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Study of Industrial Wastewater Treatment Comparison between Conventional Activated Systems (CAS) and Membrane Bioreactor (MBR) Systems

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Abstract--This paper provides a detailed literature review of waste water treatment in a membrane bioreactor process (MBR). Here the MBR system is compared with conventional wastewater treatment system. The characteristics of the bioreactor treatment process (biomass loading rates, etc.) and the membrane separation of microorganisms from the wastewater is discussed in detail. The present study has been undertaken to evaluate the performance of the 60 KLD Beverages industrial sewage treatment plant located at Nemam, Poonamallee, Thiruvallur District, Tamilnadu. The plants are designed and constructed with an aim to manage wastewater in order to minimize and/or remove organic matter, solids, nutrients, disease-causing organisms and other pollutants, before it reenters a water body. It is revealed from this performance study that the efficiency of the conventional treatment method in analyzing the different removal/reduction parameters (TSS, BOD, COD, HRT, SRTand F/M ratio) is poor on comparison with the MBR system.
Keywords--Industrial wastewater, Membrane Bioreactor, wastewater treatment.

I. INTRODUCTION

In India, most residential sewage treatment plants are expected to have zero liquid discharge (ZLD). Water is a source of life and regarded as the most essential of natural resources. Existing freshwater resources are gradually becoming polluted and unavailable due to human or industrial activities. The increasing contamination of freshwater systems with thousands of industrial and natural chemical compounds is one of the key environmental problems facing humanity worldwide. A growing number of contaminants are entering water supplies from industrialization like heavy metals, dyes, pharmaceuticals, pesticides, fluoride, phenols, insecticides and detergents may have adverse effects on human health and aquatic ecosystems. In view of the aforesaid problems, recent attention has been focused on the development of more effective, lower-cost, robust methods for wastewater treatment.

II. UNIT OPERATIONS IN SEWAGE TREATMENT PROCESS

The pollutants in waste water are removed by physical, chemical and biological means.

A. Physical Operations

In earlier days, treatment methods used were physical unit operations in which physical forces are applied to remove pollutants. Some of the basic physical operations are given Screening, Comminuting, flow equalization, sedimentation etc.

B. Chemical Operations

Treatment methods in which the removal or conversion of contaminants is brought about by the addition of chemicals or by other chemical reactions are known as chemical unit process. Precipitation and adsorption are the most common examples used in waste water treatment. In chemical precipitation, treatment is accomplished by producing flocks that will settle.

C. Biological Operations

Biological treatment is used primarily to remove the biodegradable organic substance (colloidal or dissolved) in waste water. The substances are converted into gases that can escape to the atmosphere and into biological cell tissue that can be removed by settling. Biological treatment is also used to remove the nutrients such as nitrogen and phosphorous in waste water.

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III. METHODS OF SEWAGE TREATMENT

Various methods for waste water treatment are given below:

Conventional method

Membrane Bioreactor (MBR)

Moving bed Bioreactor (MBBR)

Sequencing batch reactor (SBR)

A. Membrane Bioreactor

The mechanism of biodegradation is successfully used in the conventional activated sludge process for waste water treatment, and also in advanced technologies as Membrane Bioreactor (MBR).Membrane bioreactor (MBR) technology is a combination of the conventional activated sludge process characterized by a suspended growth of biomass and the membrane filtration system. The biological unit is responsible for the biodegradation of the waste compounds and the membrane module for the physical separation of the waste from the mixed liquid. The pore diameter of the membranes range between 0.01–0.1 µm so that particulates and bacteria can be removed. The membrane system replaces the gravity sedimentation unit (clarifier) in the conventional activated sludge process. Hence the MBR offers the advantage of higher product water quality and low footprint.

IV. PLANT LOCATION

The wastewater sample was collected from Beverages (Nemam) Poonamallee Sewage treatment plant in Tamilnadu. This plant was based on the conventional treatment method (pre-treatment method) till DEC 2014, after which the plant is to be revamped to Membrane bioreactor same capacity 60 m^3/day. The conventional method of the sewage treatment plant lay out shown in Fig 1. Fig 2 shows the Membrane Bioreactor method of sewage treatment plant lay out.

