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Analysis of Leachate from the Municipal Solid Waste Disposal Site and Its Impact on Ground Water Quality at Lucknow Cantonment

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***Abstract:** Open dumping of municipal solid waste is prone to groundwater contamination because of leachate production. In this report, an attempt has been made to assess the pollution potential of leachate generated from the solid waste disposal site and its impact on aquifers in Neil line Lucknow environs, Uttar Pradesh, India. Physico-chemical parameters of leachate are determined to evaluate leachate pollution index (LPI) .A large amount of the water requirement of Lucknow City is supplied from groundwater. The quality of this groundwater was determined by taking samples from wells within the study area. The purposes of this investigation were to provide an overview of present groundwater quality. To determine spatial distribution of groundwater quality parameters such as pH, electrical conductivity, C^{l-}, SO_4^{-2}, hardness, and NO^{3-} concentrations, and To map groundwater quality in the study area by using GIS and Geostatistics techniques. ArcGIS 9.0 and ArcGIS Geostatistical Analyst is used for generation of various thematic maps and ArcGIS Spatial analyst to produce the final groundwater quality map .*
***Keywords:** LPI, Heavy metals,GIS maping, Transport*

I. INTRODUCTION

This d Presently, India produces 90 million tons of municipal solid waste (MSW) annually. MSW is made up of different organic and inorganic fractions like food, vegetable, paper, wood, plastics, glass, metals, and other inert materials. In Lucknow, it is collected by the municipalities and transported to designated disposal sites (Mor et al. 2006). Due the rapid increase in production and consumption, urban society rejects and generates solid material regularly which leads to a huge increase in the volume of waste generated from several sources such as household, commercial, institutional wastes etc. So waste is a progressively growing problem at the global and regional level as well as the local levels. The main problem is proper disposal sites have not until been identified by many municipalities and those are identified are exhausted creating a major threat for the land, air, and water quality of the nearby areas.

The open dumping of solid waste causes a crucial impact on all the components of environment (Sharholy 2007). With increase in population and growth of industrialization, groundwater quality is being increasingly destroyed by the disposal of urban and industrial solid waste (Raju et al. 2011; Singh et al. 2015a).

After dumping o solid waste in low-lying areas, they may come into contact with groundwater or rain water along with run-off resulting in the generation of leachate (Akinbile et al2012) Such leachate contains innumerable hazardous and inimical chemicals which, if introduced into groundwater, would impact its quality or destroy the ability to use it for drinking and other domestic use (Naqa 2004; Cumar and Nagaraja 2011).

The rate of depletion of groundwater levels and deterioration of groundwater quality is of immediate concern in major cities and towns of the country (Raju 2006; Prasanna et al. 2011).

Lucknow is the capital city of the most populated state of Uttar Pradesh and is one of the rapidly developing urban centers of India. Lucknow district is a part of Central Gangatic Plain covering an area of 2, 528 km^2 . and lies in middle of North latitudes 26°30' and 27°10' and East longitudes 80°30'and 81°13' with total population of 34 lakhs as per 2011 (Anonymous, 2011). The city is facing a frequent change in environmental quality. Rapid urbanization leads to number of problems as it places large demand on land, water, housing, transport, health, Education etc (Gyananath et al., 2001). The city has an alarming increase in population, it increased from 0.497 million in 1951 to 2.267 million in 2001 and 2.714 million in 2006 to 3.306 in 2011 increased 4.56 times (456 per cent) during the last fifty years. The growth rate of Lucknow (UA) was at 7.12% per annum (Lucknow Master Plan, 2010). This rising population density has vast impact on natural resources of the area majorly on water quality and quantity.

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II. STUDY AREA

Lucknow district of Uttar Pradesh, India, has been introduce in detail. The whole city is spreads over an area of 2528.km^2 . Lucnow is located between 26°55' North latitudes and 80°59' East longitudes, on both the sides of river Gomti. Total population of Lucknow is 3,765,000 as per latest provisional figures released by Directorate of Censusin 2021, a increase of 2.39% from 2020.As per census 2021, density of Lucknow District per square km is 8100 .

