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# Anthropogenic Impact on Physico-Chemical Characteristics of Sacred Lakes of Himachal Himalayas: A Review

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***Abstract:*** ***Glacial and freshwater lakes of Himachal Himalayas provide important ecosystem services and help to maintain ecological balance of the region. Some of the lakes of state hold a sacred value due to which thousands of pilgrims visit per year for holy dip. These sacred practices somewhere are affecting natural serenity as well as water quality of these holy lakes. The present study was aimed to analyze and assess anthropogenic effects on physico- chemical parameters of sacred lakes of Himachal Himalayas. The present study becomes crucial as all these lakes are located on high altitudes of state and are natural lakes. The study concluded a distinct contrast in variation of water quality in lakes those suffer more anthropogenic activities while the lakes those are away from touch of human activities still show lesser or no variation.***
***Keywords: Himalayas, Himachal Himalayas, Lakes, Water Quality, Dissolved ion chemistry***.

## I. INTRODUCTION

The word Himalayas has been derived from Sanskrit language and it means “Adobe of Snow”. Himalayas comprises of three main mountain ranges named Western Himalayas, Central Himalayas and Eastern Himalayas. Most of the Indian Himalayas fall under Western Himalayan ranges and include entire Himachal Himalayas (5). Himachal Himalayas covers about 55,672 square kilometres area and are located between latitudes of 30º22' N to 33º12' N and longitudes of 75º47' E to 79º04' E. Himachal Himalayan ranges are adorned by numerous freshwater lakes that are scattered to entire area and cover different altitudes. These altitude lakes hold a significant position being extremely sensitive as their flushing rates are comparatively high (28). Lakes help in maintaining hydrological balance (10) and are sensitive indicators of changes in patterns of climatic variations and outflow and inflow of groundwater in terms of seepage, evaporation and outflows (7). Lakes along with their surroundings present invaluable ecosystem for humankind as well as for nature and hold significant cultural, religious, biodiversity, aesthetic and social values (15). Some of these high altitude lakes are considered sacred and are named as “Dal”. Each year swarms of pilgrims and tourists visit these lake sites for holy dips. These sacred lakes have been a source of enlightenment and inspiration for poets, sages, writers, philosophers, scientists and many others for ages and are unfortunately witnessing a rapid deterioration of quality and quantity potential mainly due to anthropogenic causes (25, 24). Due to excessive visitors influx rates each year, these lakes are experiencing declining biodiversity, reducing catchment areas and depth (12, 19, 20) and sudden proliferation of some aquatic vegetation (16) . Some of these lakes have also become the waste disposal sites either directly or indirectly to which restoration and lake basin management practices are not in pace (31,16) . Despite of such great sacred history and values of these lakes, a little efforts are been taken to heal this deterioration. Limited knowledge of complex hydrology and minimal attention of researchers and scientist community are major setbacks in rejuvenation and sustainable management planning of these sensitive and sacred reserves. A thorough hydrological understanding of Himalayan Lake Systems is needed urgently to overcome deterioration due to climatic changes, population influx and anthropogenic activities. In this present study, existing knowledge and literature of sacred lakes of Himachal Himalayas is reviewed and assessed. This paper aims to cover knowledge on water quality characteristics, hydrology, topography, influences and impacts of anthropogenic activities sacred and freshwater lakes of Himachal Himalayas.

## II. LOCATION AND GENERAL FEATURES

The Himachal Himalayas form the state of Himachal Pradesh and are located in western Himalayas (Fig. 1) between latitudes 30º22' N to 33º12' N and longitudes 75º47' E to 79º04' E. These mountain ranges are bordered by Ladakh, Tibet, Jammu and Kashmir, Uttarakhand, Punjab and Haryana. Himachal Himalayas are dotted with many lakes and most of these lakes hold sacred values and lie mostly in Kangra, Lahaul Spiti, Mandi, Sirmaur and Chamba districts.

