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# Assessment of Heavy Metal Contamination in the Industrial Region of Kanpur's Tannery Sector and Its Removal from Water Using Biochar

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***Abstract:*** ***The leather tanning industry in Kanpur, India, has grown exponentially over the years, becoming one of the largest producers of leather in the country. However, this rapid industrial growth has resulted in significant environmental contamination, primarily due to heavy metals. Key pollutants like chromium, lead, cadmium, nickel, and copper are frequently found in the effluents discharged from the tanneries. This paper investigates the causes, mechanisms, and consequences of heavy metal contamination in the industrial areas of Kanpur, focusing particularly on the tannery industry in Jajmau. It assesses the effects on human health, ecosystems, and the economy while evaluating current pollution control measures and suggesting solutions to mitigate the ongoing crisis.***
***Keywords: Tanney Industry, Metal Contamination, Heavy Metals, Industrial Chemistry, Effluent Disposal***

## I. INTRODUCTION

### *A. The Role of Kanpur's Tannery Industry in the Economy*

Kanpur, one of the largest industrial cities in northern India, is often referred to as the "Leather City of the World" due to its long-standing prominence in leather production. The city's leather industry, which began in the colonial period, has grown to become one of the largest leather manufacturing hubs in India, playing a pivotal role in the country's economy. The tanning industry in Kanpur, particularly in the Jajmau region, contributes significantly to the local and national economy, providing employment to thousands of workers and generating substantial foreign exchange through exports of leather products. These products range from footwear, bags, belts, and gloves, to high-end leather goods that are exported to various countries across the globe, including the United States, European Union, and the Middle East.

The industrial growth of Kanpur's leather sector has been accompanied by rapid urbanization and increased demand for leather goods. This sector contributes heavily to the country's export market, with India being one of the largest exporters of leather products worldwide. Kanpur's tanning industry alone is responsible for a significant share of the country's leather export revenue. The city's proximity to major transportation networks, access to raw materials, and skilled labor have all contributed to the growth of the industry.

While the leather industry in Kanpur has significantly contributed to its economic development and the broader Indian economy, it has also been a major cause of environmental degradation. The rapid expansion of the tanning sector, combined with limited oversight and regulation, has resulted in severe environmental pollution, particularly through the discharge of untreated wastewater and the improper disposal of hazardous waste. This pollution has not only affected the water quality in the Ganges River, a major source of drinking water for millions of people, but it has also contaminated the surrounding soil and air, affecting both human and ecological health. The contamination from heavy metals like chromium, cadmium, and lead poses a serious risk to public health, particularly to workers in the tannery industry and local residents who depend on the Ganges River for water.

## II. THE PROBLEM OF HEAVY METAL CONTAMINATION

The tanning process, essential for converting raw hides and skins into durable and usable leather products, typically involves the use of several chemical agents, most notably chromium. Chromium salts, primarily chromium sulfate and other chemical compounds, are used in the process of tanning leather to provide the final product with stability, flexibility, and durability. While chromium salts are effective in preserving the leather, they also present significant environmental and health risks. Specifically, hexavalent chromium (Cr (VI))**,** which is commonly used in the tanning industry, is highly toxic, carcinogenic, and water-soluble, making it one of the most dangerous contaminants.

 

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Apart from chromium, other heavy metals such as lead, cadmium, nickel, and copper are frequently used in various stages of leather processing. These metals, when disposed of improperly, can leach into the environment, contaminating nearby soil and water bodies. One of the major concerns with these heavy metals is their ability to accumulate in living organisms, including humans, over time, leading to chronic health issues such as kidney failure, neurological disorders, and developmental problems in children. Moreover, some of these metals, like lead and cadmium, are not biodegradable, meaning they persist in the environment for decades, if not longer, causing long-term damage to ecosystems.

The untreated discharge of industrial effluents from Kanpur's tanneries into the Ganges River has resulted in alarming levels of heavy metal contamination. Despite the fact that the Ganges is a sacred river for millions of Hindus and a vital water source for various uses, the pollution caused by the tannery industry has made large stretches of the river water unsafe for consumption and other essential activities. The effects of this pollution are far-reaching, impacting not just the environment but also the economy and public health.

## III. BACKGROUND OF THE TANNERY INDUSTRY IN KANPUR

### *A. Historical Development*

The leather industry in Kanpur dates back to the British colonial era, when it was established as a source of leather goods for the British Empire. The tanneries in the Jajmau area grew rapidly in the 20th century, driven by increased demand for leather products both domestically and internationally. By the late 1980s and early 1990s, Kanpur had become one of the largest leather-producing cities in India, with tanneries employing thousands of workers.

