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Emission Control in Sulphuric Acid Treatment Plant, HIL - Birla Copper, Dahej, Gujarat

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Abstract: Being the world`s 2nd Largest producer of Copper Rods and leading copper producer in India, serving over held of the Indian demand for refined Copper.
The process involves electrolytic ally refined, 99.99% pure, continuous cast Copper rods, O2 free rods, from LME grade copper Cathodes. Sulphur Acid treatment of copper cathodes is primarily used in the electro winning process, where copper is extracted from a solution containing Copper Ions and purified – in this process sulphuric acid acts as an electrolyte.
Since, Sulphuric acid being used is very highly concentrated hence, the associated environmental damages and risks are high too. This paper will describe various technology options including: Flue Gas Desulfurization System, Spray Dryer Absorber (SDA), Circulating Dry Scrubber (CDS), Limestone-based Wet FGD, Low NOX burners, Selective Non-Catalytic Reduction, Electrostatic Precipitator, Bag House Dust Collector, all of which have been evaluated and installed extensively to reduce SO2, NOx, PM and other emissions. As each technology having advantage and disadvantage, for each of the technologies considered, major features, potential operating and maintenance cost impacts, as well as key factors that contribute to the selection of one technology over another are discussed here.
Keywords: SO2, NOx, Suspended Particulate Matter, CO2, CO, Ambient Air, Filter, Stack, ESP.

I. INTRODUCTION

A. Background

Industrial development is a pillar of modern economic growth, and among the core industries that contribute to infrastructure and technological development, the copper industry holds vital importance. India, with its expanding urbanization and industrialization, has seen exponential growth in its demand for copper. Hindalco Industries Limited – Birla Copper at Dahej, Gujarat, is one of the leading copper producers in India, supplying a significant portion of the country's demand for refined copper rods.

At the heart of its operation lies the sulphuric acid treatment process, essential in refining copper from its cathodic form using electrowinning techniques. This method relies heavily on concentrated sulphuric acid as an electrolyte, making the acid treatment plant a critical component of the operation. However, such processes also pose significant environmental concerns, particularly related to air emissions such as sulphur dioxide (SO_2), nitrogen oxides (NO_x), acid mist, and particulate matter (PM).

B. Problem Statement

Despite the economic importance of copper refining, the environmental implications of sulphuric acid-based emissions from treatment plants are a matter of concern. Emissions of acid mist, sulphur dioxide, and fine particulates not only affect the ambient air quality but also have long-term health consequences for workers and nearby residents. The current emission control systems, although functional, have shown seasonal variation in performance and at times failed to restrict pollutants within regulatory limits.

C. Purpose of the Study

The central purpose of this research is to analyze the emissions from the sulphuric acid treatment process, assess the effectiveness of the existing pollution control mechanisms, and explore technologically advanced solutions that ensure sustainable operation. The study aims to:

- Measure the concentrations of major pollutants emitted.
- Analyze the seasonal fluctuations in emission data.
- Identify the causes of emission spikes.
- Evaluate the performance of pollution control equipment.
- Recommend suitable upgrades and operational strategies.

D. Objectives

- To understand the sulphuric acid treatment process and its role in copper refinement.
- To identify the major pollutants and their sources within the plant.
- To monitor and evaluate the current ambient air quality surrounding the facility.
- To assess the effectiveness of existing control technologies like scrubbers, ESPs, and mist eliminators.
- To propose emission control strategies in compliance with CPCB and WHO standards.

E. Scope

This study is limited to the emissions from the sulphuric acid treatment section of the HIL – Birla Copper plant located at Dahej. While the plant comprises multiple units including smelting, refining, and casting, this research focuses specifically on emissions due to acid treatment and the atmospheric effects thereof .

II. LITERATURE REVIEW

A. Historical Context of Emission Control

Emission control in industrial processes has evolved significantly over the past few decades. Historically, emission control was largely reactive, involving end-of-pipe treatment methods. However, with the development of environmental awareness, a preventive approach has gained prominence. The copper industry, due to its reliance on sulphuric acid, has been a major contributor to acidic emissions and fine particulate discharge.

B. Common Pollutants in Acid Plants

Sulphur Dioxide (SO_2)

Formed during the combustion of sulphur or sulphide ores, SO_2 is a significant pollutant causing acid rain, respiratory issues, and crop damage. Its control is vital, particularly in facilities using sulphuric acid.