Fig 1 Conventional method sewage treatment plant layout

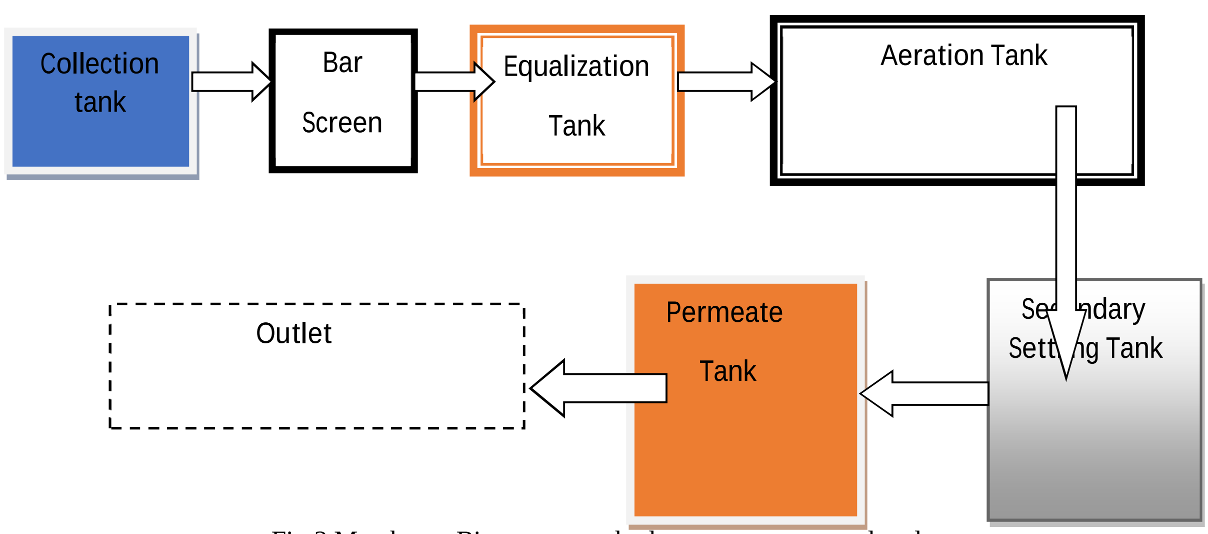

Fig 2 Membrane Bioreactor method sewage treatment plant layout

In this plant revamping membrane bioreactor is installed manufactured by GE.

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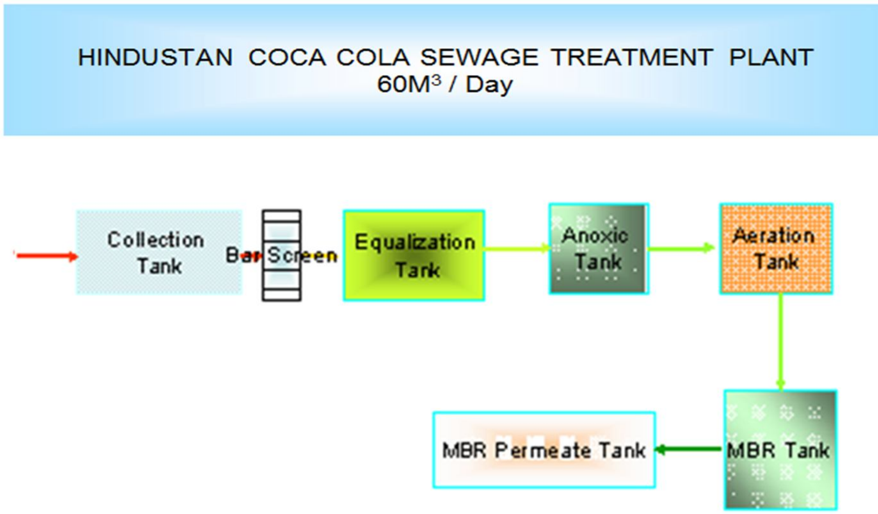

V. MEMBRANE SPECIFICA1TIONS

Specification of membrane used in the Beverages sewage treatment plant given in table 2

