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Life Cycle Assessment of Water Treatment Plant Using Open LCA Software

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Abstract: India is bearing from one of the world's worst national water crises. More than 50% of the population from India has no access to safe drinking water. The production of potable water from surface water includes several processes, energy consumption, and chemical dosing.

Yet, the water treatment industry may be responsible for significant global environmental impacts, the most common amongst which are the depletion of natural resources and indirect release of pollutants into the water, land, and air through chemicals and energy consumption.

Life cycle assessment (LCA) is a tool that could be used to generate information on the environmental impacts of water treatment systems. Hence this study identifies the impact of WTP Miraj by using the LCA approach to determine the holistic profile. Impacts were assessed for construction phase and operational phase by considering the emissions from raw material extraction, manufacturing and use.

OpenLCA software was used as an assessment tool. The research aims to determine the treatment efficiency for the Miraj Water Treatment Plant life cycle assessment (LCA) by evaluating the physicochemical characteristics at each stage of the WTP and conducting an inventory analysis. The life cycle impact assessment (LCIA) phase is explained in this study, with an emphasis on the salient features of the underlying models and techniques.

Keywords: Life cycle assessment, Water treatment plant, WTP Miraj, OpenLCA software

I. INTRODUCTION

India is facing one of the world's worst national water crises. The country's current water requirements, according to the Union Ministry of Water Resources, are roughly 1100 billion cubic meters per year, with estimates of 1200 billion cubic meters in 2025 and 1447 billion cubic meters in 2050. The process which makes the quality of water better to make it appropriate for a specific use is called water treatment.

This use includes drinking, industrial, irrigation, agriculture. This process removes pollutants and unwanted components, or makes their concentration less so that the water becomes suitable for its desired end-use. Water treatment is necessary to our health and allows humans to access from both drinking and irrigation use.

A life-cycle assessment is a method for assessing environmental impacts at all phases of the life cycle of a commercial product, process, or service. For example, environmental effects of a manufactured product are analyzed from the extraction and processing of raw materials (cradle), through manufacturing, distribution, and usage of the product, and finally through recycling or final disposal.

A. Scope of Work

From the literature review, it was observed that the operation phase was considered mostly to carry out a life cycle assessment of water treatment plants. Different software like Eco-invent, SimaPro 6.0, and Gabi was used to calculate impact potential parameters. There was the negligence of construction phase impact to calculate impact potential parameters. The impact of the construction phase has a significant role in the emissions and hence it cannot be neglected. In some of the literature use of equipment's in the construction phase while calculating impact parameters were not considered. Since the burning of fuel has a contribution to environmental impact, hence it should not be neglected. The goal of the study is to carry out a life cycle assessment for the Water treatment plant, Miraj.

The plant has a capacity of 10 MLD. The assessment for eight impacts potential will, done by using OpenLCA software and CML baseline. Two phases will be considered viz. Construction and operational and maintenance phase. Thus, the study will conclude by the software results and report.

B. Research Methodology

Figure 1 describe detailed methodology of project study

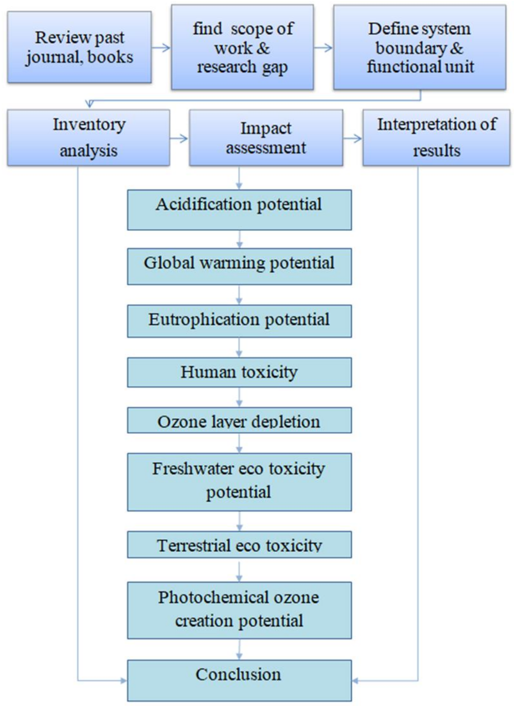

Figure 1: Flowchart of Methodology

II. LITERATURE REVIEW

A. Mohamed-Zine et al. (2013) "The study of potable water treatment process in Algeria by the application of life cycle assessment (LCA)" Journal of Environmental Health Science & Engineering Vol.11 pp 1-9.

