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Predictive Design Calculation for the Shejar Wastewater Treatment Plant in the City of Sokna

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Abstract: As a result of increased environmental awareness and a genuine interest in protecting the environment from pollution, restrictions on wastewater disposal have increased. This has created a need for wastewater treatment plants before random disposal. Given the importance of these facilities and their enormous construction, operation, and maintenance costs, a design model was developed for the city of Sokna. This model was developed based on a prediction of per capita wastewater consumption of 115 liters/day. The estimated future population density of Sokna is 10,000 people, and the resulting organic load per capita is 50 grams/day.

The calculations were completed and the results were acceptable according to existing references for wastewater treatment plant design. The Shagar plant in Sokna is considered one of the modern plants for small residential communities and will serve as a future model for other cities in Libya if it is operational.

Keywords: Wastewater, Shejar, Sokna, Treatment, Sewage

I. INTRODUCTION

Sewage is water containing sediment, suspended matter, pollutants, and other substances, making it unfit for human consumption. Consequently, the water loses its properties due to the presence of these variables, which significantly alter its physical properties. This water contains microbes and infectious diseases that cause illness in humans. Sewage comes from a variety of sources, including household wastewater and factory wastewater. This water consists of organic materials and residues resulting from domestic and industrial uses, such as washing, cleaning, and cooling machines, organic materials, and other materials [1, 2].

Interest in water treatment has increased significantly due to the severe shortage of water around the world, caused by the increasing and high consumption of it. However, it is important to note that the water that is treated... Studying the relationship between urban development and health and the infrastructure services sectors is of particular importance to urban planners. To improve urban health, sewage networks and wastewater treatment plants must be provided before discharging it into water or land. The lack of necessary sewage services, or their inefficient implementation, will contribute to the creation of an environmental problem in the urban area due to human activities and activities, such as discharging wastewater into irregular pits, from which the water seeps into the surrounding environment, polluting groundwater and soil. It may overflow to the surface, causing unpleasant odors and undesirable sights, in addition to attracting disease-carrying insects [3, 4].

Sewage or wastewater is liquid waste resulting from various human activities, whether domestic, commercial, institutional, or industrial. It is collected through a network of pipes and channels to reach a specific collection point for treatment [5].

II. DEFINING THE PROBLEM

There are problems facing us in terms of plant operation, in addition to the massive energy consumption and lack of proper sanitation. A clear national strategy, with clear criteria for selecting priority cities for wastewater treatment, is needed. Given the high water table in the city of Sokna, the mixing of groundwater with wastewater, and the lack of national expertise in the operation and maintenance of treatment plants, we summarized the most important problems in this study as follows:

1) The lack of monitoring and programming in most wastewater treatment plants.
2) The climatic conditions experienced by Sokna, including high temperatures in the summer and climate fluctuations throughout the rest of the year.

III. PROJECT OBJECTIVES

1) Identify the treatment plant units.
2) Explain the treatment processes taking place in the plant units.

3) Calculate the performance of the Shejar wastewater treatment plant by predicting the values of various barometers over time, such as the concentration of suspended solids, ammonia concentration, and BOD in the outflow from the plant, and in response to changing climatic conditions.

IV. LITERATURE REVIEW

The problem of water pollution and the environment has become a danger that threatens the extinction of the human race, and even threatens the lives of all living beings, including plants. Since the emergence of the industrial revolution in the middle of the last century, the world has witnessed a rapid and continuous increase in the production of huge quantities of various chemical materials for various uses. All of this was for the sake of raising life to a better level [6, 7]. However, this would not have been achieved without the occurrence of many environmental disadvantages resulting from the entry of these foreign materials into the environment and their disruption of ecosystems, whether on land, in water, or in the air alike. The problem of pollution has become one of the most important problems facing developed and developing countries, and all of this is due to man and his excessive selfishness. Human is behind every mistake, and nature does not accept leniency.

The Earth contains large quantities of fresh water in the form of groundwater, 40% of which is exploited for general consumption, which is constantly increasing and often exceeds the population growth rate. Water consumption has doubled at least twice in the twentieth century. In addition to this depletion, water resources suffer from various forms of pollution [8, 9, and 10]. If water pollution continues at the current rate, with increasing quantities of exploited water, this will lead to the depletion of fresh water in the near future. Groundwater is the primary source of water in the Sokna region. Groundwater is the water found in the interior of the Earth, stored in the pores or cracks of rocks. The quantity of groundwater varies depending on the depth from the Earth's surface.