Membrane model	Zee Weed 500D (Hollow Fiber)
Membrane material	PVDF
Membrane module surface area	$340ft^2$ ($31.6m^2$)
Membrane pore size	0.04 micron
Operating pH range	5 to 9.5

VI. MATERIALS AND METHODS

The experimental method involved the collection of composite samples in clean plastic containers of 5 liters capacity at four different units of treatment plant, namely, a) Influent to the treatment plant, b) Effluent of aeration tank (considered for the influent of secondary clarifiers) and c) treated water from conventional method, d) treated water from MBR method

The samples were analyzed using the standard methods (APHA, EPA, and USEPA). IS 3025 (PART44-Reaffirmed 2003)The primary parameters included pH,total dissolved solids(TDS),total suspended solids (TSS),Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Sludge Volume index (SVI), MLSS, SRT, HRT.

A. Performance of MBR in Sewage Treatment Plant

1) Sludge Volume Index Method (SVI): 1lit of sewage inlet water sample taken beaker 10 min settle bottom.

The SVI of the process was 360 mg/L

2) Hydraulic Residence Time (HRT: HRT is the average residence time of wastewater in the aeration tank

HRT $=24*V_{at}$ / Q units: hr

Where

Vat = Volume of aeration tank ($m^{3)}$

Q = Flow rate of wastewater influent to aeration tank (m^3/hr)

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HRT = (24* 27)/ (9m^3/hr)
= 72 hrs

3) Food-To-Microorganism (F/M) Ratio): F/M is the amount of BOD to which a unit mass of bio solids is exposed on a daily basis (loading based on microorganisms)

F/M = (Q • S_o) / (MLVSS • Vat)

Where

Q = Influent flow (m^3/hr)

So = Influent BOD concentration (mg/L)

MLVSS = Mixed liquor volatile suspended solids concentration in aeration tank (mg/L)

V_{at} = Volume of aeration tank (m^3)

Influent flow = 9 m^3/hr

Volume of aeration tank =27 m^3

S_o = 128 mg/L

MLVSS = (A-B)*1000/ (Sample of volume mL)
= (1.6-0.8)*1000/ (10)
= 80
= 80*27

MLVSS = 2160 mg/L

(F/M) ratio =1152/2160
= 0.533

4) Solids Retention Time (SRT):

$$SRT = \frac{MLSS * Aeration\ Volume * 8.34}{(WAS\ TSS)*(WAS\ Q)*8.34 + (Effluent\ TSS)*(Q)*8.34}$$

$$= \frac{2160*27*8.34}{(92*7*8.34) + (104*9)*8.34}$$

= 486388.8/ (5370.96 +7806.24)

= 36.911 hrs.

5) Volumetric BOD Loading: BOD applied to a unit volume of aeration tank:

VBL = 8.34 • (Q • So) / Vat

Where
Q = Influent flow
So = Influent BOD5 (mg/L)
Vat = Volume of aeration tank

VBL = 8.34*(9*122)/2

= 339.16 lb/1000ft^3.day

6) Density:

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= Mass/ Volume

= 800 / 1000

=0.800 g/L

= 800 kg/m^3

VII. RESULTS AND DISCUSSION

Determined the general efficiency indicator to compare overall performances of the different plants in terms of average TSS, COD, BOD, CHLORIDE removal efficiencs.Similarly,the, the efficiency of plants is generally measured in terms of removal of organic matter. The pH directly affects the performance of a Secondary treatment process (Metcalf and Eddy, 1991 &2003) Because the existence of most biological life is dependent upon narrow and critical range of pH .since, the solids removal is an important measure for the success of a primary treatment unit (McGhee, 1991) and the dissolved solids content of the wastewater is of concern as it affects the reuse of wastewater for agricultural purposes.