The climate is typically humid subtropical characterized by hot summer March to mid May and cold winter November to February and annual rainfall is about 999 mm, mostly localized between June to September. Situated at an average altitude of 123 m from mean sea level, it slopes gently from northwest to southeast. Lucknow district is flanked by the perennial rivers Gomti.The soil of the Lucknow is of quaternary alluvium type comprising mostly sand and sandy clay with varying amounts of calcareous nodules.

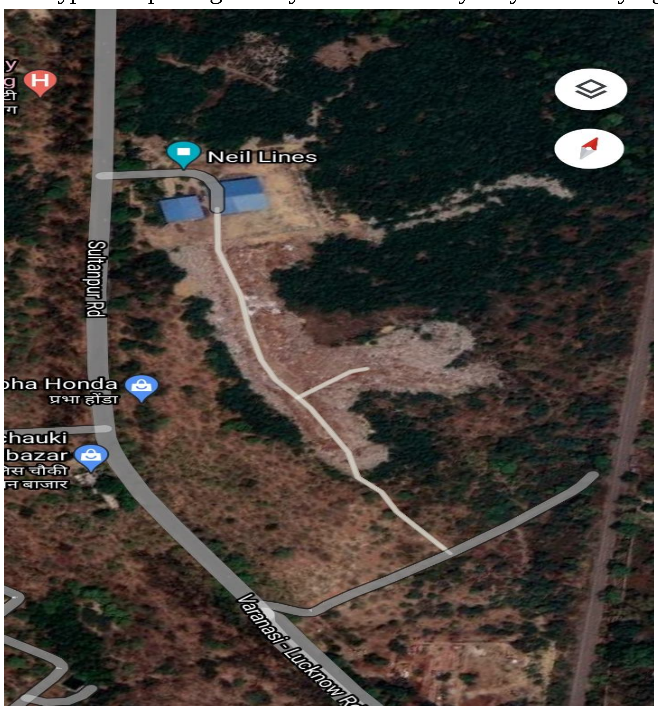

Fig. no. – 1 site view

III. OBJECTIVE

1) To assess the pollution potential of leachate generated from the solid waste disposal site and its impact on ground water in the Neil Line Lucknow, Uttar Pradesh, India.
2) To determine Physico-chemical parameters of leachate and groundwater samples will be determined to evaluate leachate pollution index (LPI) .
3) The migration of heavy metals from leachate through the soil profile.

IV. METHODOLOGY

Dug wells and bore wells were selected for sampling, which are functional and continuously in use for drinking and domestic purposes. A total of 21 groundwater samples were collected from dug wells and bore wells (hand pumps) in the study area during April, 2012 and one leachate sample at the solid waste disposal site. Samples bottles were cleaned by rinsing them with distilled water followed by their treatment with 1 M solution of the preservative acid. In the case of bore wells (hand pumps) the water samples were collected after pumping for 10–15 min in order to remove stagnant groundwater. Water samples collected in polyethylene bottles were used for measuring major cations and anions while samples for metals were collected in separate clean polyethylene bottles after filtering and were acidified with nitric acid to a pH below 2.0 to minimize precipitation and adsorption on container wall (APHA 2005). Heavy metal estimation in the leachate sample was done by digesting 50 ml sample in 10 ml of conc. HNO_3 at 80 °C until the solution becomes transparent (APHA 2005). Then the solution was filtered through Whatman filter paper and the volume make up with 100 ml distilled water. Iron (Fe), Chromium (Cr), Cadmium (Cd), Zinc (Zn), Lead (Pb), Manganese (Mn), and Arsenic (As) for groundwater and leachate were analyzed by atomic absorption spectroscopy.

pH and electrical conductivity (EC) were measured by pHand EC meters respectively. Total dissolved solid (TDS) was also measured by the EC meter in the field using the standard procedure. Fluoride (F) was analyzed using Orion ion selective electrode 4 Star. Sodium (Na), and Potassium (K) were determined by using flame photometer (Elico CL-378). Calcium (Ca), bicarbonate (HCO3), total hardness (TH), and chloride (Cl) were analyzed by titrimetric method and magnesium (Mg) estimated by the difference in the hardness and calcium.

