of this region. In addition to the increased industrialisation, the increased population in the study area has resulted in the deterioration of the groundwater quality.

B. *Sample Collection*

A total of 13 water quality monitoring stations were identified(Fig.1) and water samples were collected from tube wells in various identified sampling locations during the beginning of the month of October, 2018 and the end of the month of March, 2019.

C. *Parameters Under Monitoring*

The obtained groundwater samples were analysed for the parameters which include pH, EC, sulphates, nitrates, chlorides, carbonates, bicarbonates, phosphates, TH, fluorides, Ca(II), Mg(II) using standard methods. The values obtained for all of the parameters for both of the months were averaged to generate the data for the year 2018-2019.

D. *Water Quality Index(WQI)*

WQI of groundwater was calculated using the following steps.

1) *Step I:* A weight(w_i) was assigned to each of the parameters according to their relative importance in the overall quality of water for drinking purpose ranging from a maximum of 5 to 2 as the importance of the parameter for drinking purpose decreases.
2) *Step II:* Relative weight(W_i) for each parameter was calculated by the equation given below:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \qquad equation(i)$$

3) *Step III:* According to the guidelines laid by BIS, a quality rating scale(q_i) for each parameter was calculated using the equation below:

$$q_i = \frac{c_i}{s_i} * 100 \qquad equation\ (ii)$$

where c_i = concentration of the chemical parameter
s_i = Indian drinking water standard for each parameter

4) *Step IV:* Sub-index for each parameter was calculated as:

$$SI_i = W_i * Q_i \qquad equation\ (iii)$$

5) *Step V:* Finally WQI was calculated by aggregating all the obtained sub-indices i.e.

$$WQI = \sum_{i=0}^{n} SI \qquad equation\ (iv)$$

Table 1. Water quality classification based on WQI value

S.No.	WQI	Water Quality
1.	<50	Excellent
2.	50-100	Good
3.	100-200	Poor
4.	200-300	Very Poor
5.	>300	Unsuitable

Table 2. Water Quality Guidelines BIS Standards - 10500:2012

S.No.	Parameters	Acceptable (ppm)	Max. Allowable (ppm)
1.	pH	7	8.5
2.	Total Hardness (as $CaCO_3$)	300	600
3.	Chloride (as Cl)	250	1000
4.	Fluoride (as F)	1.0	1.5
5.	Sulphate (as SO_4)	200	400
6.	Calcium (as Ca)	75	200
7.	Magnesium (as Mg)	30	100
8.	Nitrate (as NO_3)	45	45

III. RESULTS AND DISCUSSION

A. Hardness

Hardness in water is primarily caused due to the presence of carbonates and bicarbonates of calcium and magnesium and can also be caused due to sulphates, chlorides and nitrates. The Total Hardness was classified into four classes (140-224.5 mg/l ; 224.5-309 mg/l; 309-393.5 mg/l and 393.4-478 mg/l) and the spatial variation map was prepared based on these ranges and is presented in Fig.2. It was observed from the map that low ranges of Total Hardness was observed at 7 locations out of the total locations i.e. in the upper north region (<300mg/l i.e. permissible limit).Then at the remaining locations hardness was found to be high (300-600 mg/l) i.e. in the lower region of the Ludhiana district.