Physico – Chemical properties of sewage water of coca cola sewage treatment plant for conventional and MBR method

METHOD	SAMPLING LOCATION	pH	COD(mg/l)	BOD(mg/l)	TSS(mg/l)	TDS(mg/l)	TS(mg/l)	CHLORIDE (mg/l)
CONVENTIONAL	Initial	7.24	480	108	90	1050	1140	623
	After aeration	7.18	304	52	82	1058	1140	486
	Final	7.05	192	29	24	850	874	425
MEMBRANE BIO REACTOR	Initial	7.48	462	128	95	1025	1120	595
	After aeration	7.24	325	76	82	1008	1090	420
	Final	6.98	36	8	12	514	526	280

After membrane revamped process continuous monitoring inlet and outlet for every 72 hrs because HRT design 72 hrs, SRT design 37 hrs, F/M ratio 0.533 to be calculate

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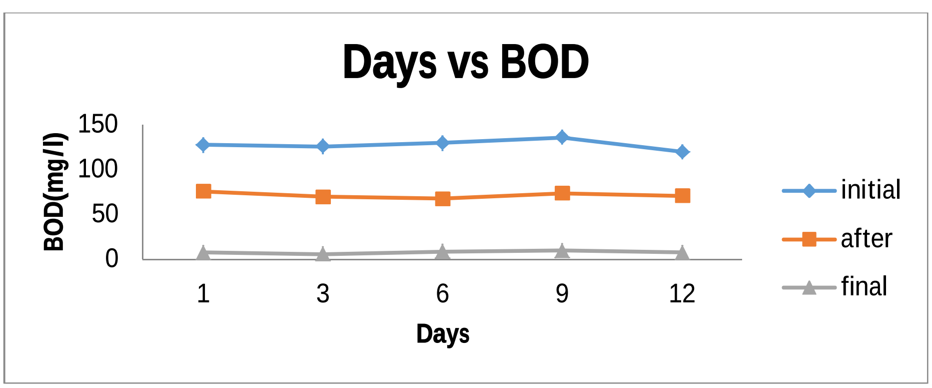
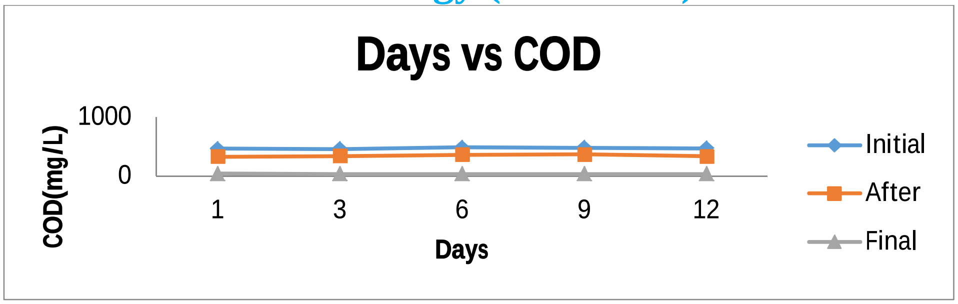
Days	condition	pH	COD (mg/L)	BOD (mg/L)	Cl (mg/L)	TSS (mg/L)	TDS (mg/L)	TS (mg/L)
1	Initial	7.48	462	128	595	95	1025	1120
	After aeration	7.24	325	76	420	82	1008	1090
	Final	6.98	36	8	280	9	514	523
3	Initial	7.49	460	126	590	104	1086	1190
	After aeration	7.20	340	70	432	88	1068	1156
	Final	7.03	32	6	272	10	528	538
6	Initial	7.52	486	130	586	102	1098	1200
	After aeration	7.33	358	68	438	90	1077	1167
	Final	7.1	30	9	286	9	534	543
9	Initial	7.48	478	136	572	99	1076	1175
	After aeration	7.28	364	74	425	83	1036	1119
	Final	6.95	34	10	278	8	518	526
12	Initial	7.48	470	120	570	94	1056	1150
	After aeration	7.19	332	71	418	80	1021	1101
	Final	6.92	28	8	268	7	498	505

Table 3 Physico – Chemical properties of sewage water of coca cola sewage treatment plant for MBR method