As the tanneries expanded, so did the environmental pollution. The process of tanning involves soaking, dehairing, and treating leather with chemicals such as lime, sodium sulphide, and chromium salts. Over the years, with limited regulation and insufficient waste treatment infrastructure, large quantities of untreated effluents containing these harmful chemicals were discharged into nearby water bodies, leading to widespread contamination. The resulting pollution affected not only the water quality but also the soil and air quality in the surrounding areas, causing severe ecological damage.

Kanpur is home to over 400 tanneries, with most of them located in the Jajmau industrial area. The city's leather industry contributes significantly to the local economy, providing employment to thousands of workers and generating substantial revenue from leather exports. However, the growth of the industry has been unchecked, and environmental damage has occurred alongside economic benefits. The effluent discharge from the tanneries has led to the contamination of nearby water sources such as the Ganges River, which is an essential lifeline for millions of people.

### *B. Types of Heavy Metal Contaminants in the Tannery Industry*

Chromium is the primary metal used in leather tanning, particularly in the form of chromium salts. While chromium in its trivalent state (Cr(III)) is relatively less toxic, it can oxidize into hexavalent chromium (Cr(VI)) during the tanning process. Cr(VI) is a known carcinogen and can cause severe health problems, including respiratory issues, skin rashes, and kidney damage. It is highly persistent in the environment, making it difficult to remove from contaminated water and soil.

Lead is another heavy metal found in tannery waste, though its usage has decreased in recent years. Lead is used in the finishing process and in some dyes, and it can leach into the environment through the discharge of wastewater and improper disposal of solid waste. Lead exposure can result in neurological damage, especially in children, and can also cause kidney and cardiovascular diseases.

Cadmium is primarily used in certain leather dyes and finishing chemicals. It is a toxic heavy metal that can cause a range of health problems, including kidney damage, lung cancer, and osteoporosis. Cadmium accumulates in living organisms, posing a significant risk to both humans and wildlife. In Kanpur, cadmium contamination in soil and water is a result of the improper disposal of tannery waste containing cadmium-based chemicals.

Copper is widely used in the leather industry, especially in the dyeing and finishing stages. While copper is an essential nutrient in small amounts, excessive concentrations can be toxic to both aquatic and terrestrial life. In the environment, copper contamination can lead to the death of aquatic organisms, disrupt plant growth, and negatively impact the health of humans exposed to high levels of copper in drinking water or food.

Nickel is another toxic metal used in the leather industry, particularly in some finishing treatments. Nickel exposure can lead to skin rashes, lung disease, and an increased risk of cancer. Like other heavy metals, nickel accumulates in the environment, posing long-term risks to ecosystems and human health.

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## IV. PATHWAYS OF HEAVY METAL CONTAMINATION

The release of heavy metals into the environment from industrial activities, particularly from the tannery industry, follows multiple complex pathways that lead to contamination of air**,** soil**,** water, and even biota. In the context of Kanpur's tannery industry, these pathways are critical to understanding the mechanisms by which heavy metals such as chromium**,** cadmium**,** lead**,** and **nickel** spread through the local environment and affect both human health and ecosystem stability. The discharge of untreated tannery effluents, along with poor waste management practices, plays a significant role in the contamination of surrounding environments

### *A. Water Contamination Pathway*

Water pollution is one of the most prominent pathways through which heavy metals from the tannery industry spread into the environment. The tannery effluent, which contains high concentrations of toxic metals, is often discharged directly into the Ganges River and nearby water bodies without sufficient treatment. These heavy metals—chromium, cadmium, lead, and nickel—are either dissolved in the water or bind to suspended particulate matter, which can eventually accumulate in the riverbed and sediments.

The untreated effluents, containing hexavalent chromium (Cr(VI)), cadmium, nickel, and other heavy metals, are often flushed directly into the surface waters. As these metals are water-soluble, they spread quickly through the water columns of local rivers, lakes, and ponds. Once in the water, these metals can be absorbed by aquatic organisms, such as fish, amphibians, and invertebrates, leading to biomagnification in the food chain. These metals also cause toxicity in aquatic life, leading to reduced biodiversity and the disruption of the ecosystem.

