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Development of Nutrient-Rich Fertilizer Pellets by Integrating Fly Ash and Vermicompost for Enhanced Soil Health

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Abstract: This study focuses on the development of nutrient-rich fertilizer pellets by integrating fly ash and vermicompost to enhance soil health and agricultural productivity. Fly ash, an industrial byproduct, contains essential micronutrients such as silicon, calcium, and potassium, while vermicompost is rich in organic matter humic substances, and beneficial microorganisms. Combining these materials into pelletized from offers a controlled-release fertilizer that improves nutrient availability, enhances soil microbial activity, and minimizes nutrient leaching.
The research aims to optimize the composition of fly ash and vermicompost for effective nutrient delivery, asses the physical and chemical properties of the pellets, and evaluate their impact on soil health and plant growth. Special attention is given to the potential risk associated with heavy mental contamination from fly ash and methods to mitigate them.
Keywords: Nutrient rich fertilizer, fly ash, soil health, vermicompost, organic matter.

I. INTRODUCTION

A. *Scope of this Project*

The increasing demand for agricultural products due to growing global populations has placed significant pressure on agricultural system to improve productivity. At the same, time intensive farming practices have led to the overuse of chemical fertilizer, resulting in negative consequences for soil health, water quality, and the environment. In light of these challenges, there is growing interest in developing sustainable and eco-friendly alternatives that can enhance soil fertility while minimizing environmental degradation.

However, fly ash is rich in essential material, micronutrients, and trace elements, making it a valuable resource for soil enhancement. Vermicompost , on the other hand, is organic matter that has been processed by earthworms, transforming it into a nutrient-rich, biologically active fertilizer that promotes healthy soil structure and microbial diversity.

This project aims to develop a nutrient-rich fertilizer pellets that provides a sustainable solution for improving soil health. The combination of fly ash and vermicompost not only offers a rich source of essential nutrients but also helps in improving soil structure, enhancing water retention, and increasing microbial activity.

These pellets can deliver nutrients in a controlled and sustained manner, reducing the need for chemical fertilizer and improving the soil health and productivity of crop yields.

B. *Objectives*

1) Develop sustainable fertilizer pellets by integrating fly ash and vermicompost.
2) Evaluate the nutrient profile of the developed pellets compared to commercial fertilizers.
3) Assess the impact on soil health, including structure, microbial activity, and fertility.
4) Examine the effects on crop growth and yield in agricultural settings.
5) Promote waste recycling by utilizing fly ash and vermicompost in fertilizer production.t
6) Minimize environmental impact by reducing chemical fertilizer use and fly ash disposal.

II. LITERATURE SURVEY

1) *Dr. Lesley Sloss, etal "Achieving 100% Ash Utilization at Coal-Fired Power Plants in India".*

The paper "Achieving 100% Ash Utilization at Coal-Fired Power Plants in India" explores methods and strategies for managing the large amounts of ash produced by coal-fired power plants, aiming for complete utilization. Coal ash is a significant byproduct, and its improper disposal leads to environmental concerns like soil and water contamination. The paper, authored by Dr. Lesley Sloss, Sanjeev Kumar Kanchan, Dr. Wojciech Jozewicz, and Paul Baruya, emphasizes the potential of coal ash in various industrial applications, such as in cement production, road construction, and as a filler in concrete.

The authors examine current practices in India and propose measures to enhance ash utilization, aligning with environmental regulations and sustainability goals. They highlight technological innovations and advancements, such as the development of more efficient ash-handling systems and the use of ash in value-added products. Additionally, the paper discusses the importance of collaboration among stakeholders, including the government, industry, and researchers, to improve infrastructure, encourage research, and implement policies that incentivize ash utilization.

2) *Shri G.C. Chattopadhyay, Etal "Issues in Utilization of Ash by Thermal Power Plants in the Country".*

The paper by Shri G.C. Chattopadhyay, titled *"Issues in Utilization of Ash by Thermal Power Plants in the Country"*, discusses the challenges faced by thermal power plants in effectively managing and utilizing the ash produced during power generation. In India, coal-based thermal power plants are the primary source of electricity generation, and they generate substantial amounts of ash as a byproduct. However, the utilization of this ash remains a significant issue. The paper highlights the environmental concerns caused by the improper disposal of ash, such as air pollution, land degradation, and contamination of water bodies. Despite the potential for ash to be used in various industries like cement manufacturing, brick production, and road construction, its utilization remains below the desired levels due to several obstacles. These include inadequate infrastructure, lack of awareness among industries about the benefits of using ash, and the high transportation costs associated with its movement.