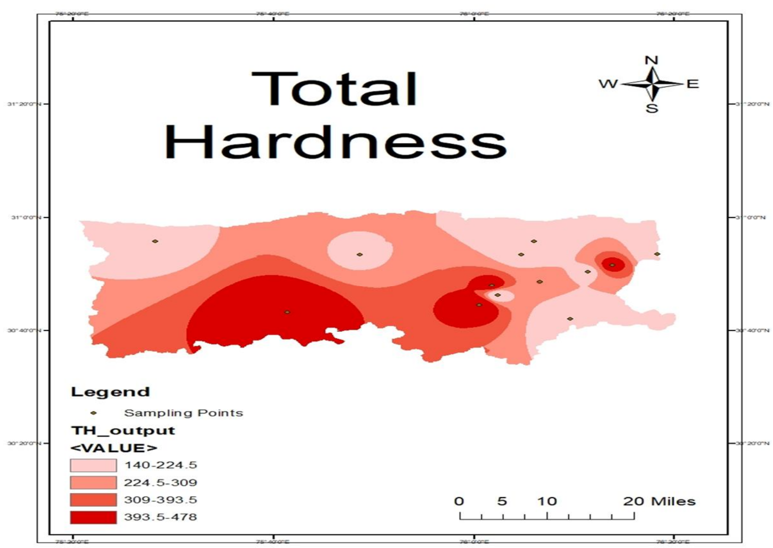

Figure 2. Spatial Distribution of Total Hardness

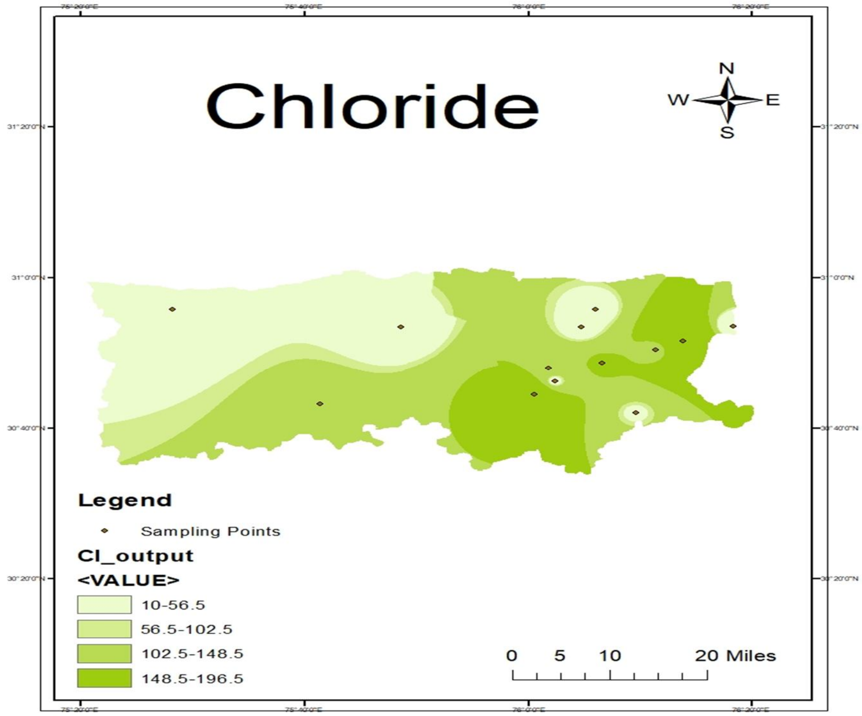

Figure 3. Spatial Distribution of Chloride

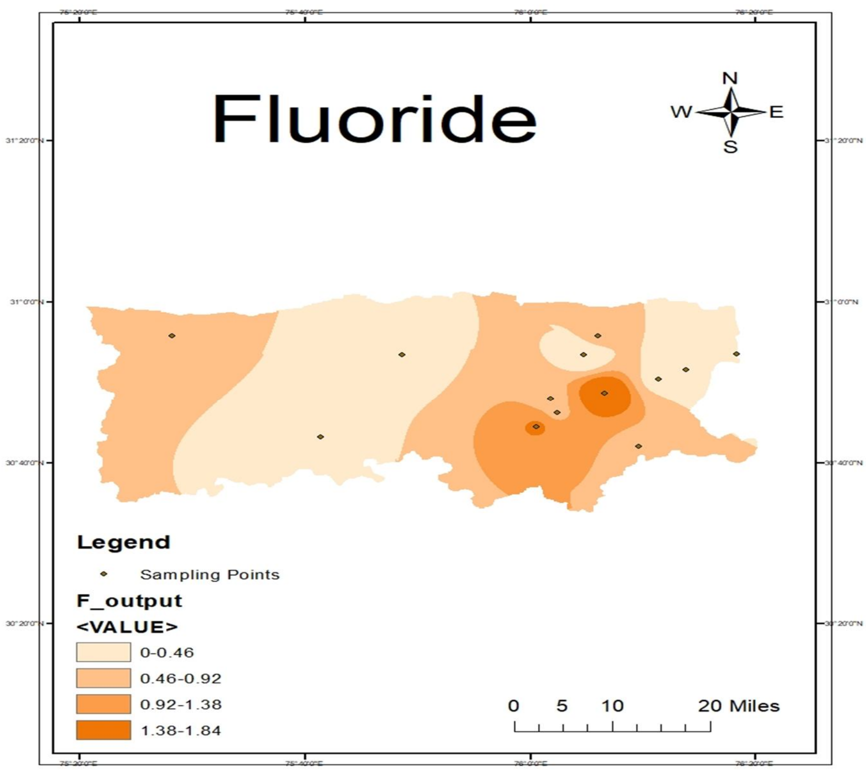

Figure 4. Spatial Distribution of Fluoride

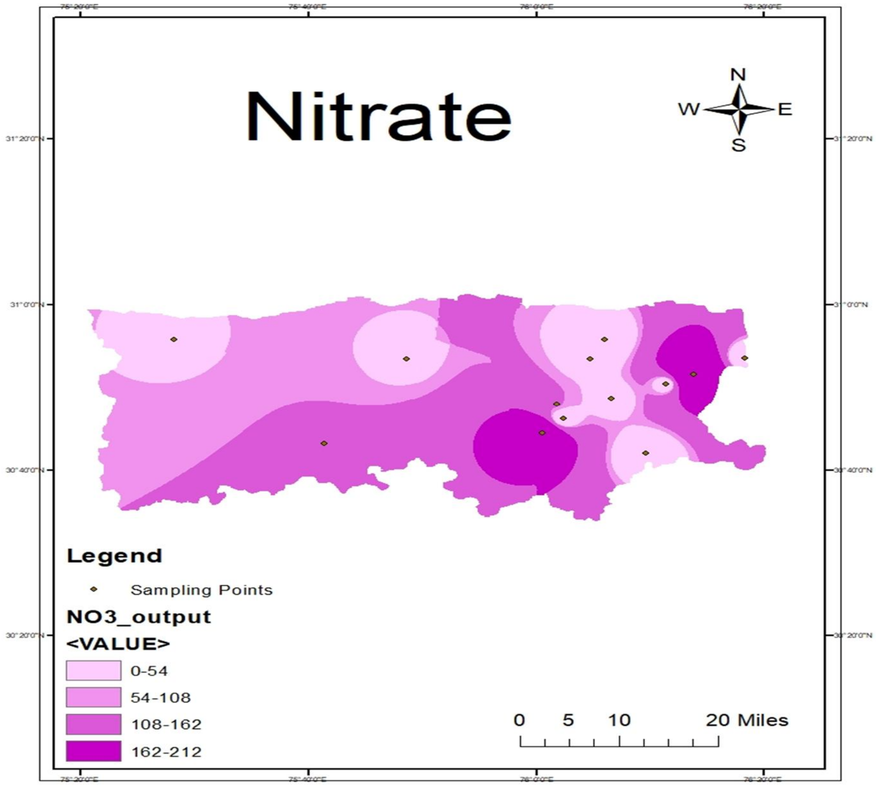

Figure 5. Spatial Distribution of Nitrate

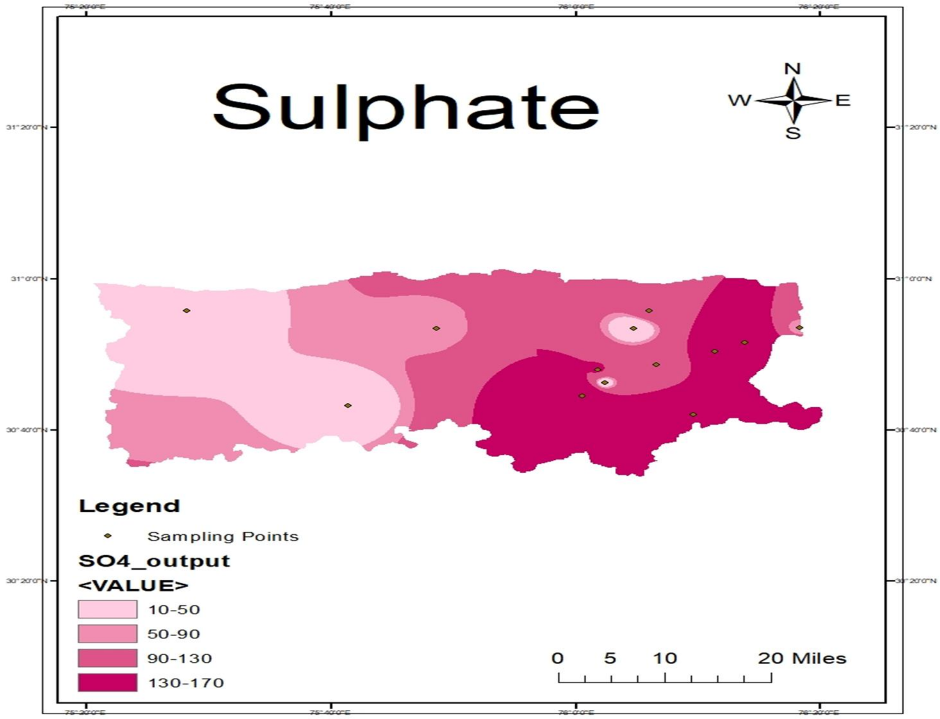

Figure 6. Spatial Distribution of Sulphate

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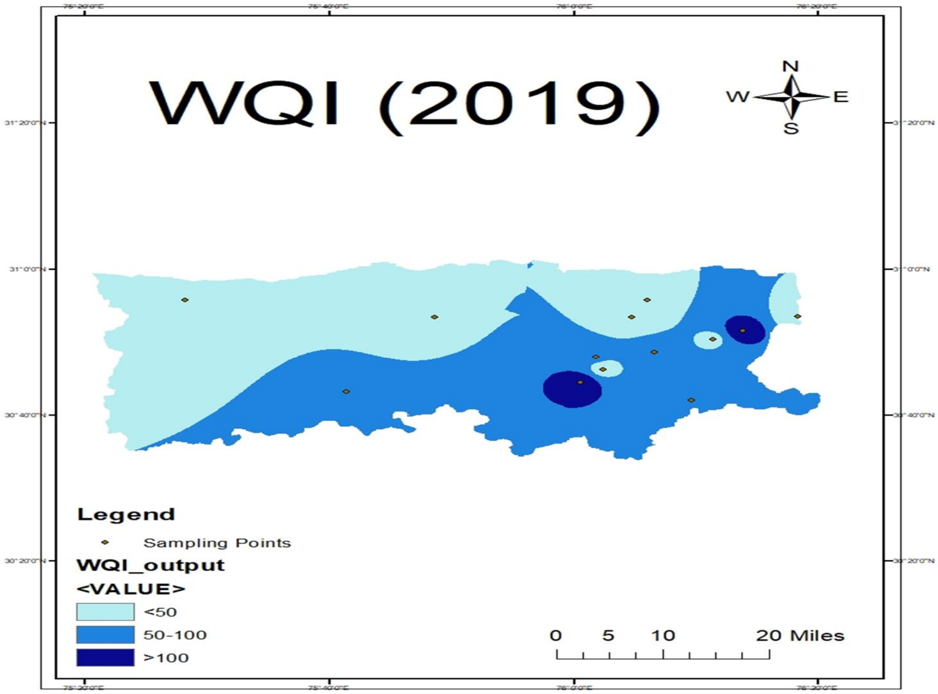

Figure 7. Spatial Distribution of WQI

B. Chloride

Chloride is one of the most important chemical parameter in estimation of the quality of water and higher concentration of chloride indicates higher amount of organic pollution. Permissible limit of chloride content in drinking water according to BIS is 250mg/l. In the study area, spatial distribution of chloride was obtained due to chloride content fluctuating between 10-196.5 mg/l (as shown in Fig.3.). Therefore, in the current analysis it was observed that chloride content in all the areas is less than the permissible values.

C. Fluoride