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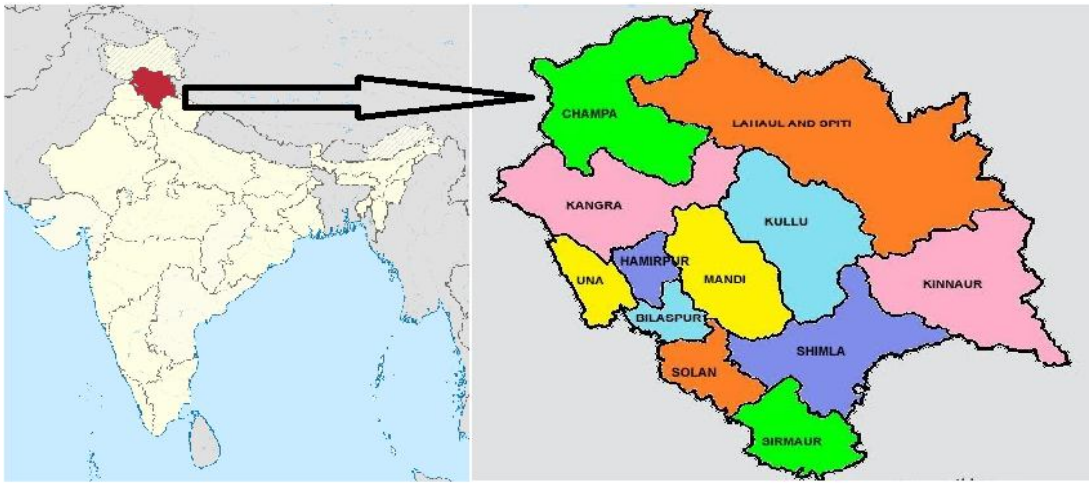



Fig. 1 Location of Himachal Pradesh

The main 8 lakes studied in this paper are: Manimahesh Lake, Suraj Tal, Chander Tal, Renuka Lake, Rewalsar Lake, Prashar Lake, Kareri Lake and Lam Dal (Fig. 2).

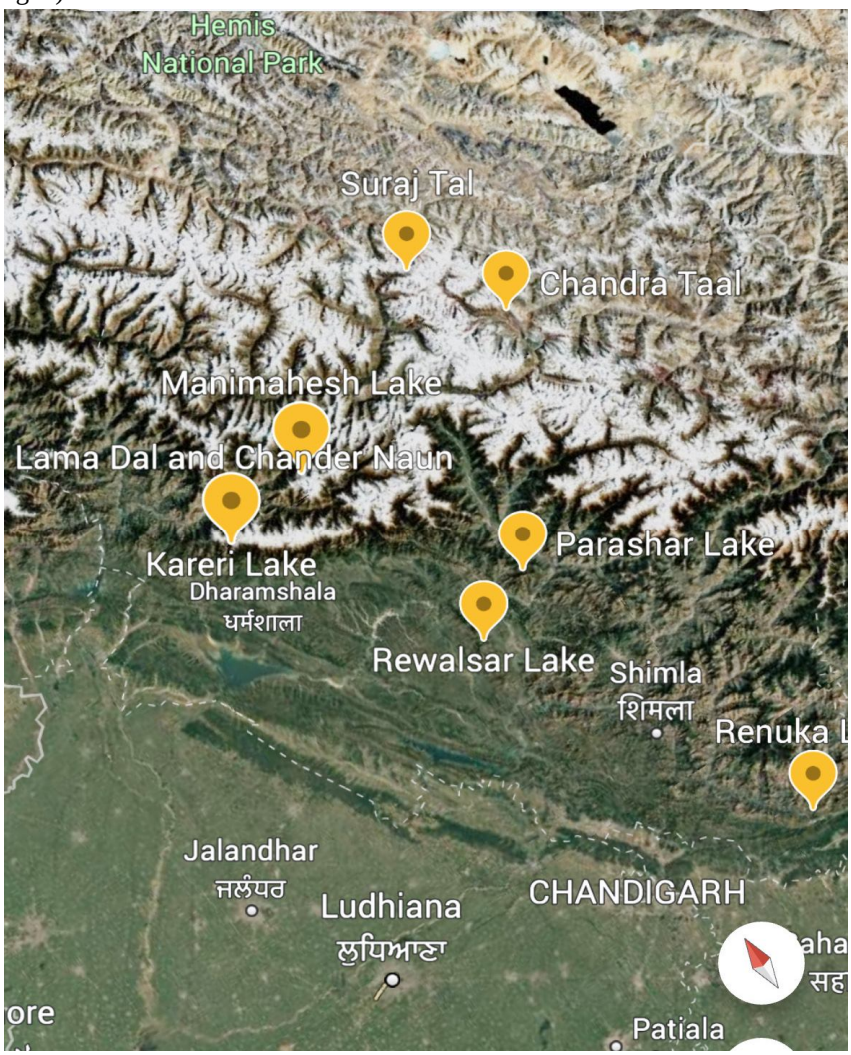



Fig. 2 Location map of lakes

General features of these 8 lakes are shown in Table 1.