Extractable groundwater is found in rocks with good porosity and permeability. The group of layers containing groundwater within an aquifer is called an aquifer. There are two types, depending on the rock stratigraphic relationships and the recharge method: unconfined aquifer [11].

It is fed by rainwater seeping from the entire surface of the area beneath which the aquifer is located. Confined aquifer: The water is confined between two non-porous rock layers and is fed from specific locations.

Many countries rely on groundwater as their primary water source, including many Arab countries with arid climates where surface water is scarce [12, 13].

Groundwater exploration in various countries using traditional methods, including geological and geophysical studies, can require significant effort, human and financial resources, and considerable time. Agricultural development and the need to provide drinking water for some cities in a country often necessitate the urgent need to identify water resources, especially groundwater [14, 15].

Many environmental problems are caused by humans, who are always striving for luxury. They have introduced many chemical, agricultural, and industrial wastes into the household system, which in turn has led to an imbalance in the environment and affected the health of living organisms, especially humans. Since water is the basic element for any aspect of life and is one of the most important elements of natural wealth in the universe and includes the basis of daily nutrition for the animal and plant kingdoms, water pollution is considered an extremely dangerous matter. Hence, the importance of water purification and desalination is highlighted. There is no doubt that the use of highly pure water reduces the spread of diseases and epidemics that occur as a result of water pollution. The amount of water on the Earth's surface is estimated at about one and a half billion square kilometers of water, which exists in the form of surface and groundwater. Almost all of this water requires treatment or desalination. More than 99% of the water found in nature is unfit for direct human use for physical, chemical, or biological reasons. Only less than 0.007% of natural water can be used directly by humans, and even this amount requires biological treatment. Humans use water in various ways in their lives. They use between 60-66% of their total consumption in agriculture and approximately 30-34% in industry [8, 16, 17].

Only about 1% is used for drinking and domestic uses and less than 1% for other services [18]. This is in industrialized countries. In developing countries, the numbers differ slightly. About 83% of water is consumed in agriculture, 14% is consumed in domestic services, about 3% in industry, and less than 1% for other uses. Since each use of water requires a specific quality of water, water purification and desalination plants have spread in various countries of the world. The proper management and operation of these plants ensures the distribution of life according to the type of use and improves uncontaminated water for human use, and thus the lowest rate of diseases that can spread through the use of contaminated water [19, 20].

V. SOURCES AND PROPERTIES OF WASTEWATER

Sewage is classified according to its source as follows:

1) Domestic wastewater is wastewater coming from homes, commercial premises such as markets and restaurants, and institutional premises such as schools and hospitals. The quantity of wastewater coming from homes varies depending on the time of day, the day, and the season. New domestic wastewater has a kerosene-like odor, while old wastewater has a very unpleasant odor, similar to the smell of rotten eggs and hydrogen sulfide. New wastewater is gray in color. Old wastewater is black in color. The temperature of domestic wastewater ranges between 10-20 degrees Celsius.
2) Industrial wastewater is wastewater coming from various factories.
3) Infiltrated and flowing water is water that infiltrates into sewage networks from groundwater wells by seepage and seepage through damaged pipes or pipe connections, in addition to rainwater that enters through manholes and drains.
4) Rainwater is rainwater or snowmelt that enters wastewater networks. Wastewater components: Chemical components: Wastewater is approximately 99% water, and 1% is organic and inorganic matter in the form of dissolved and suspended matter [1, 21]. Protein, cellulose, lipids, and inorganic matter are present in the form of suspended matter, while alcohols, acidic lipids, and amino acids are present in the form of dissolved matter. The pH value of domestic wastewater ranges from 6.7-8, while the pH of industrial wastewater varies according to its chemical components. Biological components: Microorganisms found in wastewater vary between droplets, bacteria, protozoa, viruses, and microalgae.

VI. COMPONENTS OF A SEWERAGE NETWORK

1) Water treatment plant.
2) Pump station or pumps.
3) Main drainage lines, which transport large quantities of waste. These lines are large pipes or, in some densely populated countries, huge tunnels.
4) Subsidiary drainage lines.
5) Manholes.
6) Grinding mills.