Author studied the drinking water treatment in Algeria. The LCA was done by using SimaPro 6.0 software. Result concluded that steps responsible for most of the GHG emissions throughout the water treatment process life cycle was the chemicals products for coagulation and demineralization (soda, lime, sulfuric acid). Stated the Global warming potential for each step of the potable water production processed life cycle. Distribution of emissions were 75% the disinfection carbon footprint 5% the plant's carbon footprint 40% the disinfection impacts on Ozone layer depletion 90% the plant's impacts on ozone layer depletion.

B. Rodriguez et al. (2016) "Life cycle assessment of four potable water treatment plants in northeastern Colombia" An Interdisciplinary Journal of Applied Science Vol. 11 Pp 269- 278.

Researchers carried out Life Cycle Assessment (LCA) for evaluation of the environmental loads of four potable water treatment plants located in northeastern Colombia. The functional unit was defined as 1 m3 of drinking water produced at the plant. The data were analyzed through the database Ecoinvent v.3.01, modeled and processed in the software LCA-Data Manager. The results showed that in plants PLA-CA and PLA-PO, the flocculation process has the highest environmental load, which was mostly attributable to the coagulant agent, with a range between 47-73% of the total impact. In plants PLA-TON and PLA-BOS, electricity consumption was identified as the greatest impact source, with percentages ranging from 67 to 85%.

C. Alaa Saad et al. (2018) "Life cycle assessment of a large water treatment plant in Turkey" Environmental science and pollution research Vol.18.

Author studied the environmental sustainability assessment of a large water treatment plant through the life cycle assessment (LCA) approach. The results denoted that the environmental impacts were dominated by electricity consumption that in turn depends on the energy sources adopted. The impact profile indicates 60% of the total global warming potential, 90% of total acidification potential, 87% of total eutrophication potential and 88% contributed to ozone depletion potential.

D. Pennington et al. (2004) "Life cycle assessment Part 2: Current impact assessment practice", Environmental International, Vol. 30, Pp 721-739.

Author described life cycle impact assessment (LCIA) phase, focusing on the key attributes of the supporting models and methodologies. LCA models and methodologies provided LCA practitioners with the factors they need for calculating and cross-comparing indicators of the potential impact contributions associated with the wastes, emissions and resources consumed that are attributable to the provision of the product in a study. The Impact potential category indicators with impacts on human, plant and environment was studied.

III. THEORETICAL STUDY

A. Life Cycle

Successive and interconnected stages of a product or service system, from the extraction of natural resources to the final disposal are called as life cycle. Life cycle can be any things, which is around us. Life cycle deals with all the activities viz. manufacturing to disposal and after disposal to its reuse.

B. Life Cycle Assessment

A set of procedures for gathering and assessing material and energy inputs and outputs, as well as environmental impacts, that are directly traceable to the functioning of a product or service system across the course of its life cycle. It's a method for evaluating the environmental aspects and potential characteristics of a product by:

1) Collecting a list of connected inputs and outputs,
2) Assessing the potential environmental impacts of those inputs and outputs, and
3) Interpreting the results of the inventory and impact stages in connection to the study's goals.

C. Life Cycle Inventory Analysis (LCI)

Inventory analysis is a process of gathering data and doing calculations to evaluate the relevant inputs and outputs of a product system. The process of collecting an inventory analysis is iterative. Within the system boundary, data for each unit process shall be collected for each unit process. The data collection, calculation procedures includes validation of data collected, relating data to unit processes and relating data to functional unit.

D. Life Cycle Impact Assessment (LCIA)

Using inventory results, this step of LCA designed to define the importance of potential environmental impacts. Selection of impact categories, category indicators, and characterization models are all required components of the LCIA phase. The impact category such as acidification, climate change and each impact category has different characterization factor. The impacts are calculated based on the inventory results of the life cycle.