Fluoride is present in the groundwater usually due to the dissolving of the geological formations in it. The desirable range of fluorides in groundwater as stated by the BIS is 0.5-1.5mg/l, and water is considered to be of poor quality beyond this limit. The spatial distribution for fluorides was obtained in the study region for fluoride content ranging from 0 mg/l to 1.84 mg/l (as shown in Fig.4.). A small part in the south-east region of the district have poor range > 1.5 mg/l (exceeding the higher limit) of fluoride contents.

D. Nitrate

The permissible limit for nitrate content in the drinking water according to BIS is 45mg/l. An increase in the nitrate content of drinking water can be dangerous for human beings and can cause blue-baby disease in children. Water having more than 45 mg/l of nitrate content is considered of poor quality. The spatial variation in nitrate content in the Ludhiana district has been shown in Fig.5. by dividing the region into 4 classes in accordance with the nitrate content present in them (0-212 mg/l). It was observed that the water from two of the sampling locations i.e. Mushkabad and Ikolahi region had more than the permissible amount of nitrate content i.e. 212.84 mg/l and 137.2 mg/l respectively.

E. Sulphate

High concentration of sulphate in drinking water when combined with calcium and magnesium can result in a laxative effect. Sulphates can be present in groundwater due to discharge of effluents from mines, wood-pulp industries and leather-tanning industries. The study area has been divided into 4 classes w.r.t. the amount of sulphate present in the groundwater. The amount of sulphate content that is permissible in drinking water according to B.I.S. is 200-400 mg/l. As observed from Fig.6. the water in the entire district is fit for drinking purpose.

F. Water Quality Index (WQI)

Fig.7. shows the spatial distribution of WQI in the study area with values ranging from 52 to 161. Major area of Ludhiana district i.e. Ludhiana city, Panjeta, Sherian and Sidwabet region is found to have good quality water with WQI ranging from 0-50. From the map it was observed that Maksudra and Mushkabad had the worst quality of groundwater (WQI ranging from 100-200). The south-east part of the study area had moderate quality of water with WQI ranging from 50-100.