VII. LOCATION OF STUDY

The Sokna area is located in the municipality of Al-Hufra, which extends between latitudes 26 and 30 north and longitudes 15 and 19 east. It is worth noting that the area is surrounded by several highlands, represented by the Waddan Mountains, which occupy the eastern side, while the Black Mountains occupy the southern part of the Al-Jufrah region. Note the diversity of surface features in this area, from mountains to transition zones between the desert and the mountains. The variation in topography is due to the geological structure of the rock masses, the physical and chemical composition of the rock layers from which the topography is formed, and the various types of erosion factors and the extent of the rocks' resistance to erosion, to which the topography is subjected by ground movements. That fined that the Waddan Mountains are part of the Rawagha mountain range, with a maximum height of approximately 671 meters above sea level. In the southeastern part, the so-called Afia Mountains appear, overlooking Sukna and Hun. These formations are weak compared to the other highlands... the black Waddan Mountains. The Afia highlands are located on a high area south of Sukna, making them appear higher than the rest of the highlands, and also more exposed to the winds. This difference in level shows the fluidity of water movement from the Sukna area to the Waddan and Hun areas. As for the type of formations contained in the desert area in the Jufra region, they are the soft sands that spread over wide areas and consist of longitudinal ranges of dunes that appear in the shape of a crescent according to the wind speed.

VIII. SEWAGE TREATMENT PLANT (SHEJAR PLANT)

The Shejar Treatment Plant is located in the municipality of Al-Jufra (Sukna City), northeast of the city center, approximately 6 kilometers away. It is considered one of the most modern treatment plants in the world and is surrounded on the western side by a mountain range. The waste generated by this plant is discharged into the valley adjacent to this mountain range.

It has been in operation by the Public Works Company since 1999 and was completed in 2010.

IX. DESIGN CALCULATION FOR SHEJAR WASTEWATER TREATMENT PLANT

TABLE I:
DATA RELATED TO THE STATION DESIGN

NO	Index	Value
1	per capita discharge rate	115 L/day
2	Design population	10000
3	Organic load per capita	50 Gm/day

TABLE II:
DATA RELATED TO THE OPERATION OF THE TREATMENT PLANT

NO	Index	Value
1	Removal BOD rate	90-95%
2	Concentration of BODS in the water coming out of the station	20m/g
3	Chemical used at the plant	Chlorine
4	Running time	24 h

A. Design basics:

Design flow = Number of users*Per capita discharge*Percentage of water reaching the station

Whereas:

The current population of Sokna is 8,000, and the design will be based on a future population of 10,000.

The average per capita water discharge is approximately 115 liters per day.

The percentage of water reaching the station is 80%, with some of the water being lost in plant irrigation and cleaning operations. Therefore:

Design flow = 0.8 * 115 * 10,000 = 9,200,000 liters per day = 920 cubic meters per day

The water reaching the station, resulting from the activities of the city's residents, is supplemented by water seeping into the sewage network and seeping from the elevated groundwater. Depending on the region's climate, this amount seeping into the station is estimated at 80 cubic meters per day, according to information obtained from the station's archives. Therefore, the following equation is:

Design flow = Calculated flow - Seepage flow = 920 + 80 = 1,000 cubic meters per day

B. Sand removal basin:

The effective height of the upper chamber designated for sand settling (the lower chamber is designated for sand collection) is 0.75 m. The effective height is the vertical distance between the bottom of the channel floor entering the upper chamber and the bottom of the upper chamber. The radius of the upper chamber is 0.6 m, so the volume of the upper chamber designated for sand settling is:

Volume of the sand settling chamber = 2(0.6) * 3.14 * 0.75 = 0.85 cubic meters

Residence time = 0.85 / 0.02 = 42 h = 0.02 * 3600 = 72 sec

C. Wet Well:

Dimension of wet well = (3 * 2.2 * 2.5) m

So the volume of the wet well = 3 * 2.2 * 2.5 = 16.5 m^3

From this, the residence time in the wet well can be calculated = Wet Well Volume / Flow

Residence Time = 16.5/42 = 0.392 hours = 23.6 minutes

D. Aeration basin:

The volume of the aeration basin is given by the following equation:

Vr = ϴc * Q*Y (SO-S)/X (1+kd* ϴc)…………………………………………. (1)

Where:

Vr: Volume of the aeration tank.

ϴc: The duration of sludge retention in the aeration tank, taken as 28 days.

Q: Average daily inflow (1000 cubic meters per day).