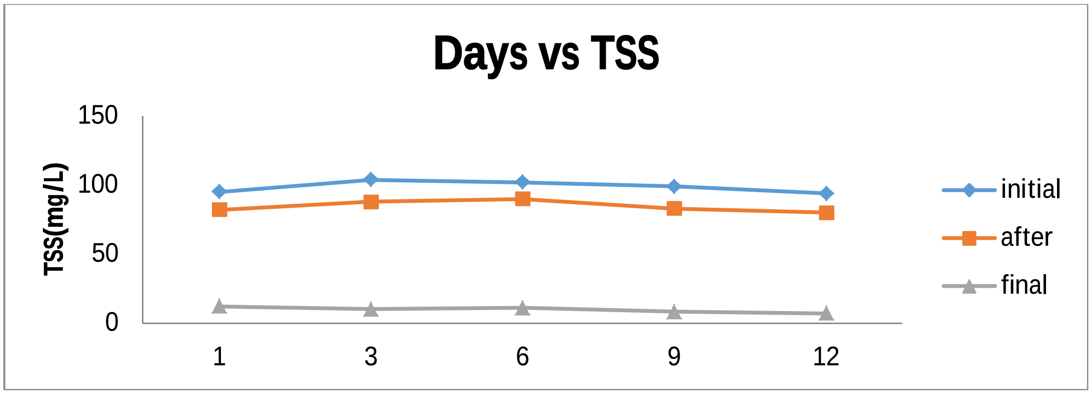
VIII. BIOLOGICAL OXYGEN DEMAND



CHEMICAL OXYGEN DEMAND



TOTAL SUSPENDED SOLIDS



A. Characteristics of Wastewater Influent to Inlet Of Treatment Plant

Coca Cola (Nemam) Poonamallee Sewage treatment plant in Tamilnadu, at the inlet, performance study of 7 months collected and analysis the concentration ranges of total dissolved solids, total suspended solids, BOD and COD were 1025 – 1096 mg/L, 90 – 104 mg/L, 120 – 136 mg/L, 460 – 486 mg/, While the average chlorides were 570 – 595 mg/L.The pH varied from 7.24 to 7.52.

B. Characteristics of Wastewater Effluent To Aeration Tank

Aeration tank in the both the treatment plant is considered a most important step in activate sludge process and the priority was intended to increase the dissolved oxygen level of sewage so that the aerobic digestion facilitates decomposition of organic matter this has to be ensured because of low dissolved oxygen content (nil) in the influent. The DO in aeration tank range from 1.2 to 2.6 mg/L.

MLSS Concentration in the aeration tank range between 2160 -2380 mg/L. Conforming suitability in terms of microbial content. A SVI value 100 – 350 indicates good settling of suspended solids that can be achieved for proper MLSS Concentration. The SVI was 320 mg/L.

C. Characteristics of Wastewater Effluent to Treated Tank

Treated water tank in most important for wastewater treatment in this effluent treated conventional method was calculated by considering the BOD, COD and TSS were 29 - 35 mg/L, 190 -202 mg/L, and 25 – 32mg/L. Sewage Treatment Plant after revamped conventional system to MBR systems Samples were collected and analysis MBR method was calculated by considering the BOD, COD and TSS were 7 - 9 mg/L, 28 -36 mg/L, and 9 – 11mg/L.pH varied from 6.98 – 7.12

D. Overall Efficiency of the Two Treatments Methods

The overall efficiency of the two treatments methods was calculated by considering the TDS, TSS, COD and BOD of the influent and final effluent from conventional method and MBR Method. The percentage reduction in COD is 192 - 202 mg/L and 58% - 60% in Conventional Method, MBR Method reduction of COD is 28 - 36 mg/L and 92.5% - 94% respectively. The percentage reduction in BOD is 29 -35 mg/L and 74% -76% in Conventional Method, MBR Method reduction of BOD is 6 - 9 mg/L and 93% - 95 % satisfactory. The percentage reduction in TSS is 25- 32 mg/L and 69% -72% in Conventional Method, MBR Method reduction of TSS is 7 - 10 mg/L and 90% - 92% satisfactory.

OVER ALL EFFICIENCY FOR CONVENTIONAL SYSTEM AND MEMBRANE BIOREACTOR SYTEM

IX. CONCLUSION

The maximum COD and BOD, TSS, TDS removal was observed at 72hrs the optimum HRT is assessed for every 72hrs, for effective Removal of COD, BOD, TDS, and TSS, Removal BOD, COD (Microorganism and organic contamination) optimum for 6 to 9 days, Removal of TSS, TDS optimum for 6 days. MBR maximum efficiency 30 to 35 % compared to conventional method. Comparison between industrial wastewater treatment conventional Method and Membrane Bioreactor System, so this process conventional method treated wastewater using garden purpose only. Sewage Treatment Plant after revamped conventional system to MBR systems treated water reuse gardening, flushing, cooling tower.