3) *Thuy Thu Doan, Etal "Impact of compost, vermicompost and biochar on soil fertility, maize yield and soil erosion in Northern Vietnam: a three-year mesocosm experiment".*

The study titled "Impact of compost, vermicompost and biochar on soil fertility, maize yield and soil erosion in Northern Vietnam: a three-year mesocosm experiment" examines the effects of three soil amendments—compost, vermicompost, and biochar—on soil quality, maize productivity, and soil erosion in Northern Vietnam. Conducted over three years, this mesocosm experiment aimed to identify sustainable practices to improve soil fertility and mitigate soil degradation in regions affected by erosion and declining agricultural productivity. The authors, including Thuy Thu Doan, Thierry Henry- des-Tureaux, Cornelia Rumpel, Jean-Louis Janeau, and Pascal Jouquet, observed that all three soil amendments significantly improved soil fertility, as evidenced by increased organic carbon content, enhanced nutrient availability, and better soil structure. In terms of maize yield, both compost and vermicompost showed positive effects, with vermicompost resulting in the highest maize productivity. Biochar, while improving soil structure and reducing soil erosion, had a relatively moderate effect on maize yield.

4) *Su LinLim,etal"The use of vermicompost in organic farming: overview, effects on soil and economics".*

The paper "The use of vermicompost in organic farming: overview, effects on soil and economics" by Su Lin Lim, Ta Yeong Wu, Pei Nie Lim, and Katrina Pui Yee Shak explores the role of vermicompost in organic farming, focusing on its effects on soil health and the economics of its use. Vermicompost, produced by earthworms breaking down organic matter, is presented as an eco-friendly and sustainable alternative to conventional fertilizers. The study provides an overview of the benefits of vermicompost in organic farming systems, emphasizing its positive effects on soil fertility, structure, and microbial activity. It highlights that vermicompost improves soil nutrient availability, enhances water retention, and boosts soil organic matter content, which in turn promotes healthy plant growth and increases crop yields. Furthermore, it enhances soil biodiversity and reduces the need for synthetic chemical fertilizers.

5) *Anil Kumar, Etal "Potential of Vermicompost for Sustainable Crop Production and Soil Health Improvement in Different Cropping Systems".*

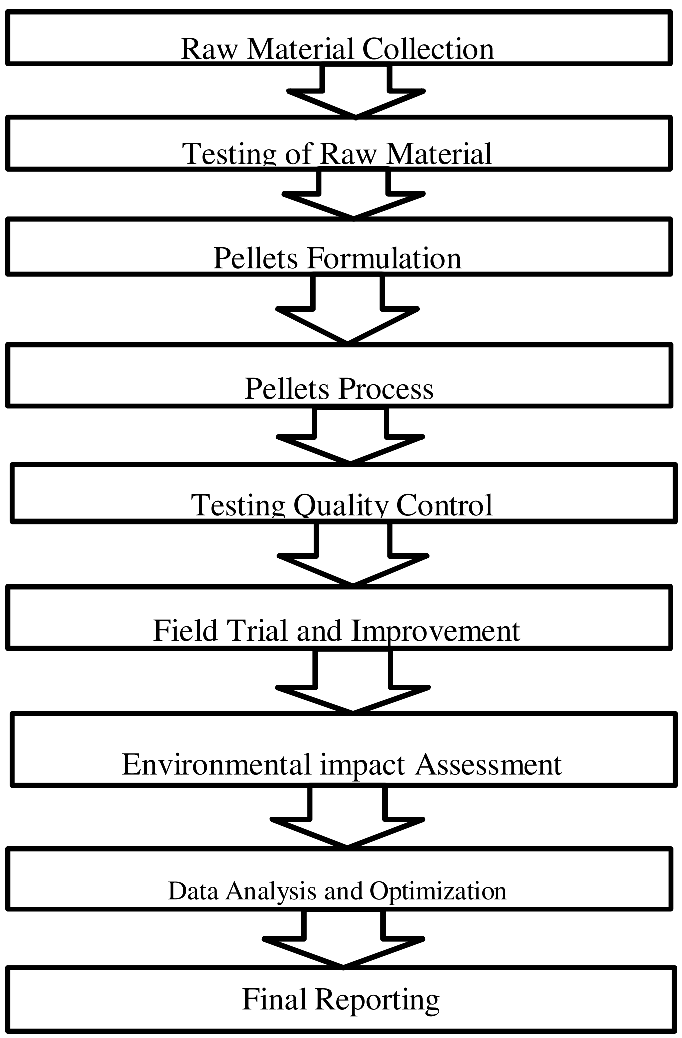
The paper titled "Potential of Vermicompost for Sustainable Crop Production and Soil Health Improvement in Different Cropping Systems" by Anil Kumar, C.H. Bhanu Prakash, Navjot Singh Brar, and Balwinder Kumar explores the potential benefits of using vermicompost as an organic amendment to improve soil health and enhance crop productivity across various cropping systems.