SO: BOD concentration in the inflow (500 mg/L).
S: BOD concentration in the outflow, (20 mg/L).
X: Volatile solids concentration in the aeration tank, chosen as 3400 mg/L.
kd: Decomposition coefficient, chosen as 0.4.
Y: Biomass production coefficient, chosen as 0.6. However, after taking into account all volatile and non-volatile substances, the value of this coefficient is:
Y=0.6/0.8=0.75…………………………………………………………… (2)
Therefore, the volume of the aeration tank is:
Vr = 28 * 1000 * 0.75 * (500 - 20) / 3400 (1 + 0.4 * 28) = 1400 m^3
Required volume of the aeration tank
Vr = 1400 m^3

E. Secondary Sedimentation Basin:
Surface area of the sedimentation basin = 64 m^2
Size of sedimentation basin = 3.5 m
Volume of the sedimentation basin = Surface area * Height = 64 * 3.5 = 224 m^3
Residence time in the sedimentation basin = Volume / Flux = 42/224 = 53 h

F. Checking the hydraulic loading ratio:
Hydraulic loading ratio = Daily flow / Catchment surface area
Hydraulic loading ratio =
=1000/64 = 15.62 m^3/m^2.d
The hydraulic loading ratio is achieved and within the reference [22] (16.28 - 8.14) m^3/m^2.d

G. Solids Loading Rate:
Solids Loading Rate = Daily Amount of Suspended Solids Entering the Tank / Surface Area of the Tank
Per capita daily solids production is approximately 75 grams per capita
Daily Suspended Solids Input into the Tank = 0.075 * 10,000 = 750 kg per day = 32 kg per hour
Solids Loading Rate = 32/64 = 0.5 kg/ (m^2/h)
Solids Loading Rate (SLR) = Flux * MLSS x Surface Area of the Tank
MLSS = MLYSS/0.8 = 3500/0.8 = 4375 mg/L = 4.375 kg/m^3
SLR = 42 * 4.375/64 = 2.9 kg / (m^2 .h)
According to Reference [22], the SLR value should be within the range (0.97 – 4.88) kg / (m^2 .h)
The solids load on the tank is light, so there is a safety factor in the event of high solids content in emergency situations.

H. Calculating Excess Sludge Flow:
The daily per capita production of organic matter according to the male reference is 41, but in the design, this production is considered to reach 50 grams per capita per day for safety reasons. Therefore, the daily organic load (BOD) produced by the city is:
The daily organic load (BOD) produced by the town = Population * Daily per capita production of organic matter.
The daily organic load (BOD) produced by the town = 100, 00*0.5 = 500 kg
Since the daily population flow is 31,000 m, the BOD concentration is = 1000/50,000 = 500 mg/L
Since the BOD concentration in the outflow is 20 mg/L, the injected BOD concentration is:
480 mg/L = 20-500.
Therefore:
BOD removed = 100 * 0.480 = 480 kg
The percentage of sludge withdrawn from the reactor to maintain bioluminescence is calculated using the equation:
Yobs = Y/ (1 + Kd * ϴ) = 0.7 / (1 + 0.04 * 28) = 0.33
The amount of volatile biomass produced in the reactor is calculated using the equation:
Yobs * Q * (S0 - S)/1000 = 0.33 * 1000 * (500 - 20)/1000 = 158 kg VSS/day
The total amount of biomass produced in the reactor (volatile biomass accounts for 0.8% of the total)

Px (ss) = 158/0.8 = 198 kg/day
The weight of biomass (sludge) withdrawn from the sedimentation tank daily is:
Amount of biomass produced by the reactor - Amount of suspended solids escaping with the outflow. Sludge weight =
198 - 1000 * 30/1000 = 168 kg per day
Assuming the outflow of suspended solids = 30 mg per liter

I. Volumetric Load Calculation:

Volumetric load is given by the equation:
VL=Q*S0/V=1000*500/1400*1000=0.4 kg BODY/m^3 day
It is within the range 0.4 - 0.16 kg BODY/m^3 day. As the reference [22]

J. Sludge tank calculations:

Sludge condensation and aerobic digestion tank:
Surface area of the basin = 52 m^2
Wading height = 4.2 m
Volume of the basin = 52 * 4.2 = 218.4 m^3
Residence time in the sludge basin = 218.4 / 16.8 = 13 days
This is achieved according to the aforementioned reference (10-15 days)

K. Sludge Drying Tank:

Required tank space = Annual sludge volume / Sludge loading rate
The previously calculated sludge loading rate is 98 kg/m^2.year.
The annual sludge volume is calculated as follows:
The daily sludge removal volume was previously calculated as 16.8 m^3, which represents 99% moisture content, meaning that 1% of the solids are present. After condensation and digestion, the volume is 2.5%, reducing by two and half times. This means that the daily sludge volume reaching the drying tanks is 6.72 m^3. Therefore, the weight of the sludge before digestion is 168 kg. However, in the sludge digestion tank, approximately 50% is digested and converted into water vapor and carbon dioxide, leaving 50% and transported to the drying tanks (84 kg/day). Therefore, the annual sludge volume reaching the drying tanks = 365 x 84 = 30 tons
Area required for drying = 30,000/98= 306 m^2
There are four pools, each 11.5 m long and 6.5 m wide.
Area of the pools = 4 * 5.6 * 11.5= 300 m^2