Another significant pathway of contamination is through the infiltration of heavy metals into the groundwater. When tannery effluents are discharged on land or near water sources, the metals can gradually seep through the soil layers into the groundwater. This is particularly concerning in areas where local populations depend on groundwater for drinking and irrigation. Chromium and cadmium are highly soluble and can travel deep into the ground, contaminating the aquifers. Over time, this can result in long-term contamination of drinking water sources that are difficult to reverse. Heavy metal-laden water used for irrigation can also lead to the accumulation of toxins in agricultural products, creating a potential threat to food safety and public health. Heavy metals can also settle at the bottom of water bodies, accumulating in the sediments. This sediment contamination is of particular concern because these metals can persist in the environment for years, continuing to release toxins back into the water under changing conditions (such as low oxygen levels).

These contaminated sediments become an ongoing source of pollution for the water body, contributing to a persistent cycle of contamination. Over time, sediment-bound metals may be re-suspended into the water during floods, storms, or when aquatic life disturbs the riverbed, leading to further bioaccumulation in aquatic organisms.

### *B. Soil Contamination Pathway*

The soil contamination pathway plays a significant role in the dissemination of heavy metals from the tannery industry. The large-scale discharge of untreated tannery wastewater and improper disposal of solid wastes, including sludge and chemical residues, directly affects the soil quality in nearby areas.When tannery effluents are disposed of on land or along riverbanks, the heavy metals contained in the effluents infiltrate the soil. Chromium, cadmium, and other toxic metals are highly persistent in soil and can bind to soil particles.

Over time, these metals accumulate in the soil and are not easily degraded or removed. High levels of chromium in the soil can decrease soil fertility, inhibit plant growth, and disrupt microbial activities. As these metals are toxic to plants, they can impair the growth of crops and trees, which are important for both agricultural production and maintaining local ecosystems.

The presence of heavy metals in the soil can result in leaching, where rainwater or irrigation water carries these metals deeper into the ground, ultimately contaminating the subsurface water or groundwater. Additionally, during periods of heavy rainfall or storms, runoff can carry the contaminated soil and sediments into nearby rivers and lakes, thereby spreading heavy metals to wider areas and causing further water pollution. This process not only contaminates nearby water bodies but also affects the agricultural land downstream, making it unfit for cultivation.

As heavy metals accumulate in the soil, they can be absorbed by plants, either directly through their roots or indirectly through contaminated rainwater or irrigation water. Over time, these metals can accumulate in plant tissues, including edible crops. When people or animals consume these crops, the heavy metals are transferred into the food chain through bioaccumulation. This poses serious health risks to the local population, especially since chromium and cadmium are known to cause severe health issues, such as kidney damage, neurological disorders, and cancer.

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### *C. Air Contamination Pathway*

Though the primary routes of heavy metal contamination from the tannery industry are water and soil, air pollution can also play a significant role in the spread of toxins, particularly in densely industrialized areas like Kanpur.During the tanning process, the use of various chemicals, including chromium compounds, can result in the release of fine dust particles or fumes that contain toxic metal vapors into the air.

These particles can then settle onto the surrounding environment or be inhaled by workers and local residents. Hexavalent chromium fumes, in particular, are highly toxic and carcinogenic. Exposure to these fumes can lead to serious respiratory diseases, such as asthma, bronchitis, and lung cancer.

In addition to gaseous emissions, airborne particulate matter (PM), which contains fine particles of heavy metals, can settle on land and water surfaces, contributing to soil contamination and water pollution. Particulate matter containing nickel and lead can travel significant distances through wind currents, affecting nearby rural or urban areas. These airborne toxins pose serious public health risks, especially for children and individuals with pre-existing respiratory conditions.

### *D. Biological Pathway (Biomagnification)*

The biological pathway of heavy metal contamination occurs when heavy metals accumulate in the food chain, a process known as biomagnification. As heavy metals are absorbed by plants, they are consumed by herbivores, which are in turn consumed by carnivores. Over time, the concentration of these metals increases as they move up the trophic levels.

In aquatic environments, fish and other marine organisms can absorb heavy metals like chromium and cadmium through the water. These metals accumulate in the organisms' tissues over time, leading to high levels of toxins in top predators like fish-eating birds and humans who consume fish. Similarly, on land, plants contaminated with chromium and lead can be ingested by herbivores, which are then consumed by carnivores or humans. This accumulation of heavy metals in higher trophic levels poses a significant risk to public health and wildlife.