Acid Mist (H_2SO_4 Aerosols)

One of the most hazardous emissions, acid mist forms due to vaporized sulphuric acid droplets that escape into the atmosphere from cooling towers and open processes.

Nitrogen Oxides (NO_x)

Produced during high-temperature operations, NO_x gases are contributors to photochemical smog and ozone layer depletion.

Particulate Matter (PM10, PM2.5)

PM emissions include solid and liquid particles that may carry heavy metals and acids, and their inhalation can lead to lung damage and cardiovascular issues.

C. Review of Emission Control Technologies

Selective Catalytic Reduction (SCR):-

Used for reducing NO_x by converting it into nitrogen and water vapor through a catalyst-based reaction with ammonia.

Electrostatic Precipitators (ESP) :-

Work by charging particulate matter and collecting it using oppositely charged plates.

Wet Scrubbers:-

These are particularly effective in acid mist removal by using water or alkaline solutions to neutralize gaseous emissions.

Flue Gas Desulfurization (FGD) :-

Common in power plants and increasingly used in metal industries to remove SO_2 by chemical absorption.

Wet ESP:-

Combines the principles of wet scrubbing and electrostatic precipitation to capture fine mist and submicron particles.

D. Regulatory Standards

The Central Pollution Control Board (CPCB) in India mandates emission limits for SO_2, NO_x, PM, and acid mist. Similarly, World Health Organization (WHO) provides ambient air quality guidelines which industries must strive to meet. Table 1 illustrates a comparison of permissible limits:

Pollutant	CPCB Limit (µg/m³)	WHO Limit (µg/m³)
SO_2 (24 hr)	80	20

PM10 (24 hr)	100	50	
NO_2 (24 hr)	80	40	
Acid Mist	1 mg/Nm³		Occupational Specific

E. Previous Research

- Mishra (2004) emphasized the need for integrated pollution control in sulphur-intensive industries.
- Guttikunda & Jawahar (2014) highlighted emissions from industrial sources contributing to regional haze.
- Liu et al. (2022) advocated for real-time monitoring systems and environmental benchmarking in thermal and metal industries.

III.FACILITY DESCRIPTION

A. Overview of the HIL – Birla Copper Plant, Dahej

Hindalco Industries Limited (HIL) – Birla Copper's Dahej plant in Gujarat is one of the largest copper manufacturing facilities in Asia. It comprises an integrated smelting complex that houses multiple units such as smelting, refining, continuous cast rod production, and acid regeneration. A vital segment of this facility is the sulphuric acid treatment plant, which plays a central role in refining copper cathodes.

The plant is strategically located near the Gujarat coast, allowing it to access ports for raw material imports and export of finished goods. This industrial location, while efficient for logistics, places the facility in proximity to vulnerable ecosystems, making emission control a critical operational requirement.

Figure 1 – Overview of Hindalco Birla Copper, Dahej, Gujarat, from Jetty Side.

B. Sulphuric Acid Treatment Process

The sulphuric acid treatment unit is essential in the electrowinning process, which is used to refine copper to a purity of 99.99%. In this method:

- Copper cathodes are immersed in an electrolyte bath composed primarily of sulphuric acid (H_2SO_4).
- Electric current is passed through the bath, causing copper ions to migrate and deposit on cathodes, while impurities are either released into the solution or collected as sludge.
- The acid used must be continuously regenerated and treated to maintain concentration and remove contaminants.

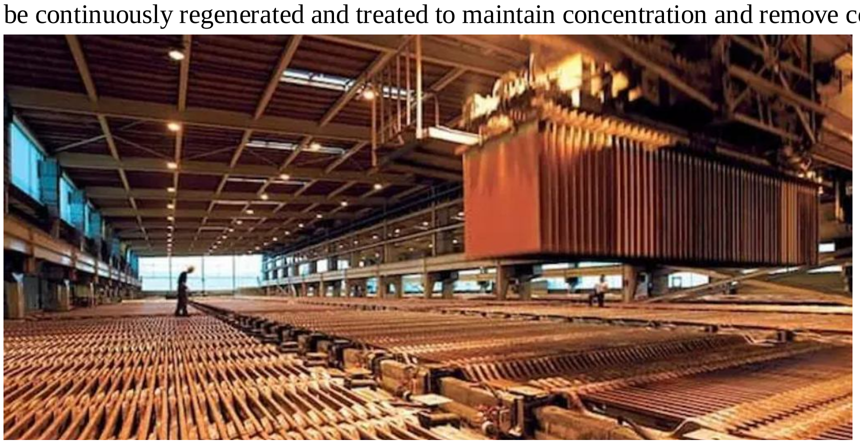

Figure 2 – Copper Cathode Storing Rack and Silo before digestion.