L. Purification Tank Calculations:

According to the reference, the residence time in purification tanks is between 20-30 min for average flow.
The length of the purification tank is 11.5 m and its width is 1.5 m.
Therefore, the area after deducting the area of the partition walls is 10 m^2 and the height is 1.75 m.
The volume is 17.5 m^3.
Therefore, the residence time is 17.5/ 42= 0.42 hrs = 25 min.

M. Aeration Requirements Calculations:

The aeration tank's requirements, as indicated in Reference [6], indicate that for every 1 kg of BOD removed, 1-12 kg of oxygen is required.
If the daily BOD removed is 480 kg, the required oxygen quantity is:
= 480 * 1 kg O_2 /day
Multiply by a capacity safety factor of 2 to cover the maximum requirement and nitrification requirements, if necessary. Therefore, the required oxygen quantity is:
Amount of oxygen = 2 * 480 = 960 kg O_2 /day
The specific gravity of oxygen is 1.2 kg/m^3, so the required oxygen volume is
960/1.2 = 800 m^3
The percentage of oxygen in the air is 21%

The required air volume = 0.21/800 = 3810 m^3 of air per day
The effectiveness of the air diffusers is 12.5%
The actual required air quantity is = 8 * 3810 = 30480 m^3 of air per day
Amount of air required for the aeration tank = 24/30480 = 1270 m^3 of air per minute.

N. Sludge Digestion Tank Requirements:

Each 1 cubic meter of sludge digestion tank volume requires 0.04 liters of air per minute.
Sludge Digestion Tank Volume: m3256
Amount of air required per minute = 10.24 = 0.04 * 256614 Sludge Digestion Tank Requirements:
Each 1 cubic meter of sludge digestion tank volume requires 0.04 liters of air per minute.
Sludge Digestion Tank Volume: 256 m^3
Amount of air required per minute = 0.04 * 256614 = 10.24 m^3per hour

O. Air Lift Pump Requirements:

1) Amount of air required for the air lift pump for recycled sludge:
1.5 * 1000 m^3 per day = 1500 m^3per day
This flow, with an 85% pump immersion ratio, requires 30 m^3 of air per hour.
2) Amount of air required for the air lift pump for excess sludge:
The excess sludge is discharged at a rate of 19 m^3/dper hour

P. Air Lift Pump Requirements:

1) Amount of air required for the air lift pump for recycled sludge:
1.5 * 1000 m^3per day = 1500 m^3 per day
This flow, with an 85% pump immersion ratio, requires 30 m^3 of air per hour.
2) Amount of air required for the air lift pump for excess sludge:
The excess sludge is discharged at a rate is 19 m^3/d
The required air volume is 10 $m^3$of air per hour (at a pump immersion rate of 85%).
3- Total air volume required for air lift pumps
= 30 + 10 = 40 m^3per hour
Checking the adequacy of the supplied air:

- Total air quantity required:

Total ventilation requirement m^3/hr = 40 + 614 + 1270 = 1924

- Supply air quantity:

There is having 4 blowers, each with a capacity of 500 m^3per hour at the required pressure.
The total capacity is = 500*4 = 2000 m^3/hour

- Supply air quantity adequacy:

Note that there is a surplus = 2000 - 1924 = 76 m^3/hour, which represents a safety ratio.

X. CONCLUSION

1) After meeting with the engineers supervising the construction of the Shejar plant and speaking with them at length, it became clear that after treatment, the water is discharged into the valley. This indicates that the project is neither economically feasible nor beneficial to the city of Sokna.
2) In the activated sludge, the obtained barometer values were close to the experimental values, indicating that these results can be used to conduct studies to predict barometers over time.
3) Increasing the number of aeration stages in the activated sludge basin yielded almost the same results, indicating that changing the flow type from full mixing to plug flow does not significantly affect the treatment efficiency.
4) Next to this treatment plant is another wall for discharging recycled water from the drinking water plant at the Shejar internal treatment plant. This will mix the recycled water with the treated wastewater, which is considered one of the company's biggest design errors.