IV. EXPERIMENTAL WORK

The present investigation is restricted to Miraj city of Sangli region, having populace of 854581.The city is situated on banks of Krishna waterway. Krishna and Warna River is real wellspring of water. The treatment office for this city comprises of two water treatment plants, on old plant having limit of 28.8 MLD and new plant with 10 MLD limits. The water treatment plant has life span of 35 years

Figure 2: Miraj WTP

Figure 3: Aeration

Figure 4: Flocculation

Figure 5: Settling Tank

Figure 6: Filtration

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Figure 7: Disinfection

Table 1: Required Data for Inventory Analysis

Considered phase	Inventory data/Input	Source of data
Construction phase	Cement, sand, steel, bricks, concrete, PVC, cast iron, Aluminum frame, wood, glass, fuel used, paint, equipment used like vibrator and cutter, ceramic tiles, granite tiles, motor and transportation of materials	Estimated from drawings
Operation phase	Chemicals used, electricity and transportation of chemicals	Calculated from visits

A. Introduction to Open LCA software

OpenLCA is a free, professional Life Cycle Assessment (LCA) and Footprint software with a broad range of functions and available databases, created by GreenDelta. OpenLCA is open source software, i.e. its source code is freely available and can be modified by anyone.

With LCA software, can create a complete analysis of the environmental footprint of your products in a very short time. LCA software provides you with the data that can facilitate your business decisions to develop more sustainable products or services. The detailed step listed in following figures

1) *Step 1:* Download and Setup of OpenLCA software
2) *Step 2:* Download the Ecoinvent database and impact assessment methods .zolca extension file from open nexus
3) *Step 3:* Then load the downloaded .zolca file in Open LCA software

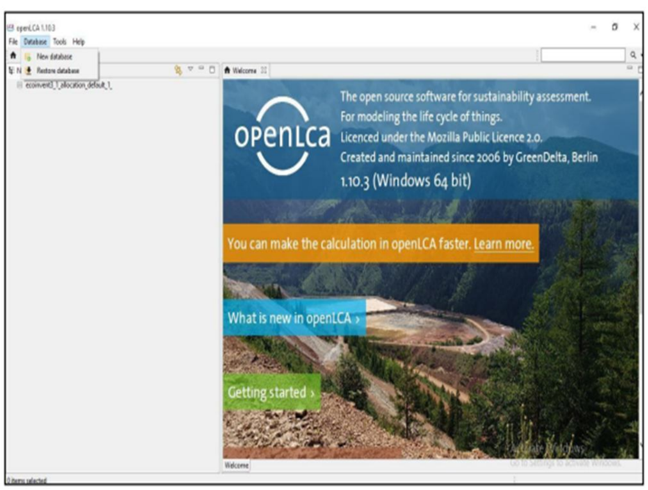

Figure 8: User Interface and Database Restore

Figure 9: Import of Database in Software

4) *Step 4:* The impact assessment method are imported in the software from downloaded file.

Figure 10: Importing Step No 2 in Open LCA

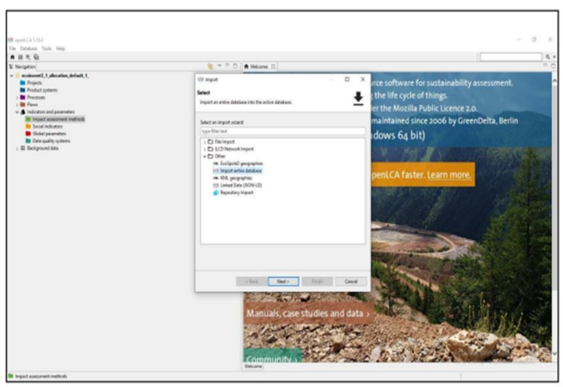

Figure 11: Selection of Option of Database

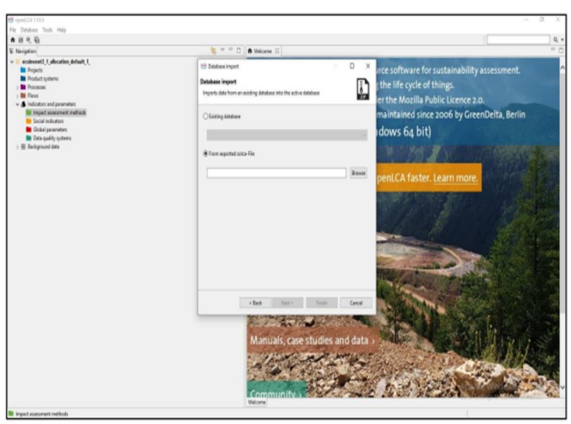

Figure 12: Database Import from Exported .zolca file

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5) *Step 5:* Creating new flow