### *E. Environmental and Health Impacts*

The contamination of the Ganges River and other water bodies near Kanpur has resulted in the death of fish and other aquatic organisms. High levels of chromium and other heavy metals reduce oxygen levels in water, making it impossible for aquatic life to survive. The pollution of the river also has adverse effects on local fisheries, which are a source of livelihood for many people living near the river.The accumulation of heavy metals in soil has led to the degradation of agricultural land in Kanpur. High concentrations of chromium, cadmium, and other metals affect soil fertility, reducing the ability of plants to grow. Crops grown in contaminated soil can also absorb heavy metals, posing a risk to human health through the food chain.

Local residents, particularly those living in close proximity to tanneries, face serious health risks due to exposure to heavy metals. Workers in tanneries are particularly vulnerable, with high rates of respiratory diseases, skin disorders, and cancer linked to prolonged exposure to toxic chemicals. Additionally, drinking contaminated water from the Ganges River and consuming crops grown in polluted soil increases the risk of heavy metal poisoning, leading to various health issues such as kidney damage, neurological disorders, and developmental problems in children.

## V. MITIGATION STRATEGIES

One of the most effective ways to reduce heavy metal contamination is the adoption of cleaner technologies in the tanning process. These include the use of vegetable tanning agents instead of chromium-based salts, which can significantly reduce the discharge of toxic metals. Additionally, advanced water recycling techniques, such as reverse osmosis, can help minimize the release of wastewater containing heavy metals.

Bioremediation and phytoremediation are promising strategies for cleaning up contaminated soil and water. In bioremediation, microorganisms are used to break down or transform heavy metals into less toxic forms. Phytoremediation involves the use of plants to absorb and accumulate metals from the soil or water. These natural processes offer an eco-friendly and cost-effective way to mitigate pollution.

Improving waste management systems is critical to reducing the environmental impact of tanneries. This includes upgrading CETPs with more efficient treatment technologies, such as membrane filtration and adsorption methods. Additionally, better management of solid waste and sludge can prevent contamination of the surrounding soil.

## VI. ADVANTAGES OF REMOVING HEAVY METAL CONTAMINATION IN THE KANPUR TANNERY INDUSTRY

Eliminating heavy metal contamination from tannery effluents will drastically improve the quality of the Ganges River and surrounding water sources. This will reduce toxicity in aquatic ecosystems, benefiting both wildlife and human populations who rely on these waters for drinking and agriculture. Heavy metal contamination diminishes soil fertility, making it less suitable for agriculture. By removing these toxins, the soil will regain its fertility, which can enhance agricultural productivity and restore natural vegetation. The reduction in pollution levels will help restore damaged ecosystems and promote the return of native plant and animal species. Healthy soil and water will create a better environment for biodiversity, sustaining ecosystems that support various forms of life.

As contaminants such as chromium and cadmium leach into water and soil, they create long-lasting environmental damage. By removing these pollutants, the risk of further contamination is minimized, ensuring healthier ecosystems.

### *A. Health Benefits*

Reduction in Health Risks: Exposure to heavy metals can cause serious health conditions, including cancer, kidney damage, and respiratory diseases. Removing these contaminants from the environment would significantly lower the risk of such health issues, particularly for communities and workers near the industrial areas.

Prevention of Respiratory and Skin Problems: Heavy metals, especially in particulate form, can cause respiratory issues and skin conditions. By reducing exposure to airborne toxins and contaminated water, local residents and workers will be at a lower risk of these health problems.

Improved Worker Health: The tannery industry is a major source of exposure to heavy metals for workers. By controlling pollution and improving workplace safety, the health of workers will improve, with fewer instances of lung diseases and skin disorders due to direct exposure to toxins.

Safer Food Supply: Contaminated soil and water lead to the accumulation of metals in agricultural produce. Removing pollutants will help reduce the chances of food contamination, ensuring safer crops for both local consumption and broader markets.

Economic Benefits-Boost to Agricultural Productivity: Cleaner soils will lead to better crop yields, directly benefiting farmers and contributing to the local economy. Healthy soil will support sustainable agricultural practices, which can lead to more abundant harvests and greater food security.

Increased Trade Opportunities: As the tannery industry cleans up its practices, it can boost its appeal in global markets, especially with eco-conscious consumers looking for sustainable and ethical products. Exporting leather goods produced through environmentally friendly methods can open new doors for international trade.