Published in the *International Journal of Current Microbiology and Applied Sciences* (2018), the study highlights the increasing importance of sustainable agricultural practices due to the adverse effects of chemical fertilizers on soil health and the environment. The authors present vermicompost as a valuable alternative to conventional fertilizers, noting its ability to improve soil structure, increase microbial activity, enhance nutrient availability, and retain moisture. These properties help promote soil fertility, which is crucial for sustainable crop production. Vermicompost has also been found to improve plant growth, yield, and resistance to pests and diseases. The paper emphasizes that vermicomposting, when incorporated into different cropping systems (e.g., cereals, vegetables, and legumes), leads to increased agricultural productivity and long-term soil health improvement. The authors advocate for the wider adoption of vermicomposting as part of integrated soil fertility management practices, offering both environmental and economic benefits. Overall, the study supports vermicomposting as an effective tool for sustainable agriculture.

6) Akram Gazi, Etal "Effect of Vermicompost on Soil Quality and Crop Productivity,"

The paper titled "Effect of Vermicompost on Soil Quality and Crop Productivity," published in *Volume 7, SP-Issue 4, April 2024*, explores the impact of vermicompost as an organic amendment on soil health and agricultural productivity. Authored by Akram Gazi, Ani Maity, Nabanita Khatua, Sudip Sengupta, Suprabuddha Kundu, and Tanmoy Sarkar, the study investigates how the use of vermicompost can enhance soil quality and increase crop yields. The research demonstrates that vermicompost significantly improves soil physical, chemical, and biological properties. It enhances soil structure by increasing organic matter, improving water retention, and promoting better aeration. Additionally, vermicompost increases the availability of essential nutrients such as nitrogen, phosphorus, and potassium, which are vital for plant growth. The paper also highlights how vermicompost enhances microbial activity in the soil, further contributing to nutrient cycling and overall soil fertility.

III. RESEARCH METHODOLOGY



A. Raw Mterial Collection

1) Fly Ash

Obtain fly ash from local power plants or industrial sources. Fly ash should be analyzed for its chemical composition, including its content of macro and micronutrients, calcium, magnesium, phosphorus, potassium.

2) Vermicompost

Vermicompost is prepared using organic waste processed by earthworms. The composted material is rich in organic matter, humic substances, and beneficial microorganisms.

B. Raw Material Testing

Physical Properties

Measures the particle size, Moisture content, and Specific Gravity of both fly ash and vermicompost to ensure they are suitable for pelletization.

Tests

- Moisture Content
- Specific Gravity
- Bulk Density

1) Moisture Content

To measure moisture content, first weight the sample to determine its initial weight. Then dry sample in an oven at 105°C for 24 hours to remove the moisture. After drying, allow the sample to cool in a desiccatore to prevent moisture absorption from the air. Once cooled, weight the sample again to obtain its final weight. Finally, calculate the moisture content by finding the percentage difference between the initial and final weight, which represents the amount of moisture lost during the drying process. Take three trial of the moisture content . Note done that results.

$$\text{Moisture Content (\%)} = \frac{\textit{itial weight} - \textit{Dry weight}}{\textit{Initial weight}} \times 100$$

a) Moisture Content of Fly Ash

Table 1: Calculation of moisture content in Fly Ash

Test	Weight of the cup (g)	Weight of the Fly ash (g)	Weight of the Dry fly ash (g)	Moisture content %
Trial 1	20	50	47	6
Trial 2	20	30	27	10
Trial 3	20	20	19	5