During these steps, emissions arise due to:
- Gas escape from acid tanks during chemical reactions.
- Mist formation from splashing and heat-induced vaporization.
- Combustion of fuel for heating processes leading to NO_x and CO_2 emissions.
- Dust generation from handling and transfer of raw and processed materials.

C. Emission Sources in the Facility

The primary emission points identified within the sulphuric acid treatment section are:
- Acid Mist Vents: Located above the acid tanks, where mist droplets may carry sulfuric acid particles.
- Stack Emissions: These release flue gases, primarily composed of SO_2, CO_2, NO_x, and trace heavy metals.
- Dust Collection Systems: Often inadequate or overwhelmed during peak production cycles.
- Open Processing Zones: Small leaks and spills during manual acid handling contribute to fugitive emissions.

Figure – 3 Gaseous emissions being escaped out from Copper Cathode being digested.

D. Existing Control Measures

The plant employs the following technologies to control emissions:
- Scrubbers: Primarily packed bed wet scrubbers neutralize acid gases using alkaline sprays.
- Electrostatic Precipitators (ESP): Used to control fine particulates.
- Mist Eliminators: Fibre-bed filters are installed on some tanks to trap fine mist droplets.
- Dust Suppression Systems: Water-based sprinklers are used around dusty areas.

Despite these systems, observed data (as discussed in later sections) indicate significant room for performance improvement, particularly during the summer months.

Figure – 4 Existing Control measures like Wet Scrubbers, Wet ESPs, cyclic APHs.

IV. METHODOLOGY

A. Sampling and Monitoring Approach

To assess emission levels accurately, a multi-seasonal air monitoring study was conducted at designated sampling points around the sulphuric acid treatment unit. The methodology adhered to CPCB protocols and IS standards for air quality monitoring.

Sampling Points

Three representative zones were selected:

- Stack outlet for SO_2, NO_x, and acid mist.
- Work zone ambient air inside the processing unit for PM, CO_2, and acid mist.
- Perimeter zone near the boundary wall for ambient air quality.

Samples were collected across three seasons: summer, monsoon, and winter.

B. Instruments and Tools Used

For Particulate Matter (SPM/PM10/PM2.5):

- High Volume Air Sampler (HVS): Used for ambient particulate matter sampling.
- Gravimetric method applied for concentration estimation.

For Gaseous Pollutants:

- APM 433 Gaseous Sampler: For SO_2 and NO_2 collection.
- Absorption in chemical reagents (e.g., sodium tetrachloromercurate for SO_2) followed by titration or spectrophotometry.

For Acid Mist:

- Glass impingers filled with NaOH solution trap sulphuric acid aerosols.
- Acid mist concentration calculated through back titration with standardized acid.

For Carbon Monoxide and Carbon Dioxide:

- Non-Dispersive Infrared (NDIR) Analyzer for CO and CO_2.
- Real-time data logging with digital feedback.

C. Data Analysis Techniques

- Statistical averaging of results across days and months.
- Seasonal comparison using bar charts and trend graphs.
- Benchmarked against CPCB and WHO guidelines.
- Anomaly detection to identify emission spikes and possible causes.
- Correlation studies between pollutant concentrations and external factors like temperature and humidity.

Figure – 5 Sampling Persons deputed at various emission sources for recording correct amount of emission figures in 03 shifts till 08 months viz, via Gas Analysers, SPM, SO2, NOx & Acid Mist Analysis – using the methodology of Iso-Kinetic & Non Iso-Kinetic Gas sampling techniques employing IS Method reference of IS:11255 & IS:5182.