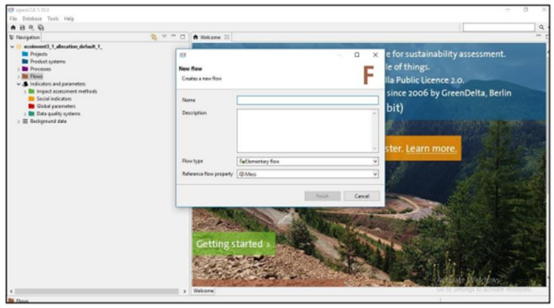

Figure 13: Assigning Name for Flow

6) *Step 6:* Creating new Process

Figure 14: Interface for Creating New Process

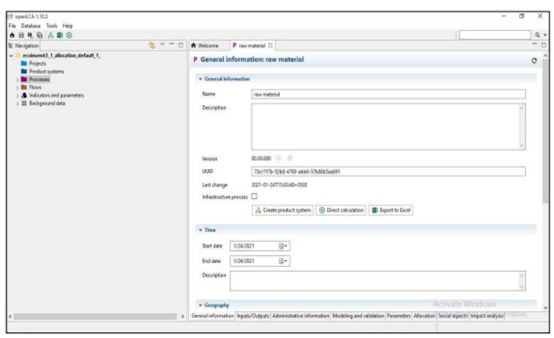

Figure 15: Interface for Input

7) *Step 7:* The data assembled in inventory will be taken as input.

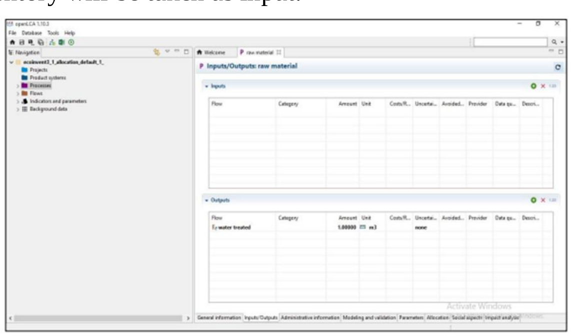

Figure 16: Interface for Input and Output

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8) *Step 8:* After input of data, the impact parameters will be calculated

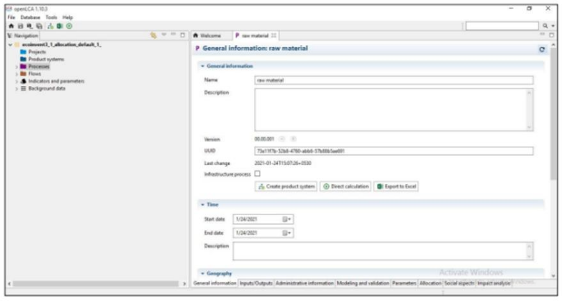

Figure 17: Interface for Impact Parameters

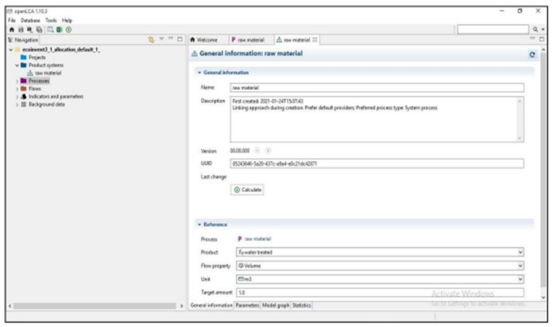

Figure 18: Interface for Input of Material Information

9) *Step 9:* The CML baseline method will be selected to estimate impact potential parameters