Weight of the cup =20g

Weight of Fly ash =50g

Weight of Dry fly ash =47g

$$\text{Moisture Content (\%)} = \frac{\textit{Initial weight} - \textit{Dry weight}}{\textit{Initial weight}} \times 100$$

$$MC\% = \frac{50-47}{50} \times 100$$

$$= \frac{3}{50} \times 100$$

Moisture content of fly ash =6%

b) Moisture content of vermicompost

Table 2: Calculation of moisture content inVermicompost

Test	Weight of the cup (g)	Weight of the vermi-compost (g)	Weight of the Dry vermi-compost (g)	Moisture content %
Trial 1	20	50	42	16
Trial 2	20	30	25	13
Trial 3	20	50	43	14

Weight of the cup =20g

Weight of vermicompost =50g

Weight of Dry vermicompost =42g

$$\text{Moisture Content (\%)} = \frac{\text{Initial weight} - \text{Dry weight}}{\text{Initial weight}} \times 100$$

$$MC\% = \frac{50-42}{50} \times 100$$

$$= \frac{8}{50} \times 100$$

9Moisture content of fly ash =16%

2) Specific Gravity

To measure the specific gravity using of pycnometer, start by determine the weight the Empty pycnometer, Second weighing the sample to determine its initial weight. Next immerse the sample in water and measure its apparent weight while submerged. For solids, the apparent weight in air due to the buoyant force exerted by the water. Using these sample weights, calculate the specific gravity by dividing the weight of the sample in air by the difference between its weight in water. For liquids, the specific gravity is a dimensionless number, indicating how dense the substance is relative to water.

$$\textbf{Specific Gravity} = \frac{W2-W1}{(W2-W1)-(W3-W4)}$$

Fig 1 : Testing of specific gravity

a) Specific Gravity of Fly Ash

Table 3. Calculation of specific gravity of Fly Ash

Test	Weight of the Pycnometer(g)	Weight of the pycnometer + FA(g)	Weight of the pycnometer + FA(g)+ Water	Weight of pycno-meter + water (g)	Specific gravity of Fly Ash (g)
Trial 1	612	812	1621	1521	2
Trial 2	612	832	1650	1521	2.4
Trial 3	612	792	1590	1521	1.7

Weight of pycnometer(W1) =612g

Weight of pycnometer + Ash(W2) =812g

Weight of pycnometer +Ash + Water (W3) =1621g

Weight of pycnometer + water (W4)=1521g

$$\text{Specific Gravity} = \frac{W2-W1}{(W2-W1)-(W3-W4)}$$

$$G = \frac{812-612}{(812-612)-(1621-1521)}$$

$$= \frac{200}{200-100}$$

=200/100

G = 2

Specific Gravity of Fly ash = 2

b) *Specific Gravity of Vermicompost*

Table4. Calculation of specific gravity of Vermicompost

Test	Weight of the Pycnometer(g)	Weight of the pycnometer + VC(g)	Weight of the pycnometer + vc(g)+ Water	Weight of pycno-meter + water (g)	Specific gravity of VC (g)
Trial 1	612	812	1584	1521	1.5
Trial 2	612	832	1620	1521	1.8
Trial 3	612	792	1550	1521	1.27

Weight of pycnometer (W1) =612g

Weight of pycnometer + Vermicompost (W2) =812g

Weight of pycnometer + Vermicompost + water (W3) =1584

Weight of pycnometer + water (W4)=1521g

$$\text{Specific Gravity} = \frac{W2-W1}{(W2-W1)-(W3-W4)}$$

$$G = \frac{812-612}{(812-612)-(1584-1521)}$$

$$= \frac{200}{200-63}$$

=200/37

G = 1.5

Specific Gravity of Vermicompost = 1.5g

Fig 2 : Specific Gravity

3) Bulk Density

To measure bulk density, first select the container of know volume. Carefully fill the container with the sample material, ensuring it is not compacted. Then, weigh the filled container to get the total weight. After that, weight the empty container to determine its weight. Subtract the weight if the empty container from the total weight to find the weight of the sample. Finally, calculate the bulk density by dividing the weight of the sample by the volume of the con tainer. The bulk density, typically expressed in g/cm^3 reflects the mass of the material per unit volume.