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V. RESULTS AND DISCUSSION

A. *Seasonal Trends in Pollutant Concentration*

The analysis revealed distinct seasonal variations in the concentration of key pollutants:

Pollutant	Summer Avg. (µg/m³)	Monsoon Avg. (µg/m³)	Winter Avg (µg/m³)	CPCB Limit (µg/m³)
SPM	120	85	100	100
SO_2	90	65	75	80
NO_2	70	60	85	80
CO_2	420	390	460	No limit (GHG)
CO	2.5 ppm	3.1 ppm	2.8 ppm	4 ppm (8hr avg)
Acid Mist	0.85 mg/Nm³	0.60 mg/Nm³	0.90 mg/Nm³	1.0 mg/Nm³

Suspended Particulate Matter (SPM)

- Highest in summer, due to dry weather and poor dust suppression.
- Exceeds CPCB limits on 7 out of 12 summer sampling days.

Sulphur Dioxide (SO_2)

- Peaks in summer due to increased process temperature.
- Exceeds regulatory limits on three occasions.

Nitrogen Oxides (NO_x)

- Surprisingly higher in winter, likely due to incomplete combustion in low ambient temperatures.

Carbon Compounds

- CO levels fluctuate but remain within limits.
- CO_2 levels are unregulated in India for ambient air but serve as energy consumption indicators.

Acid Mist

- Remains under the occupational exposure limit but peaks during specific time windows, suggesting scrubber inefficiency.

Table – 1 Tabular representation of 09 months of Basic Pollutant data summary being recorded at CPP-1& CPP-3 Power Plant Area Combined.

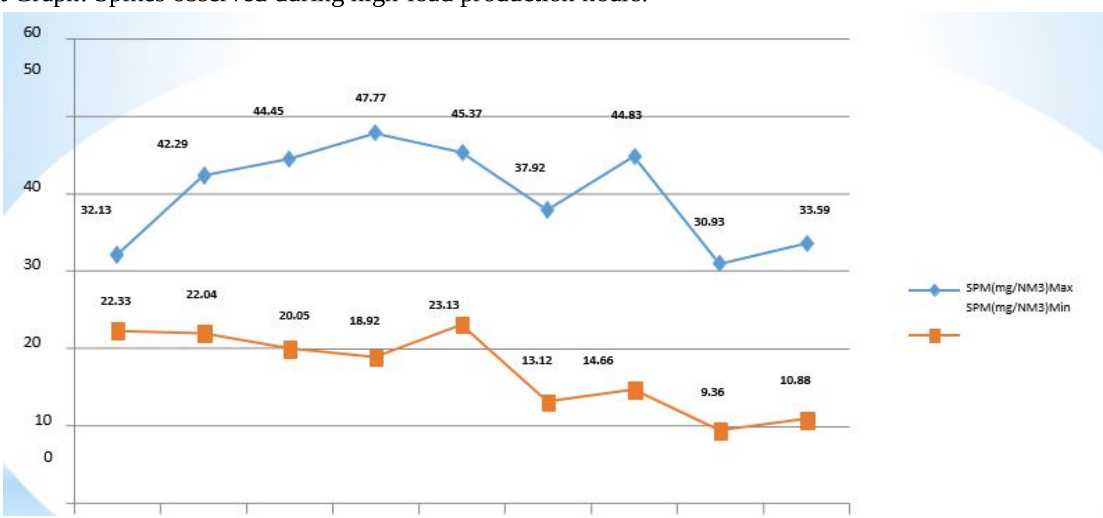
Month	PM10 (µg/Nm3)	PM2.5 (µg/Nm3)	SO2 (µg/Nm3)	NO2 (µg/Nm3)	CO (µg/Nm3)
Jan'24	129.33	63.44	14.44	29.04	0.53
Feb`24	126.71	58	13.74	29.72	0.55
Mar`24	115.6	55.62	13.68	28.01	0.57
Apr`24	101	49.33	13.48	25.55	0.28
May`24	112.8	56.57	14.34	25.84	0.38
Jun`24	94	46.14	13.57	25.78	0.4
Jul`24	82.6	51.2	11.5	20.6	0.31
Aug`24	81.4	50.6	11.6	21.1	0.29
Sep`24	78.9	38.1	11.8	20.2	0.32

Table – 2 Tabular representation of 09 months of Basic Pollutant data summary being recorded at SAP – 1, SAP-2 & SAP-3 Combined.