Titrimetric method helps to estimate the concentration of desired ion using chemical indicators which produce a physical change (color) to predict the equivalence point. Sulfate (SO4), phosphate (PO4), nitrate (NO3), total kjeldahl nitrogen (TKN), ammonia nitrogen, and dissolved silica (SiO2) were determined by UV-3200 double beam spectrophotometer model. The chemical oxygen demand (COD) was determined by open reflux digestion method and biological oxygen demand (BOD) was estimated by azide modification of Winkler method. The charge balance of cation and anion calculated was generally<5 % and ratio of TDS/EC are within acceptable limits (0.5), confirming the reliability of the analytical results.

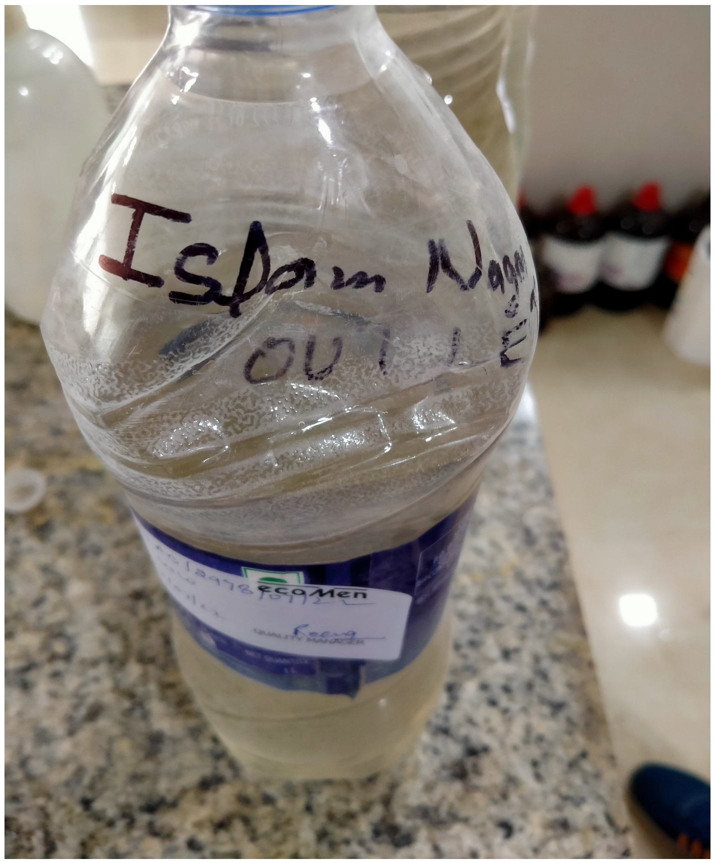

Fig. No. – 2 leachate sample

A. *Leachate Characterization and Groundwater Chemistry*

Physico-chemical parameters of the leachate depend primarily upon the waste composition and water content. The leachate characterization is carried out by collecting leachate sample in the drainage and result of the leachate is presented in the Table 1. The pH value of the leachate sample of landfill site is 7.5. Leachate is generally found to have pH between 4.5 and 9 (Christensen et al. 2001). The pH of young leachate is less than 6.5 while old landfill leachate has pH higher than 7.5 (Abbas et al. 2009). Due to the high concentration of volatile fatty acids pH is less than 6.5 at the initial stages of leachate generation, but during the methanogenic stage volatile fatty acids have been converted into methane and carbon dioxide, so pH of leachate would become alkaline. The alkaline nature of leachate shows the mature to old stage of the dumping site (Jorstad et al. 2004). The pH of the present study indicates that the Lucknow solid waste dumping shows mature stage of dumping site. To understand the effect of the leachate of groundwater resources, 11 groundwater samples in and around the solid waste dumping site have been collected randomly. A systematic study conducted to determine the impact of municipal solid waste disposal on groundwater in Lucnow cant has revealed that the groundwater of nearby wells is being significantly contaminated due to the leachate from the landfill.

The average concentration of major ions and heavy metals in the leachate and in the groundwater samples collected at varying radial distances from the landfill are shown in Table 1.