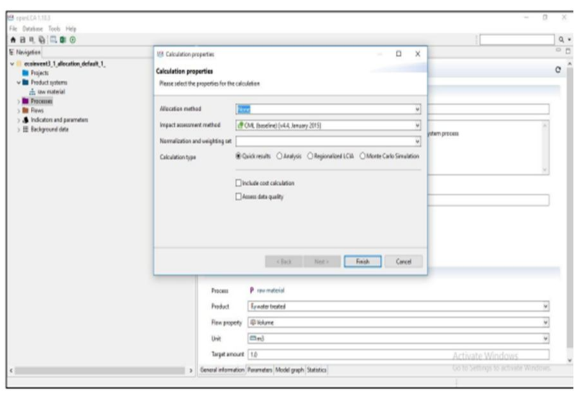

Figure 19: Interface for Calculation Properties

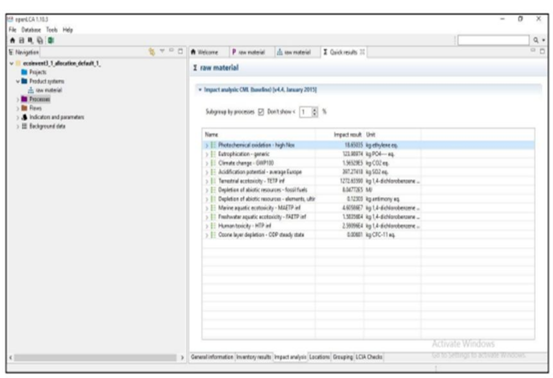

Figure 20: Interface for Final Test Results

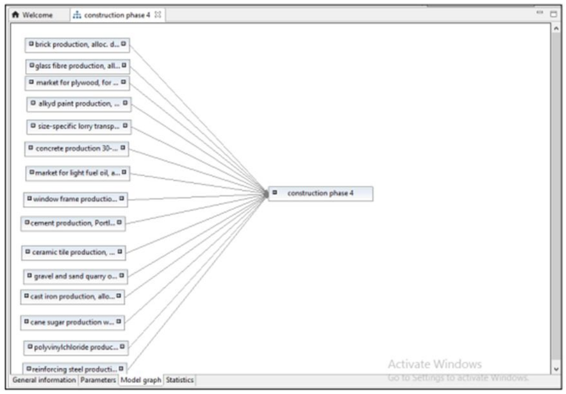

Figure 21: Model Graph Of Construction Phase

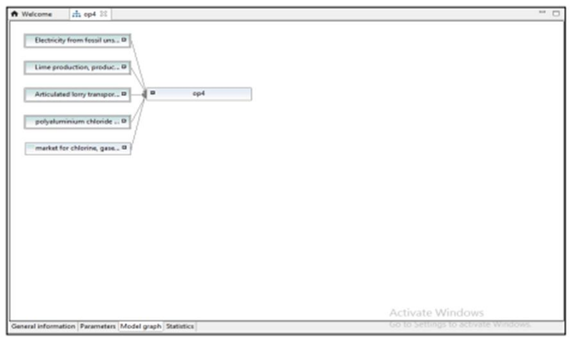

Figure 22: Model graph of Operational Phase

Table 2: Impact Potential Parameters For Both Phases Per Cubic Meter

Impact potential parameters	Unit	Construction phase value	Operational phase value
Acidification potential	$kgSO_2eq./m^3$	$1.36\ x10^{-5}$	$2.23\ x10^{-4}$
Eutrophication potential	$kgPO_4$-eq. $/m^3$	$4.2\ x10^{-6}$	$6.8\ x10^{-5}$
Global warming potential	$kgCO_2eq.\ /m^3$	$4.2\ x10^{-3}$	$1.86\ x10^{-2}$
Human toxicity	kg1,4-dichlorobenzeneeq. $/m^3$	$2.16\ x10^{-3}$	$2.49\ x10^{-2}$
Fresh water eco toxicity potential	kg1,4-dichlorobenzeneeq. $/m^3$	$1.0\ x10^{-3}$	$1\ x10^{-2}$
Terrestrial eco toxicity potential	kg1,4-dichlorobenzeneeq. $/m^3$	$6.30\ x10^{-5}$	$5.9x10^{-4}$
Photochemical ozone depletion	Kg ethyleneeq. $/m^3$	$1.03\ x10^{-6}$	$3.5\ x10^{-5}$
Ozone layer depletion	kgCFC-11eq.$/m^3$	$1.90x10^{-10}$	$9.79\ x10^{-9}$

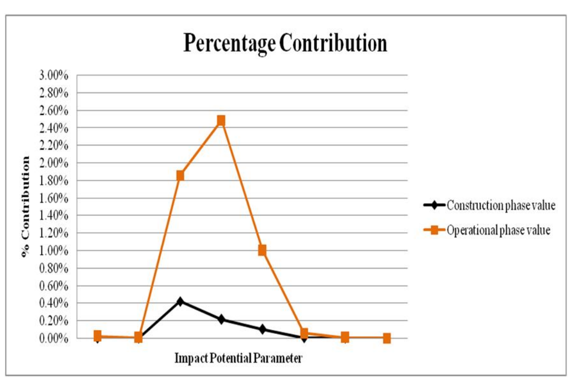

Figure 23: Percentage Contributions Of Both Phases

V. CONCLUSION

Based on the results obtained from OpenLCA software it was observed that contribution of operational phase in overall impact is due to use of chemicals. It is clear from the percentage numbers in the figure 23, that the operating stage has the greatest impact on the total environmental profile for the water treatment technique. This stage contributes more than 90% to all of the categories evaluated, but in global warming potential the contribution of this stage is 81.58%. The PAC production contributes more than 50% in all the categories in operational phase.