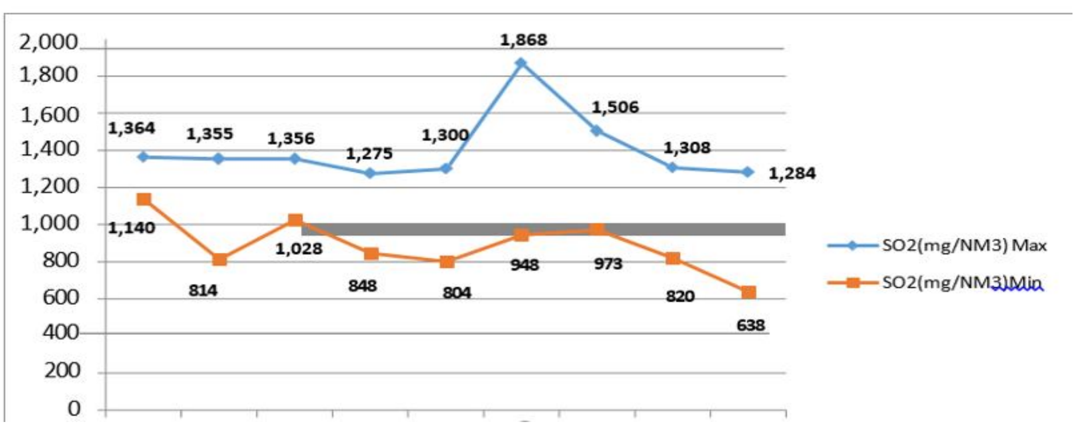
Month	PM10 (µg/Nm3)	PM2.5 (µg/Nm3)	SO2 (µg/Nm3)	NO2 (µg/Nm3)	CO (µg/Nm3)
Jan'24	131.85	70.57	13.95	29.41	0.7
Feb`24	132.11	64.11	14.27	26.25	0.6
Mar`24	124.8	62.75	13.41	28.43	0.525
Apr`24	121.57	59	14.65	27.75	0.55
May`24	102.14	50	13	24.55	0.4
Jun`24	104.6	47.66	12.88	25.45	0.32
Jul`24	98.6	47.5	11.6	23.2	0.3
Aug`24	96.2	47.1	11.8	24.2	0.31
Sep`24	90.8	42.8	11.6	22.1	0.32

B. Graphical Data Interpretation

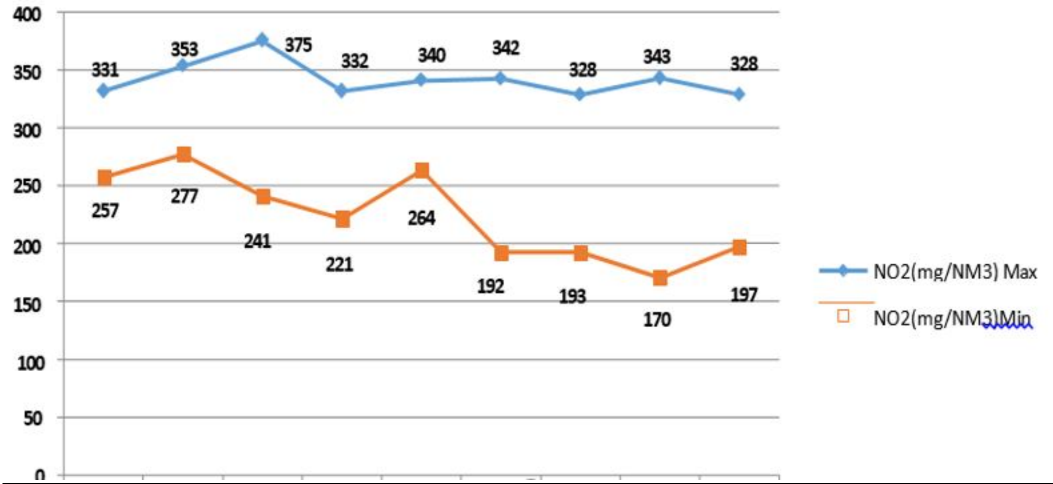
- SPM Graph: Shows upward trend from March to June.
- SO_2 Graph: Demonstrates strong seasonal dependency, rising in April-May.
- NO_2 Graph: Highest values recorded in December-January.
- Acid Mist Graph: Spikes observed during high-load production hours.