## VII. CONCLUSION

The heavy metal contamination caused by Kanpur's tannery industry is a serious environmental and public health concern. While economic factors drive the industry's growth, the environmental damage it causes cannot be ignored. The introduction of cleaner technologies, improved waste management practices, and better enforcement of pollution control regulations will be essential in mitigating the harmful effects of the tannery industry. Immediate action is needed to safeguard the environment, public health, and the livelihoods of local communities. The tannery industry can significantly reduce its environmental footprint by adopting cleaner production technologies, such as chrome-free tanning methods and closed-loop water systems, which minimize waste and heavy metal discharge. Transitioning to eco-friendly leather processing techniques like vegetable tanning and the use of biodegradable chemicals helps reduce reliance on harmful substances such as chromium salts, while also catering to the growing global demand for sustainable products. Furthermore, embracing waste-to-resource models within a circular economy framework allows for the recycling of tannery waste—such as sludge and effluents—into non-toxic, value-added products, including treated water for agriculture or biodegradable materials for other industries, thereby promoting both ecological responsibility and economic efficiency.

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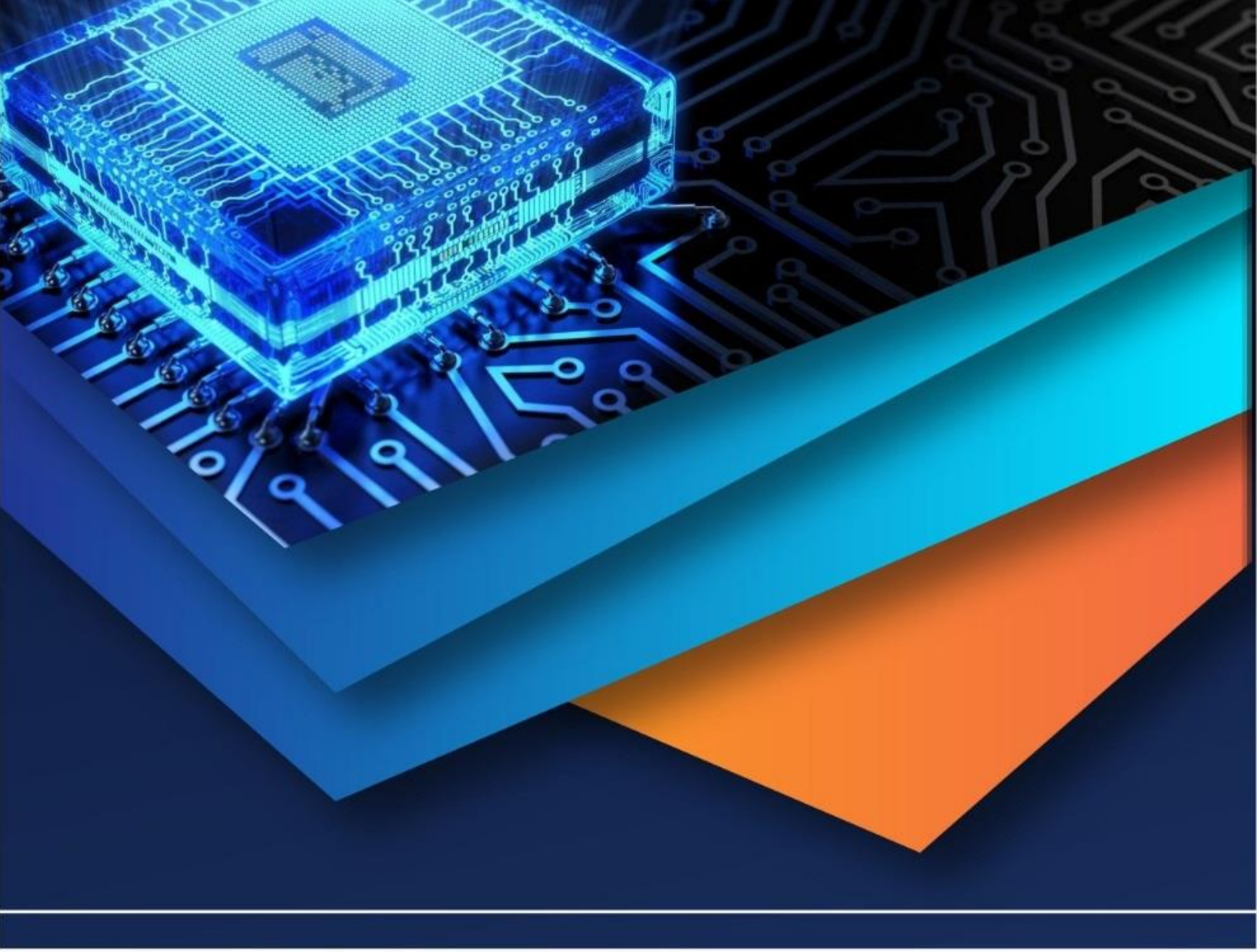

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