At the scale of the water treatment process, energy consumption is shown to carry the highest environmental burden of potable water production. Chemicals production for coagulation and remineralization represent the second major contribution to impacts. The treatment processes dedicated to alternative water resources (advanced membrane processes and desalination) have higher chemicals and energy consumption than conventional ground water and surface water treatment processes. In the current LCA framework, these alternative treatment processes therefore generate higher impacts than conventional treatment processes based on freshwater resources. Development levers for impact reduction are presented such as the installation of high efficiency pumping systems, the optimization of membrane process designs or the use of alternative chemicals.

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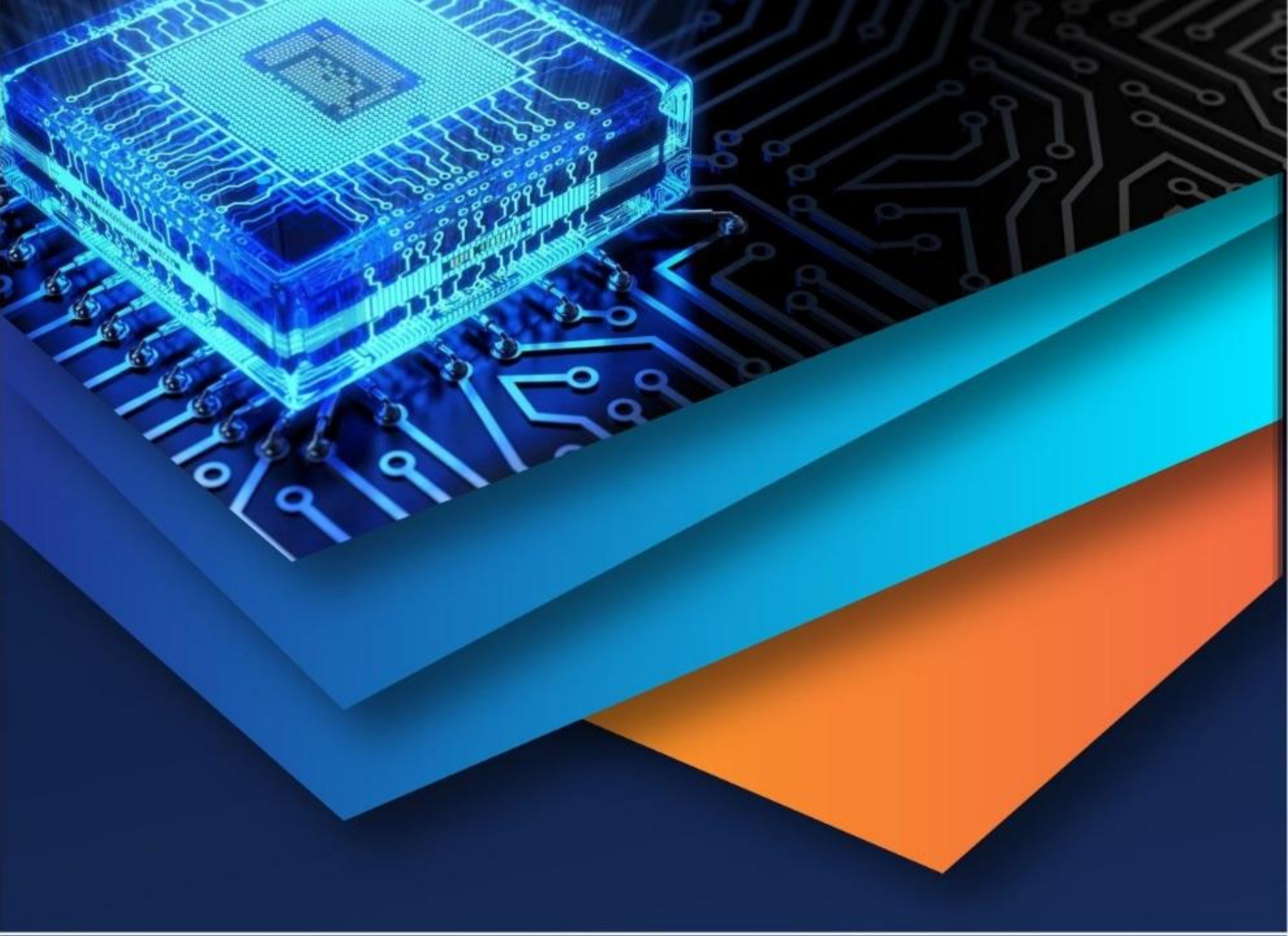

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