a) Bulk Density of Fly Ash

Weight of bottle W1 = 172g

Weight of Fly Ash + bottle W2 = 680g

$$\text{Density} = \frac{W1-W2}{V}$$

$$= \frac{680-172}{485.71} = 1.05\text{g/cc}$$

Bulk density of Fly Ash =1.05 g/cc

b) Bulk Density of Vermicompost

Weight of bottle W1=172g

Weight of Vermicompost + bottle W2= 576g

$$\text{Density} = \frac{W1-W2}{V}$$

$$= \frac{576-172}{485.71} = 1.220\text{g/cc}$$

Bulk density of vermicompost=1.220g/cc

4) Quantity of Vermicompost

$$\text{Volume} = 9\times \frac{\pi}{4} \times \left(\frac{D+d}{2}\right)^2 \times 2.5$$

$$= 9\times \frac{3.14}{4} \times \left(\frac{7+5.5}{2}\right)^2 \times 2.5$$

Volume = 689.9cm^2

m= 1.220g

m= 1.220×Volume of 1 vermicompost pellets

m = 1.220×689.9

m= 841.678g

a) Quantity of One Pellets

$$m=\frac{841.678}{9} = 93.51g$$

Water Quantity

Ratio	Vermicompost	Fly Ash	Water Quanity
100% VC	93.5	0	30
90%VC+10%FA	84.15	9.35	28
80%VC+20%FA	74.8	18.7	25
70%VC+30%FA	65.5	28.0	23

C. Pellets Formulation

1) Determining the Optimal Ratio:

Based on the nutrient analysis, experiment with different ratios of fly ash to vermicompost (90:10, 80:20, 70:30) to find the most effective blend for optimal nutrient release and soil enhancement.

2) Additives

Evaluate the need for additional additives such as binding agents to improve pellets cohesion and durability**.**

D. Pelletization Process

1) Mixing

Mix fly ash and vermicompost thoroughly to achieve a homogeneous blend. Adjust moisture content as required to facilitate the pelletization process.

2) Pelletization

Use a pellet mill or extrusion system to convert the mixture into uniform-sized pellets. Adjust parameters such as pressure, temperature, and pellet size for optimal production.

Fig 3 : Fertilizer Pellets

3) Drying

Assess the environmental benefits of using fly ash and content to a level suitable for storage and application (typically below 10%).

E. Testing and Quality Control

1) Physical Properties of Pellets:

Test the durability, size, and shape consistency of the pellets. Pellets should be resistant to crumbling or degradation during handling and application.

2) Moisture Content and Shelf Life:

Ensure that the pellets maintain appropriate moisture content for optimal storage and handling without promoting fungal growth or decay.

F. Field Trial And Improvement

1) Soil Health Improvement

Conduct field trials on loamy soil to evaluate the impact of the fertilizer pellets on soil properties such as PH, organic matter content, microbial activity, and water retention.

2) Plant Growrth and Yield Assessment

Fenugreek plants crops in trays treated with the developed fertilizer pellets and compare growth, yield, nutrient uptake with trays treated with nutrient pellets.

3) Soil Microbial Analysis

Analyze soil microbial populations before and after pellets application to assess the impact on beneficial microorganisms, which are vital for long term soil health.

G. Environmental impact Assessment

1) Leaching and pollution.

Monitor the pottential leaaching of harmful elements from the fertilizer pellets into the soil. Test for heavy metal, salt accumulation, other pollutants that may affect environmntal health.

2) Sustainability Evaluation

Assess the environmental benefits of using fly ash and vermicompost, including reduced waste accumulation, and reduced dependency on chemical fertilizers.

3) Optimization of pellets Characteristics.

Refine the formulation and pelletization conditions based on trial results to improve the nurtient release profil, pellet durability, and cost effectiveness.

H. Final Reporting and Recommendations

1) Project Results

Compile the findings from the tests and field trials into a comprehensive report that includes nutrients content, soil health impact, crop yield improvements, and environments considerations.

IV. RESULT & CONCLUSION

A. Results

The experimental investigation yielded promising results that demonstrate the effectiveness and viability of the fertilizer pellets developed from fly ash and vermicompost. Various formulations were tested, and the **70:30 ratio of** vermicompost to fly ash showed the most balanced performance in terms of nutrient availability, pellet strength, and plant growth response. The experimental results clearly indicate that fertilizer pellets developed from fly ash and vermicompost offer a nutrient-balanced, eco-friendly, and effective alternative to conventional fertilizers. They not only support healthy plant growth but also enhance soil quality over time due to their slow-release and soil-conditioning properties.

B. Conclusion

The development of nutrient-rich fertilizer pellets by integrating fly ash and vermicompost offers a promising approach to improving soil health and promoting sustainable agriculture. The combination of these two materials fly ash, a byproduct of coal combustion, and vermicompost, a nutrient-rich organic compost produced by earthworms creates a balanced fertilizer with enhanced nutrient content, including essential macro and micronutrients for plant growth.