TABLE I
GENERAL FEATURES OF HIMACHAL HIMALAYAN LAKES

| Sr. No. | Name | Co-ordinates | District | Type | Climate | Tropic Status | Altitude (masl) | Area (km²) | Depth (m) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Manimahesh Lake | 32.3950ºN 76.6372ºE | Chamba | High altitude lake | Sub Arctic | Oligotrophic | 4088 | 4.58 | -- |
| 2 | Suraj Tal | 32.7619ºN 77.3981ºE | Lahaul and Spiti | High altitude lake | Polar, Tundra | Ultra-Oligotrophic | 4883 | -- | -- |
| 3 | Chander Tal | 32.4324ºN 77.6157ºE | Lahaul and Spiti | High altitude lake | Cold, Dry cold summer | Ultra-Oligotrophic | 4300 | 0.875 | -- |
| 4 | Renuka Lake | 30.6102ºN 77.4584ºE | Sirmaur | Lesser Himalayan lake | Temperate | Hyper-eutrophic | 645 | 0.18 | 13.7 |
| 5 | Rewalsar Lake | 31.6340ºN 76.8335ºE | Mandi | Lesser Himalayan lake | Temperate | Hyper-eutrophic | 1360 | 0.036 | 6 |
| 6 | Prashar Lake | 31.7544ºN 77.1011ºE | Mandi | High altitude lake | Temperate | Oligotrophic | 2730 | 0.023 | 4-5 |
| 7 | Kareri Lake | 32º19’32” N 76º16’25” E | Kangra | High altitude lake | Cold, Dry cold summer | Oligotrophic/ Mesotrophic | 2934 | 0.026 | 6.5 |
| 8 | Lam Dal | 32º20’12” N 76º19’05” E | Kangra/ Chamba | High altitude lake | Alpine | Oligotrophic | 3972 | 0.258 | 150 |

## III. GEOLOGY AND TECTONIC SETTING

Collision of Indian and Eurasian plate during early Cainozoic started Himalayan evolution (14) and that resulted in crustal shortening and thickening (30, 13). Himalayas are divided into 4 sub-units, named Tethyan Himalayas, Higher Himalayas, Lesser Himalayas and Sub- Himalayas and these sub-units are bounded by various thrust and fault systems. Main Central Thrust (MCT) separates Higher Himalayas and Lesser Himalayas and Main Boundary Thrust (MBT) separates Lesser Himalayas and Sub-Himalayas (9, 17).

Manimahesh Lake is of glacial origin and is located in Chamba district. Manimahesh Kailash peak feeds this lake with snowmelt. Ground and recessional moraines deposited along the lake show current glacial dynamics and traces of glacial retreat. Geology of Manimahesh Lake consists of Precambrian rocks from Lesser Himalayas.

Suraj Tal is high altitude glacial tarn located in Lahaul and Spiti district near Bara- lacha- la pass which feds the lake. Suraj Tal is origin place of Bhaga River which is a tributary of Chenab River. Tectonic setting near Suraj Tal shows a perfect mosaic of Himalayan Orogeny in the form of faults and rifts. Basalts of Tethyan volcanism metamorphosed sedimentary rocks of Haimanta Group and highly metamorphosed rocks of Vaikrita Group makes the geology of entire area.

Chander Tal is also known as Moon Lake due to its crescent shape. It is a glacial lake located in Lahaul and Spiti district and is formed due to glacial retreat. Traces of glacial retreat are seen as glacial soil, scree, glacial striations, moraines and polished rocks surrounding the lake. Geology of lake area consists of limestone from Kunzam La Formation, copper mineralization and quartzite.

Renuka Lake lies in Lesser Himalayas in Sirmaur district and is of tectonic origin. Catchment area of lake shows heterogeneous blend of rocks from Neo- Proterozoic to Proterozoic era. Geology of the area shows folded, fractured and crushed rocks of Krol (limestone), Chandpur (phyllites) and Mandhali (shales, dolomites and quartzite) Formations.

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Rewalsar Lake is located in Middle Siwalik ranges of Mandi district. The lake basin shows a strike- slip fault which is trending NE-SW and due to this fault the area is under severe erosional deformation. Geology of catchment area consists of sandstones, siltstones and shales of Middle Siwalik Group.