The data indicate the landfill as the point source for all the contaminants because groundwater flow is outward from the landfill site and the concentration of pollutants decreases radically as we move away from the landfill site, but high EC, TDS, Cl, NO_3 and Na are found at the periphery (>3.5 km) of the study area due to localized anthropogenic sources i.e., agricultural activity, animal excreta, application of fertilizers and pesticides, and localized domestic sewage contamination. Electrical conductivity of leachate is 15,800 µS/cm and high EC concentrations are found in the bore wells close to the landfill site. The differences of silica of leachate and groundwater samples are very little which indicate that the source of silica in the groundwater is due to the geogenic process. Silica concentration in groundwater is most conveniently related to interaction with solid phases, as it enters the system during the weathering of silicate minerals.

The Ca, Mg, K, and Na values of leachate are 1600, 600l, 280, and 1385 mg/l, respectively. The possible source of cations in leachate is domestic wastes (Kale et al. 2010).

Fig. No. – 5 digested sample

High calcium and sodium concentrations are observed in some of the wells close to landfill site which may be due to leaching of pollutants from the landfill site or anthropogenic wastes mixing with the rainwater and percolation in the groundwater system which led to increase concentration in nearby well (≤1) from the landfill site. The anions of landfill leachate of HCO_3, F, NO_3, SO_4, Cl, and PO_4 are 141, 0.3, 327, 267, 1250, and 2.25 mg/l, respectively (Table 1). High chloride, sulfate and nitrate concentrations are primarily due to domestic wastes and kitchen wastes from households, restaurants, and hotels (Mor et al. 2006; Kale et al. 2010). Urea and ammonium nitrate are most commonly used as fertilizers, contributing nitrates to the groundwater (Raju et al. 2011). The high concentrations of chloride in nearby wells indicate the influences of leachate, domestic waste, and other agricultural activities. The heavy metals (Fe, Cr, Cd, Zn, Pb, Mn, and As) were analyzed to assess the metal pollution in the leachate (Table 1). The concentration of heavy metals in a landfill is generally higher at earlier stages because of the higher metal solubility as a result of low pH caused by the production of organic acids (Kulikowska and Klimiuk 2008). As a result of increased pH at later stages, a decrease in metal solubility occurs resulting in a rapid decrease in the concentration of heavy metals except lead because lead is known to produce a very heavy complex with humic acids (Harmsen 1983).

Parameters	Concentration in landfill leachate (mg/l)	Concentration in groundwater sample at radial distance from landfill facility			
		≤1 km	1-3km	3-5 km	≥6 km
pH	7.5	7.4	7.9	6.8	7.8
EC (µs/cm)	16,800	1121	900	768	493
TDs	6000	559	657	458	432
Ca	1500	198	145	99	132
Mg	500	38	43	31	21
K	275	5.4	30.2	3	5.6
Cl	1230	209	143	111	120
HCO_3	132	453	438	400	421
NO_3	324	21	10	58	6.2
SO_4	238	72	63	46	26
F	0.2	1.3	1.03	1.4	1.32
PO_4	2.30	2.4	2.6	1.3	1.2
TH	2000	356	289	330	291
Fe	23	1.9	1.7	1.08	1.2
Cr	0.25	0.03	0.04	0.02	0.01
Cd	0.01	0.01	0.01	0.02	0.01
Zn	2.1	0.23	0.03	0.02	0.021
Mn	0.05	0.03	0.02	0.01	0.01
As	0.006	0.01	0.0	0.0	0.0

Table 1Leachate characterization of landfill site and groundwater samples from nearby locations

There is no known natural source of heavy metals in the study area, but iron, chromium, and lead are found to be more prevalent in the leachate and nearby groundwater wells which may be due to plastics, batteries, leather, paint products, metallic items, fluorescents lamps, wood preservatives, and metal scrap dumped in the solid waste disposal site. Vehicular emissions and agricultural activities also contribute heavy metals such as Pb, Cu, Zn, and Cd to the study area.