The findings of this project suggest that the integrated fertilizer pellets can significantly enhance soil properties, including fertility, structure, and microbial activity. The fly ash helps to improve soil aeration and drainage, while vermicompost contributes essential nutrients such as nitrogen, phosphorus, potassium, and beneficial microorganisms. This synergy can improve the nutrient availability in the soil and support long-term soil health.

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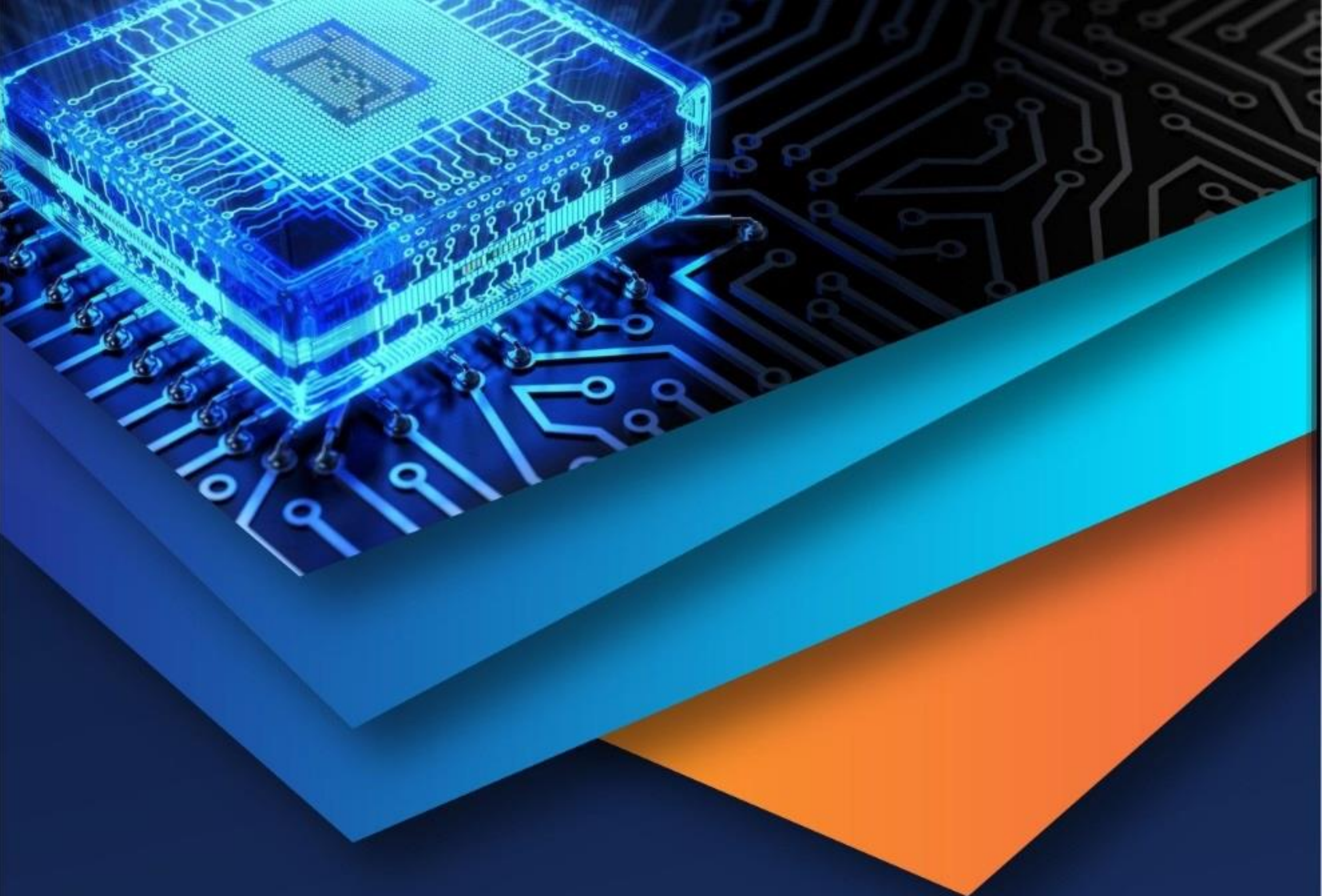

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