Prashar Lake is a high altitude glacial lake that lies in Mandi district within the Dhauladhar Ranges of Western Himalayas. This oval shaped lake has a unique and mysterious floating island of soil and vegetation and holds a strong religious belief related to Pandavas. The geology includes Precambrian rocks of Himalayan orogeny.

Kareri Lake is located in Dhauladhar Ranges of Lesser Himalayas in Kangra district. This high altitude glacial lake is fed by snowmelts of Dhauladhar peaks and show traces of past glacial activity. Geology surrounding the lake consists of granite from Dhauladhar formation, phyllites and quartzites from Chail formation and Dharamkot Limestones. A tectonically active Drini Thrust is also found near the lake.

Lam Dal is a high altitude glacial lake and is located in Dhauladhar Ranges of Kangra and Chamba districts. High elevation cause intense weathering and erosion to surrounding rocks in the area. Geology of the area consists of schists and gneisses of metamorphic origin and mafic rocks like serpentinites. Intense folding, uplifting and thrusting of the area is leading to exposure of igneous and metamorphic rocks in the region. Scree slopes, boulder fields and steep rocky ridges are encountered in the region.

## IV. PILGRIMAGES AND HOLY DIPS

Himalayan lakes are linked to Hindu deities, Pandavas, local gods, Hindu mythology and Buddhist masters. Devotees visit these lake sites for bathing and offerings each year. Bathing in these lakes is sacred ritual for spiritual solace and purification. Many Yatras and Naun (Holy Dip) fairs are arranged in these lakes each year. Pilgrimage details of 8 Himachal Lakes are summarised in Table 2.

TABLE 2
YATRAS, FAIR AND NAUN OF LAKES

| Sr. No. | Lake | Pilgrimage | Month | Deity | No. of pilgrims per year |
|---|---|---|---|---|---|
| 1 | Manimahesh Lake (Adobe of Shiva) | Holy dip and circumambulation | August/ September | Lord Shiva | In lakhs |
| 2 | Suraj Tal ( Sun Lake) | Holy dips | May- June | Surya Dev (Sun) | In Thousands |
| 3 | Chander Tal (Moon Lake) | Holy dips | June - October | Lord Indra and Pandavas | In Thousands |
| 4 | Renuka Lake | Annual Fair, Holy dip and circumambulation | November | Renuka Devi and Lord Parshuram | In lakhs |
| 5 | Rewalsar Lake | Fair | February/ March | Guru Padmasambhava | In Thousands |
| 6 | Prashar Lake | Fair | June | Sage Prashar and Pandavas | In Thousands |
| 7 | Kareri Lake | Holy dip | August | Lord Shiva and Goddess Shakti | In Hundreds |
| 8 | Lam Dal | Holy dip | July- August | Lord Shiva | Less than hundred |

## V. HYDROCHEMISTRY

Hydrochemistry of Himalayan Lakes mostly depends upon trends of precipitation, weathering of surrounding rocks and evaporation-crystallisation processes (11). Ion dominancy of lake water is highly relative to type of dissolving rocks. For about 12 Ma, weathering flux and erosion rates seems to be constant (6, 8). Influence of tectonic parameters on varying Lake Hydrochemistry is still mysterious and is a subject of assumptions (3). Anthropogenic activities, particularly cultural and religious practices, are also concerning alarms for contamination of Lake Hydrochemistry (1, 21, 23, 22, 18, and 26).

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Evaluation of dissolved ions is based on ions and their ratio relationship (27). Total dissolved solids (TDS) represent total ions of lake water and Electrical conductivity (EC) give an idea about strength of ions and mineralisation of natural water which is dependant of rate of movement, concentration and volume of ions that reflects the type of chemical weathering (4, 29, 2).

Manimahesh Lake comprises of glacial melt waters and shows dominance of silicate and carbonate weathering and thereby shows high ratios of (Ca+ Mg)/ (Na+ K) mainly due to dissolution of carbonates and sulphide oxidation. Dominant cations are $Ca^{2+}$ and $Mg^{2+}$ while dominant anions are $HCO3^{-}$, $SO4^{2-}$ and $Cl^{-}$. Surrounding groundwater also encounter high ammonium and nitrate values. The excessive load of pilgrimage during Manimahesh Yatra, flush wastes in solid and liquid form into this sacred lake that in turn contaminate the water with high Total Coliform (TC) levels.

Suraj Tal hydrochemistry shows traces of cation exchange, rock weathering and dust deposition. Lake water is mineral rich and is of Calcium- Magnesium- Bicarbonate type. Dominant cation is $Ca^{2+}$ while dominant anion is $HCO3^{-}$. Some traces of $Cl^{-}$ and $NO3^{-}$ are also encountered due to anthropogenic effects.