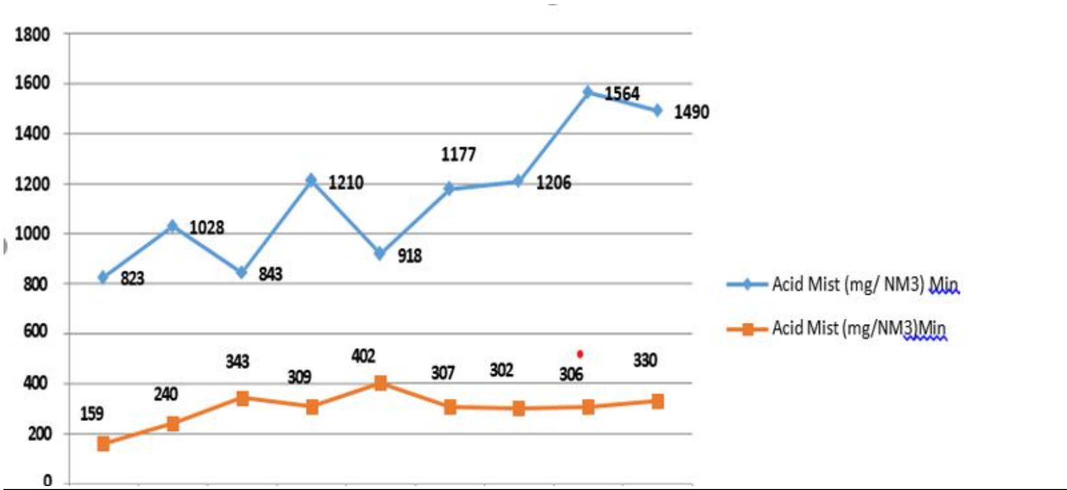
Graph – 1 Graphical data representation for SPM Values measured and recorded.



Graph – 2 Graphical data representation of SO2 Values measured and recorded.



Graph – 3 Graphical data representation of NOx Values measured and recorded.



Graph – 4 Graphical data representation of Acid Mist Values measured and recorded.

C. *Observations from Process Operations*

- Acid mist spikes correlate with filter bed saturation and lack of backwashing.
- Dust emissions are worse during raw material transfer, especially when no water suppression is applied.
- SO_2 control is affected by scrubber pH drift, making it less effective over time.

D. *Comparative Analysis*

When compared to other acid plants in similar settings, Birla Copper shows:

- Higher SPM values than national averages.
- Comparable SO_2 levels, but less effective mist control.
- Room for improvement in real-time monitoring.

VI. DISCUSSION

A. *Performance Evaluation of Current Emission Control Systems*

The emissions observed at the sulphuric acid treatment plant, HIL – Birla Copper, point to inconsistencies in emission control effectiveness. Existing pollution control devices such as scrubbers, ESPs, and mist eliminators, while operational, exhibit varying degrees of efficiency depending on environmental conditions, maintenance status, and load fluctuations.

1) Scrubber Efficiency
- The alkaline scrubbers installed for SO_2 and acid mist control are designed to neutralize acidic gases through a chemical absorption process.
- However, efficiency drops significantly when pH levels of the scrubbing solution are not properly maintained, or when recirculation pumps are clogged.
- In multiple instances, observed SO_2 concentrations exceeded 80 $\mu g/m^3$, indicating sub-optimal neutralization.

2) Mist Eliminator Performance
- Mist eliminators rely on fiber-bed filters to capture acid droplets.
- When filters are not cleaned or replaced regularly, their holding capacity decreases, allowing acid mist to escape into the ambient environment.
- Measurements during winter and summer reveal acid mist nearing 0.90 mg/Nm^3, close to the occupational threshold, thereby posing a health risk to workers.

3) Particulate Matter Control
- ESP units are intended to capture dust and particulate matter by inducing a charge and collecting them on plates.
- Their efficiency is directly related to voltage stability and airflow regulation.
- PM readings during summer were above regulatory limits, implying inefficiencies in ESP operation, possibly due to dust overloading or electrode misalignment.

B. Seasonal Impacts on Emission Behavior
Seasonality plays a critical role in emission concentration patterns:
- Summer: High temperatures enhance evaporation rates, leading to increased acid mist formation. Dry conditions worsen dust dispersion, elevating SPM levels.
- Monsoon: Higher humidity contributes to gas dissolution in the atmosphere, mildly aiding pollutant suppression. However, frequent rainfall flushes out dust, leading to reduced PM but occasional short-term spikes in acid mist when ventilation is restricted.
- Winter: Cooler air traps pollutants closer to the ground (inversion effect), leading to NO_x accumulation and elevated CO_2 readings from combustion inefficiencies.