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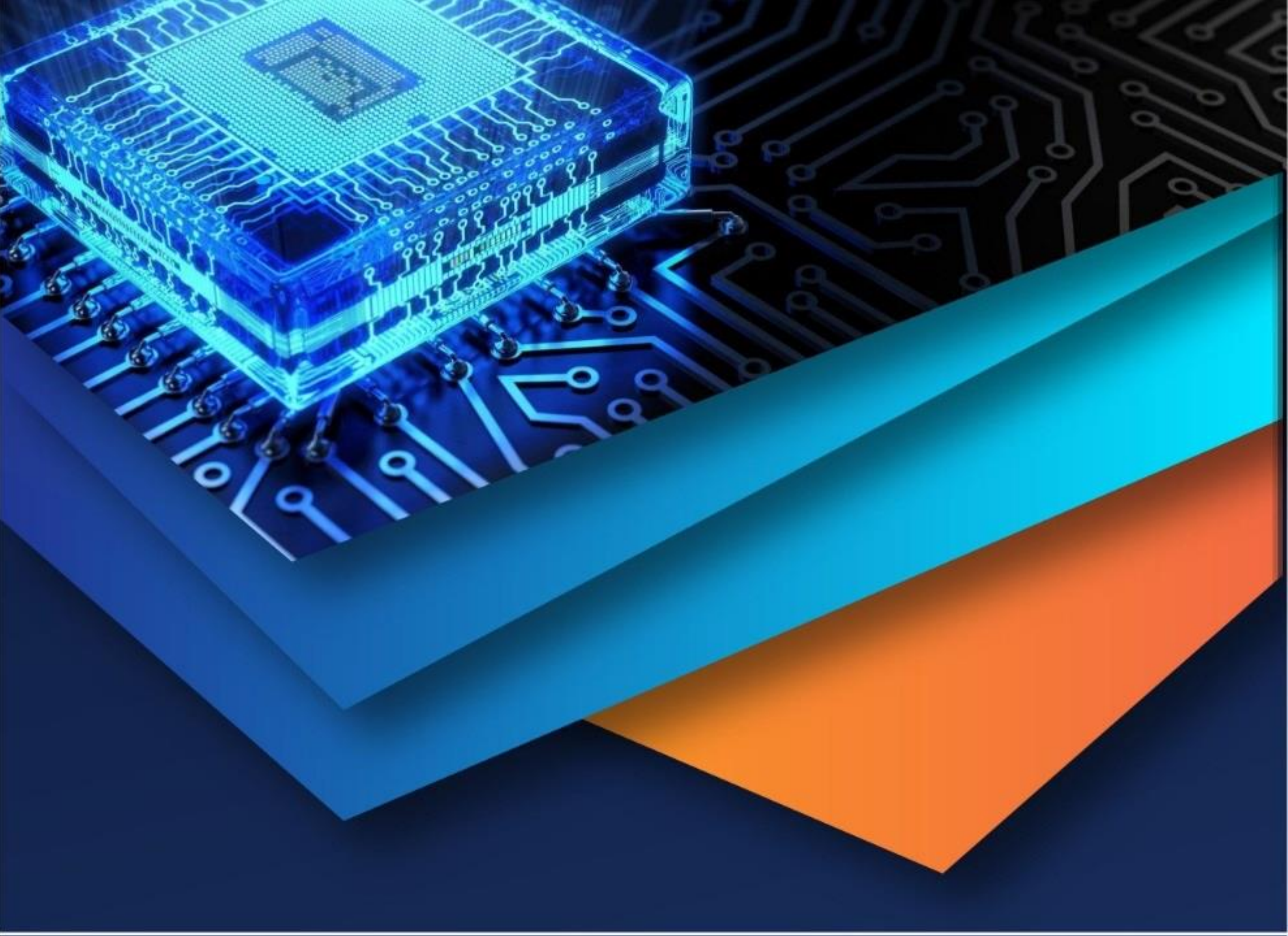

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