IV. CONCLUSION

The present study was conducted to analyse the groundwater quality of Ludhiana district by the use of GIS combined with analytical data. The spatial distribution maps of Total Hardness, Chloride, Fluoride, Nitrate and Sulphate shows that these parameters were not within the permissible limits as given by B.I.S throughout the study area uniformly. Also, the WQI analysis suggested that the groundwater in Mushkabad (WQI=153.93) and Maksudra (WQI=161.34) is of poor quality and is not fit for drinking and other agricultural purposes. This may be due to the discharge of untreated harmful effluent in the environment or due to the excessive use of fertilisers and pesticides for agricultural practices in both of these regions.

The spatial variation maps for various chemical parameters are used to demonstrate the locational distribution of water quality and helps in suggesting if the groundwater is suitable for domestic purposes.

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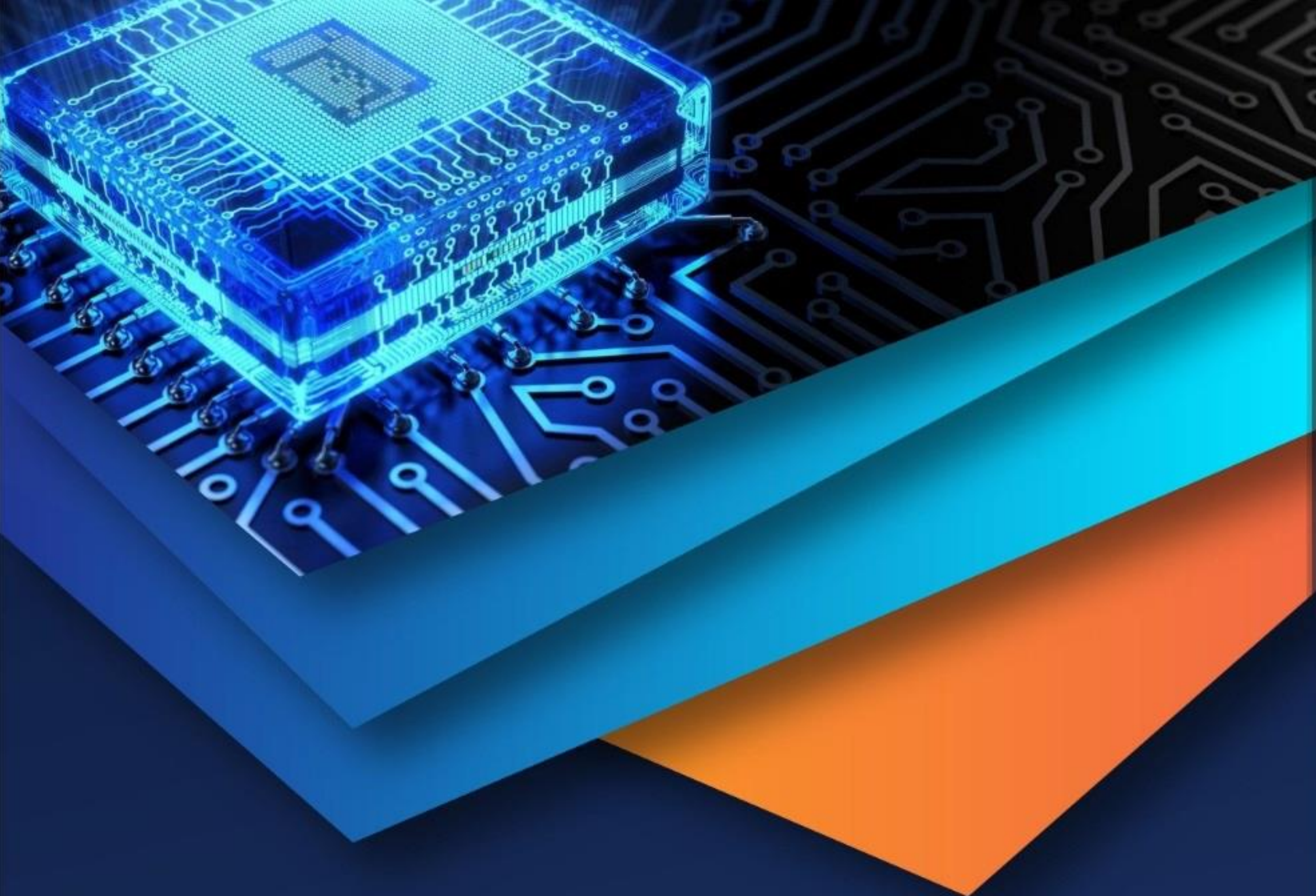

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