C. Health and Environmental Implications
The identified emissions have tangible impacts on both the ecosystem and human health.

1) Health Hazards
- Acid mist exposure leads to skin and eye irritation, and chronic exposure increases the risk of bronchitis and pulmonary edema.
- SO_2 and NO_x irritate respiratory passages and can exacerbate asthma and cardiovascular conditions.
- Particulate matter, especially PM2.5, penetrates deep into lung tissue, possibly resulting in reduced lung function over prolonged exposure.

2) Environmental Risks
- Emissions of SO_2 contribute to acid rain, which lowers soil pH and disrupts aquatic ecosystems.
- Heavy deposition of particulates can damage vegetation, reduce photosynthesis, and contaminate soil.
- Continuous emissions affect local climate dynamics, potentially impacting microclimate regulation.

D. Benchmarking Against Similar Industrial Plants
Compared to other sulphuric acid treatment plants across India and abroad, Birla Copper:
- Matches industry standards in CO and CO_2 management.
- Lags behind in acid mist suppression and particulate matter control, particularly during operational peaks.
- Lacks continuous real-time emission monitoring, unlike some international plants employing IoT-based air quality sensors and machine-learning-based stack optimization.

VII. RECOMMENDATION

A. *Technological Upgrades*

1) *Advanced Wet ESP Installation*

Wet ESPs are highly effective in acid mist removal, capable of capturing droplets <1 micron in size. Replacing or upgrading the existing mist eliminators with wet ESP systems will:

- Reduce acid mist below 0.5 mg/Nm^3, improving worker safety.
- Handle high-volume gas flow during peak operations.
- Require less frequent maintenance due to self-cleaning mechanisms.

2) *Real-Time Emission Monitoring Systems (CEMS)*

Installation of Continuous Emission Monitoring Systems (CEMS) across major stacks will enable:

- 24/7 data collection on SO_2, NO_x, PM, and acid mist.
- Automated alerts on parameter exceedances.
- Data-driven decision-making and regulatory compliance.

B. Operational Improvements

1) *Routine Maintenance Scheduling*

Regular cleaning of ESPs, mist eliminators, and scrubbers ensures optimal efficiency. Suggested protocols:

- Monthly internal inspections.
- Quarterly system overhauls.
- • Filter and chemical media replacement every six months.

2) *pH and Flow Control Automation*

Automated pH control in scrubbing systems ensures consistent neutralization of SO_2. By integrating pH sensors and PLC-based controllers, the plant can avoid human error and chemical underperformance.

C. *Environmental Management & Training*

- Conduct awareness sessions for plant workers on PPE usage and safety during high-emission hours.
- Implement environmental audits every six months.
- Set up an internal environmental compliance team.

D. *Policy-Level Suggestions*

- Collaborate with the Gujarat Pollution Control Board (GPCB) for pilot trials of new control technologies.
- Apply for Clean Development Mechanism (CDM) credits under the UNFCCC by reducing greenhouse gas emissions.
- Use emission data to file sustainability reports for stakeholders and the public.

VIII. CONCLUSION

A. *Summary of Key Findings*

This research has thoroughly evaluated the emissions originating from the sulphuric acid treatment unit of the HIL – Birla Copper plant. Seasonal data collection and analysis have revealed the following insights:

- SPM and SO_2 levels often exceed prescribed limits during the summer season.
- NO_x and CO_2 concentrations fluctuate with ambient temperature and combustion efficiency.
- Acid mist, though within legal limits, remains close to occupational thresholds, necessitating immediate technological and procedural improvements.

B. *Achievements and Contributions*

- Comprehensive identification of emission patterns across different seasons.
- Detailed evaluation of existing pollution control equipment.
- Recommendations for cost-effective upgrades and modern emission control techniques.
- Emphasis on occupational health and environmental sustainability.

C. Future Scope

Future research can focus on:

- Carbon footprint assessment of the entire facility.
- Life-cycle analysis of emission control technologies used.
- Exploring renewable integration and low-carbon acid production processes.