XI. RECOMMENDATIONS

Through this study of this station, the following points are recommended:

1) Establish an alternative electrical system to ensure the continued operation of the pumps during power outages.
2) Conduct ongoing maintenance of the Shejar station to ensure that the pipes transporting the wastewater between the sedimentation and treatment tanks do not become clogged.
3) Utilize the treated wastewater from the Shejar station by connecting it to the agricultural irrigation network near the station.
4) It is essential to provide a programmed monitoring and operation process for most of the current wastewater treatment plants in Libya to assess their effectiveness, performance, and changes in efficiency over time.
5) The design results have reached can be used as basic inputs for future computer-aided design.

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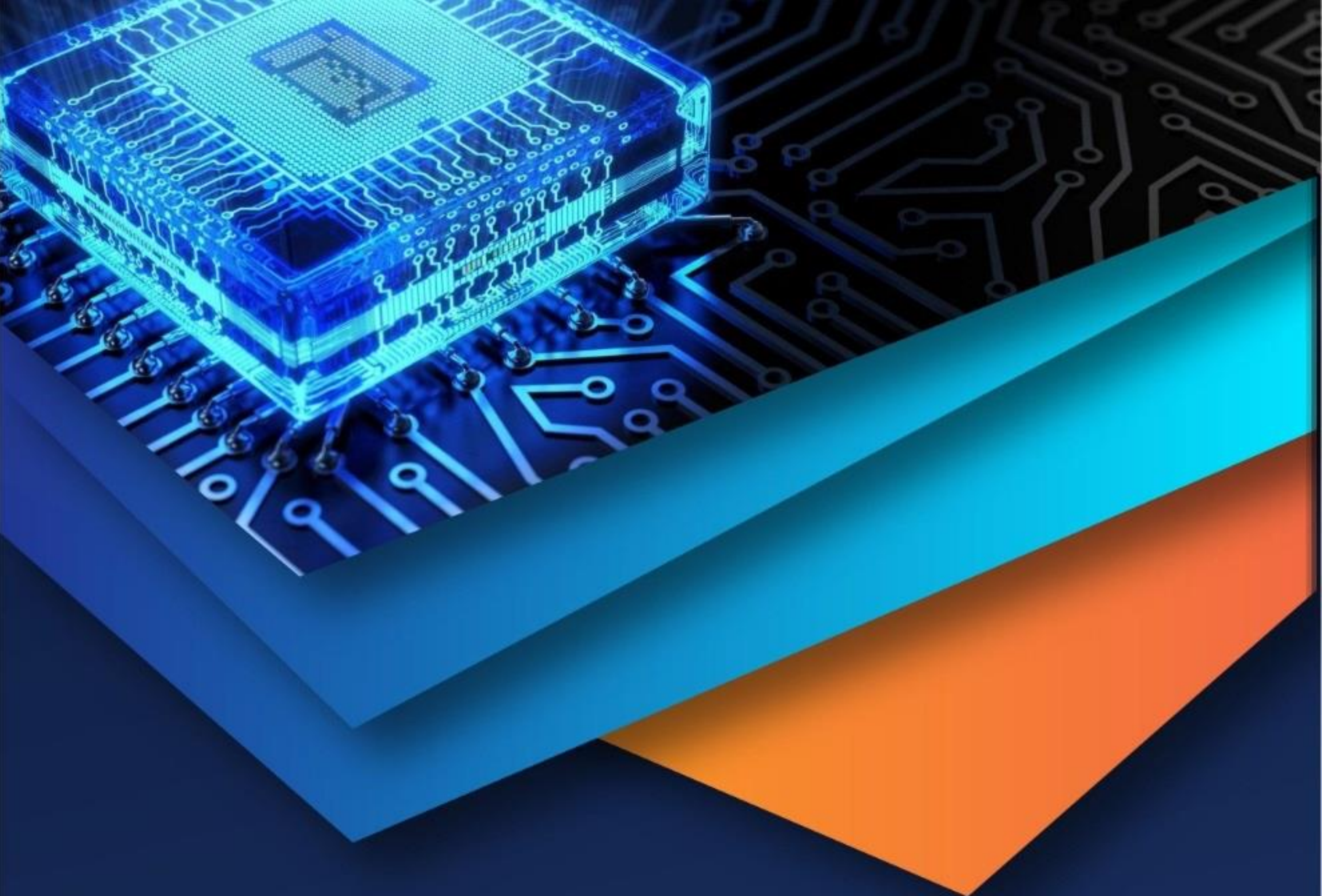

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