B. Leachate pollution index (LPI)

The leachate pollution index (LPI), a tool for quantifying the pollution potential of leachate at the landfill sites. The theoretical range of LPI is from 5 to 100 (like a unit) that express the overall leachate contamination potential of a landfill based on several leachate pollution parameters at a given time. The minimum value of 5 units of leachate pollution ensures that LPI value does not result to zero even if some of the pollutants do not show any pollution. It is an increasing scale index, wherein a higher value (LPI >35) indicates a poor environmental condition (Kumar and Alappat 2005). LPI has many potential applications including ranking of landfill sites, resource allocation, trend analysis, enforcement of standards, scientific research, and public information. Landfill age also plays an important role in the leachate characteristics and hence influences the
LPI value. The procedure for calculating LPI for a given landfill site at a given time involves the following three steps:

C. Determination of pollutants in the leachate:

Landfill leachate was analyzed to estimate the concentrations of major ions and heavy metals. LPI would be representative of the pollution potential of leachate analyzed for a particular landfill site . Eighteen chemical parameters are required for the calculation of LPI. In the study area, 12 chemical parameters are analyzed, out of 19 parameters proposed by the Kumar and Alappat (2005) for the calculation of LPI.

D. Calculating sub-index values:

To calculate the LPI, “pi” values or sub-index values quantify from the subindex curve for all the pollutant variables (Kumar and Alappat 2005). The “pi” values are obtained by locating the concentration of the leachate pollutant on the horizontal axis of the sub-index curve for that pollutant and noting the leachate pollution sub-index score where it intersects the curve.

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E. Aggregation of sub-index Values

The calculated pi value for 12 parameters are multiplied with the respective weights (wi) assigned to each parameter.Based on the significance level and weight factors proposed by Kumar and Alappat (2005). The weighted sum of all the parameters indicates the overall leachate pollution index. When all 18 (Kumar and Alappat 2005) leachate pollutant parameters of the study landfill site are not available (i.e., m < 18), the LPI can be calculated by using the following equation:

$$LPI = \frac{\sum_{i=1}^{m} WiPi}{\sum_{i=1}^{m} Wi}$$

Where LPI = the weighted additive leachate pollution index, wi = weight for the ith pollutant variable, pi = the subindex score of the ith leachate pollutant variable, m is the number of leachate pollutant parameters for which data are available. The calculated LPI value (23.56) of the study area indicates that the leachate generated from this landfill is moderate contaminated due to low organic matter in the leachate, which is indicated by the low BOD and COD value. The leachate generated in the landfill is less viscous, while corroborate with the less concentration of contaminants such as TKN, BOD, Cl, and COD present in the leachate. High total kjeldahl nitrogen (TKN) indicates organic pollution in the leachate that generated from the landfill site. In comparison to soluble organics, the release of soluble nitrogen from waste into leachate continues over longer period (Kulikowska and Klimiuk 2008). The concentration of ammonia nitrogen increases with the increase in age of the landfill which is due to hydrolysis and fermentation of nitrogenous fractions of biodegradable refuse substrates (Umar et al. 2010).

S.No	Leachate characteristic	Observed value (ppm except pH	Individual pollution rating (pi)	Significance	Pollutant weight (wi)	Overall pollution rating (pi wi)
1	pH	7.5	4.6	3.50	0.056	0.23
2	TDS	6000	15.7	3.19	0.05	0.78
3	BOD	1525	30	3.90	0.06	1.83
4	COD	4175	50	3.96	0.06	3.1
5	TKN	987	28	3.36	0.05	1.84
6	Ammonium nitrogen	897	95	3.25	0.05	4.84
7	Total Iron	23	5	2.83	0.04	0.22
8	Zinc	2.1	6	3.58	0.05	0.33
9	Lead	3.24	27	4.01	0.06	1.70
10	Cr	0.25	5	4.05	0.06	0.32
11	As	0.006	5	3.88	0.06	0.35
12	Cl	1230	12	3.07	0.04	0.57
	TOTAL				0.669	15.76

Table 2 Leachate pollution index (LPI) for the landfill site

Final value o LPI by dividing the total overall pollution rating by total W_i = 23.56 mg/l

V. CONCLUSION

Groundwater is immensely important for water supply in both urban and rural areas of developing nations. The impact of municipal solid waste disposal site has revealed that groundwater of nearby wells are significantly contaminated due to leachate. The quality of groundwater was not much affected in many wells which are far away from the landfill site. The leachate generated in the Lucknow cant Neil line landfill is less viscous due to the low concentration of contaminants such as TKN, BOD, Cl, and COD present in the leachate which represents the moderate value of LPI. The majority of the groundwater samples belong to the good quality water and only 12% of the samples show as unsuitable for drinking purposes.