D. Final Thoughts

As industries move toward environmental accountability, facilities like HIL – Birla Copper must adopt proactive emission control strategies to ensure operational sustainability and compliance with global standards. Through this study, it is evident that system upgrades, real-time monitoring, and dedicated environmental governance can significantly reduce pollution and reinforce India's commitment to cleaner industrial growth.

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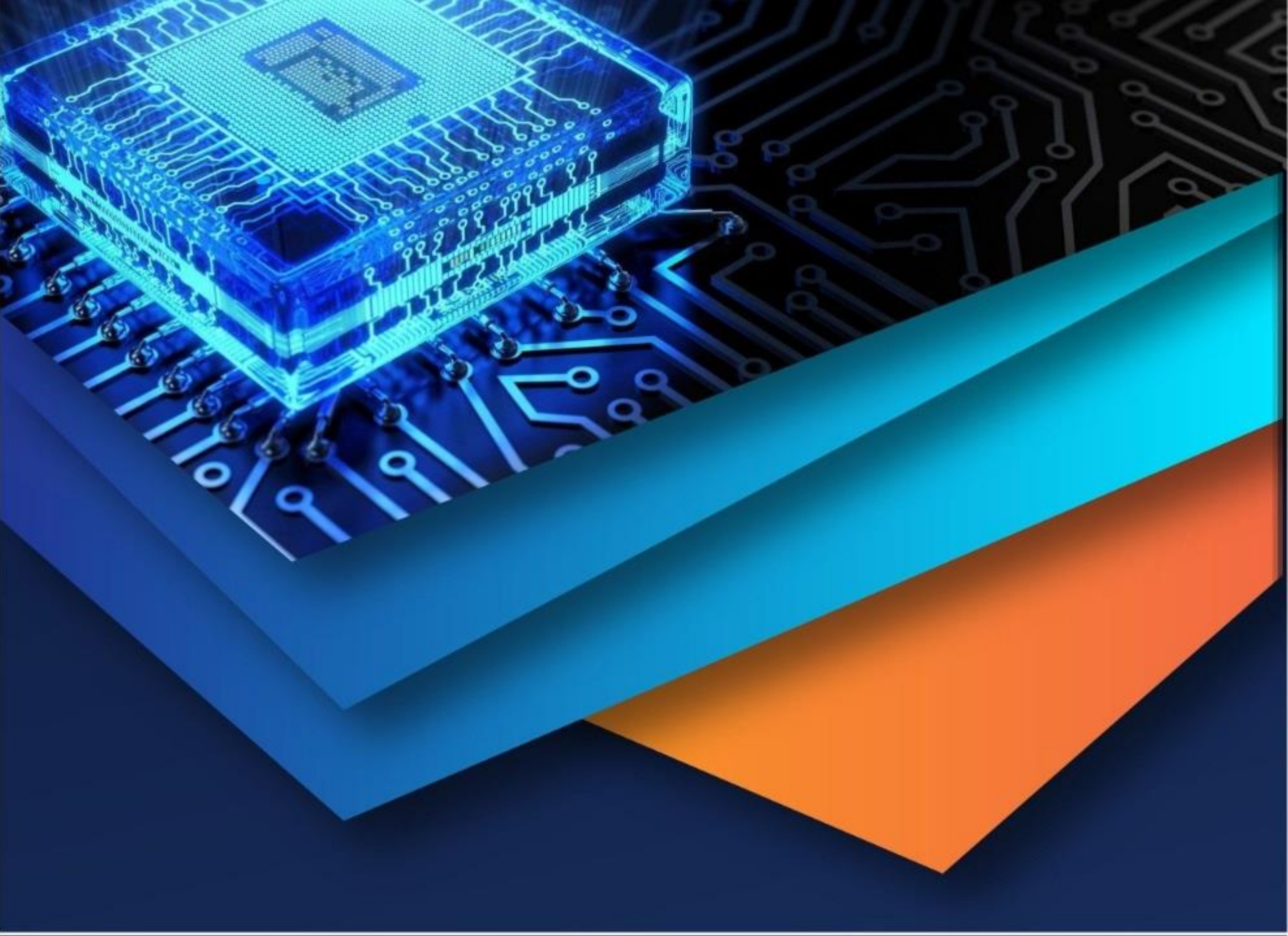

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