Chander Tal water is alkaline in nature with a pH of 8.3. Dominance of carbonate weathering is revealed by high amounts of $Ca^{2+}$, $Mg^{2+}$, Na+ and $HCO3^{-}$. There is an equivalent ratio of $Na+/Cl^{-}$ and $K+/ Cl^{-}$ suggest minor addition of these ions from outer atmosphere. PCo2 values of lake water are higher that are suggestive of disequilibrium of weathering and atmosphere.

Renuka Lake water is alkaline in nature with pH of 8.70 and show carbonate weathering due to limestone and shales. Dominate cations are $Mg^{2+}$, $Ca^{2+}$ and anions are $HCO3^{-}$ and $SO4^{2-}$. Lake is highly eutrophic and show high levels of phosphate, fluoride and heavy metals like Fe, Pb and Mn due to anthropogenic activities.

Rewalsar Lake shows dominance of carbonate and silicate weathering. Main cations are $Ca^{2+}$ and Na+ and anions are $HCO3^{-}$, $SO4^{2-}$due to rock weathering. Anthropogenic activities add up ammonium, chloride and nitrate to lake water and make it hyper eutrophic. High nutrient levels of phosphate and chlorophyll-a along with phytoplankton composition are also encountered in lake water.

Prashar Lake shows silicate weathering with presence of calcium and bicarbonates. Dominant cations are $Ca^{2+}$, Na+, K+ and Mg+ while major anion is $Cl^{-}$ . Due to anthropogenic activities, quantities of nitrates and phosphates are also encountered in lake water. The lake is oligotrophic and shows neutral pH values and varying EC and TDS values.

Kareri Lake shows carbonate and silicate weathering due to dolomite and gypsum and is Ca-HCO3 type which signifies alkaline earth metals. Dominant ions are $Ca^{2+}$ and $HCO3^{-}$ due to surrounding carbonate weathering. Higher concentrations of sodium, chloride and organic matter are encountered post monsoon due to local anthropogenic activities and precipitation.

Lam Dal shows dominance of bicarbonate and calcium ions and indicates carbonate weathering. Major ions are $Ca^{2+}$ and $HCO3^{-}$ and some traces of $Mg^{2+}$ that are indicatives of silicate and carbonate weathering. Water quality of Lam Dal is quite good as it shows low electrical conductivity.

Physico- chemical parameters of these 8 lakes are shown in Table 3.

TABLE 3

PHYSICO- CHEMICAL PARAMETERS OF LAKES

| Sr. No. | Name | pH | DO (mg/L) | BOD (mg/L) | Turbidity (NTU) | TDS (ppm) | TH (mg/L) | EC (µs/cm) | Po4 (mg/L) | NO3 (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Manimahesh Lake | 7.35 | 4 | 0.7 | 00 | 0.1 | 78.0 | 75 | -- | 9 |
| 2 | Suraj Tal | 9.1 | -- | -- | -- | 104.0 | 130.0 | -- | 0.004 | 0.130 |
| 3 | Chander Tal | 8.3 | -- | -- | -- | 114.0 | 150.0 | 220 | -- | 0.0127 |
| 4 | Renuka Lake | 8.70 | 6.7 | 1.74 | -- | 329 | 302.0 | 501 | 0.38 | 8.18 |
| 5 | Rewalsar Lake | 7.25 | 7.26 | 3.59 | 171.88 | 171.88 | 132.6 | 230 | 0.38 | 11.52 |
| 6 | Prashar Lake | 7.22 | 13.21 | 0.48 | 11.18 | 22.3 | 22.93 | 272 | 0.0245 | 0.13 |
| 7 | Kareri Lake | 8.7 | 6.57 | -- | 6.62 | 230.7 | 25.0 | 126 | -- | 6.97 |
| 8 | Lam Dal | 7.01 | 6.50 | -- | -- | 8.0 | 19.12 | 12.6 | 0.37 | 2.83 |

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## VI. CONCLUSIONS

The present lake study suggests that DO, Turbidity, TDS, TH, EC and concentration of dissolved sediments are high in those lakes that are under influence of heavy anthropogenic activity. Renuka Lake, Rewalsar Lake, Prashar Lake and Manimahesh Lake experience heavy pilgrimage load and that is resulting to deterioration to serenity and purity of these sacred lakes. Deterioration of water quality of these lakes is related to domestic wastes, religious offerings like dhoop, flowers, coins etc. during fairs and untreated wastewaters and leading to eutrophication. Urbanization near these lakes is also blooming rapidly and ultimately affecting lake health. Meanwhile, Kareri Lake, Lam Dal, Suraj Tal,Chander Tal are difficult to reach and thus are less contaminated by visitors. These lakes are still holding their purity and serenity due to less human intervention. Lake restoration measures are suggested to further check these practices and also civic sense is highly expected and needed from tourists and pilgrims to protect further aggravation.