VI. ACKNOWLEDGMENTS

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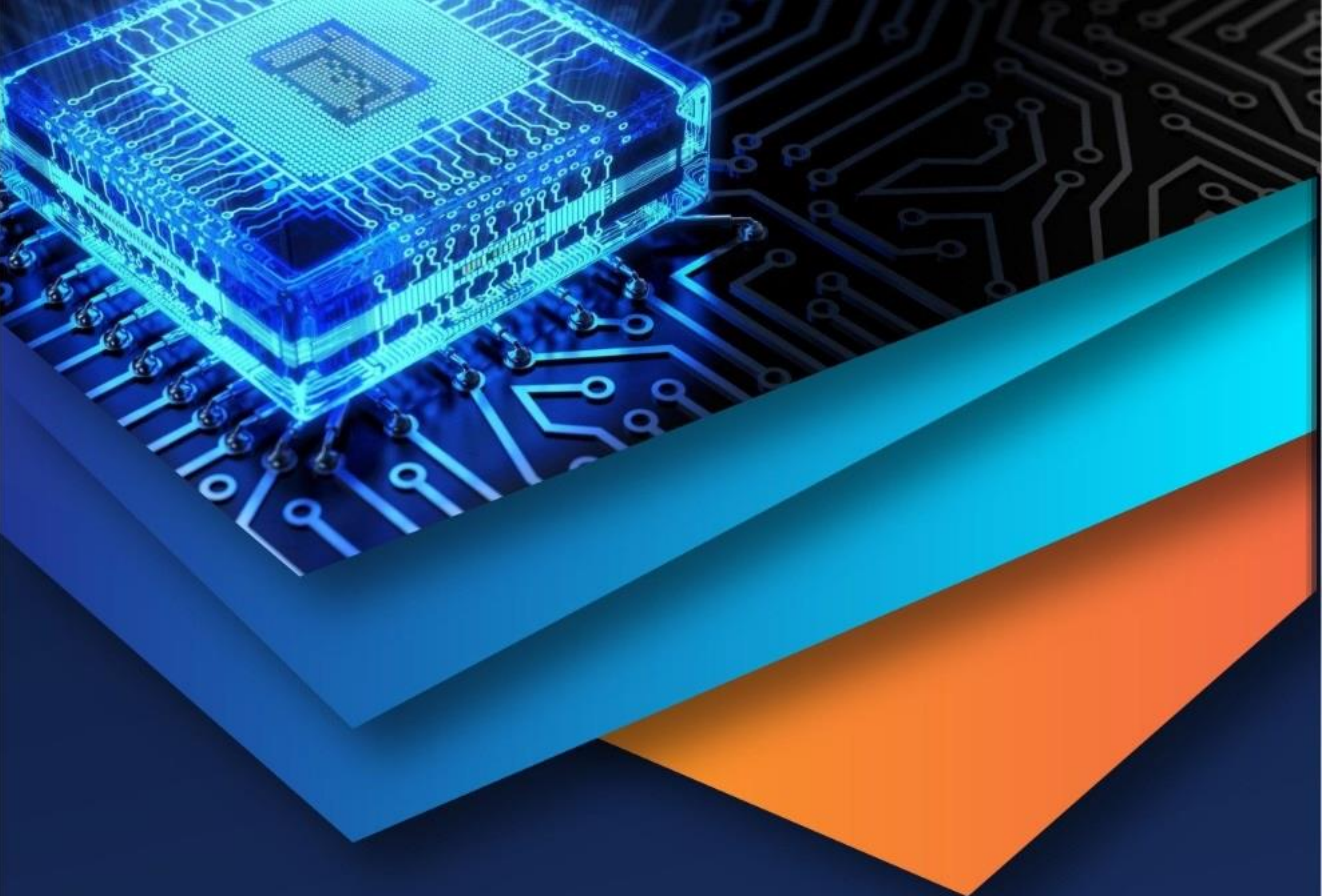

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