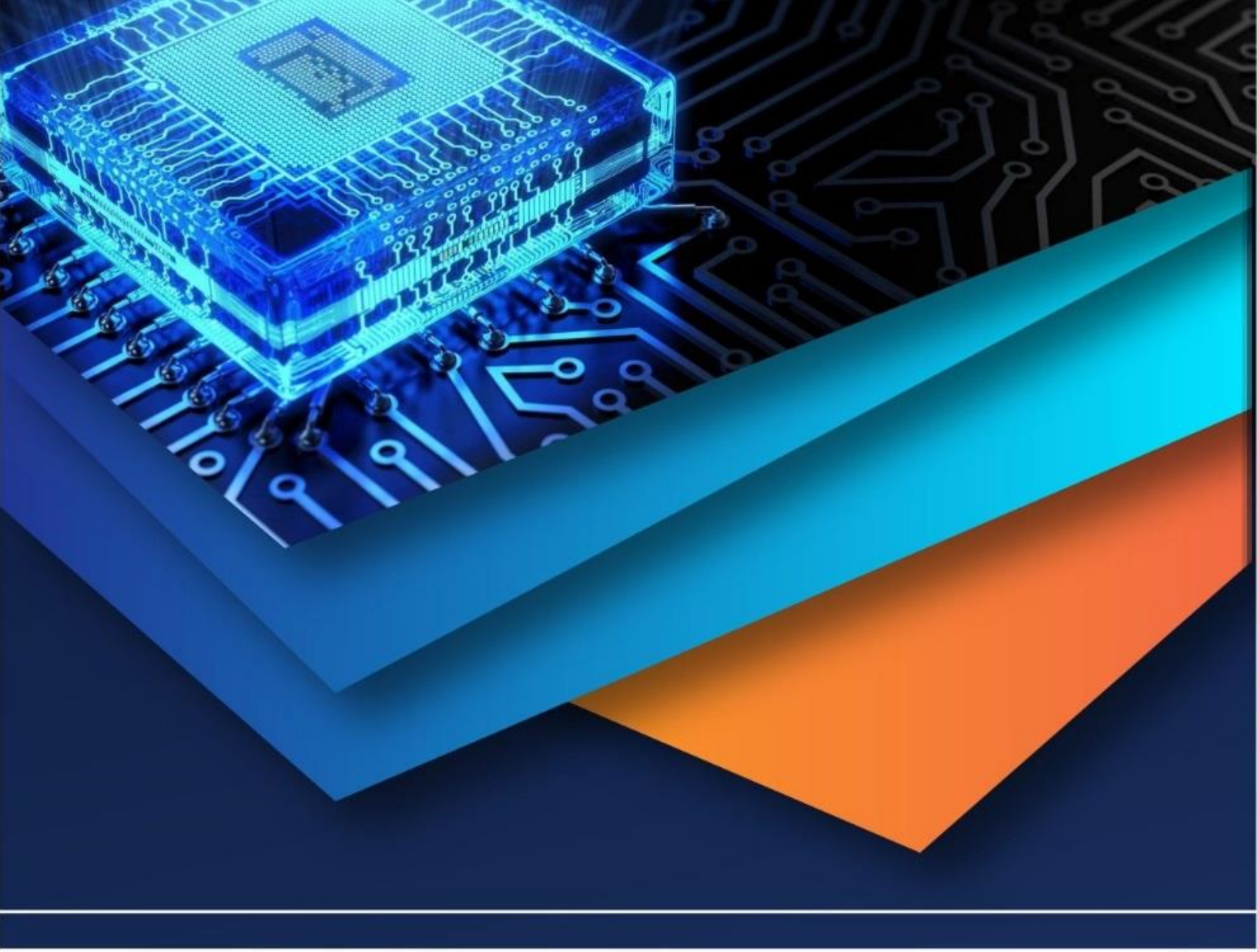
## VII. ACKNOWLEDGMENT

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