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Analyzing India's Cement Industry with a Focus on Jharkhand: Growth, Challenges, and Green Sustainability

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Abstract: With a yearly production capacity of around 500 million tons, India has the biggest cement industries in the world. This study provides an in-depth analysis of the cement industry within Jharkhand, India, scrutinizing the performance of selected cement plants and evaluating their comprehensive socio-economic and environmental impacts. Jharkhand, a mineral-rich state in India, is also home to a significant cement industry that has been growing in recent years. In terms of sustainability, the cement industry in Jharkhand has been focusing on reducing its impact on the environment. The industry has shifted its focus towards the use of alternative fuels and the reduction of greenhouse gas emissions. The government has also introduced various policies and initiatives to encourage the adoption of sustainable practices in this industry. In current study it was found that as the year increases, the carbon dioxide intensity decreases significantly. Carbon dioxide intensity measures how much carbon dioxide is emitted per unit of cement produced. This suggests that Jharkhand's cement industries have become more efficient and less polluting over time, which is a positive sign for their environmental performance. However, in terms of performance, Jharkhand's plants/companies/industries, production efficiency is lower than the national average, this suggests that the cement plants/companies/industries in India were performing better than those in Jharkhand in terms of production efficiency. Therefore, more study is needed to better understand the performance of cement industries. In conclusion, the cement industry in India and Jharkhand is a critical component of the country's and the state's economy, providing significant employment and contributing to their growth. The findings emphasize the need for a balanced approach to industrial growth, promoting operational efficiency and strict environmental adherence to ensure sustainable development in Jharkhand's vital cement sector. Concurrently, it highlights the substantial positive socio-economic contributions in terms of employment generation, revenue, infrastructure, rural development, and social welfare initiatives.

Keywords: Jharkhand, cement industry, plant performance, socio-economic impact, environmental impact, capacity utilization.

I. INTRODUCTION

Jharkhand, a mineral-rich state in India, hosts a significant and rapidly growing cement industry. The abundance of critical raw materials such as limestone and coal make it an attractive hub for cement manufacturing companies. Since the establishment of the cement plant in Sindri in the early 1950s, the industry has expanded considerably with the entry of numerous private players, including major companies like ACC, Birla Corporation, Dalmia Cement, Lafarge, and Ultratech Cement. This sector has become a vital contributor to Jharkhand's economy, generating substantial employment opportunities, contributing to state revenue, and facilitating regional infrastructure development, particularly in remote areas. Despite its economic contributions, the cement industry in Jharkhand faces substantial challenges, primarily concerning its environmental footprint. Cement production is an energy-intensive process and a significant source of greenhouse gas emissions [1]. Furthermore, the industry's heavy reliance on natural resources, such as water and limestone, has led to concerns regarding deforestation, land degradation due to mining, and water pollution from effluent discharge [2]. Logistical and transportation challenges further impede the industry's competitiveness, as the state's infrastructure is still developing. The Jharkhand government has initiated several measures to mitigate these challenges, including investments in infrastructure and the promotion of renewable energy sources within the industry. This study aims to conduct a detailed analysis of the performance of selected cement plants in Jharkhand, examining their production efficiency and utilization rates. Crucially, it will explore the comprehensive socio-economic and environmental impacts of cement production in the state, offering insights necessary for balancing economic growth with environmental sustainability and local community welfare.

II. LITERATURE REVIEW

Cement production is globally recognized as a major contributor to CO_2 emissions, accounting for approximately 5% to 9% of total anthropogenic CO_2 [3]. This has led to a global push towards carbon neutrality, with inspiration drawn from goals such as the Spanish cement industry's 2050 climate-neutral objective [4]. Several studies emphasize the necessity for the cement sector to implement more sustainable methods to mitigate its detrimental environmental effects. Strategies such as carbon storage and capture technologies, raw material replacement with sustainable resources, and energy-efficient technologies have been proposed to lessen the environmental footprint of cement manufacturing [5]. The industry's adoption of environmental management practices has seen significant improvement, though variations in effectiveness

exist across states. Notably, earlier analyses indicated that Jharkhand, alongside other states like Maharashtra, Madhya Pradesh, Rajasthan, and Andhra Pradesh, performed poorly in terms of environmental efficiency, suggesting a need for more robust environmental regulation and monitoring[6]. Research highlights the cement industry's substantial contribution to global CO_2 emissions, underscoring the imperative for sustainable management. Innovative practices and resource optimization, including reductions in energy and water use, waste management plans, and the utilization of biofuels and alternative raw materials, are crucial for environmental sustainability [7]. Studies have also assessed energy efficiency improvement and CO_2 emission reduction potentials, identifying specific technologies and processes for the Indian cement sector. Another study highlighted Indian cement sector vital role in contributing to the Indian circular economy by using renewable energy, waste materials, and performance improvers in its production process. The study suggested that in order to accomplish resource efficiency and environmental sustainability, the Indian cement industry must collaborate with all stakeholders and act as an engine in the circular economy. The study provided analysis on the production, consumption, and export of cement in India, as well as the energy consumption, CO_2 emissions, and waste utilization of the industry [8]. The widespread environmental impacts of cement production across Asia, including greenhouse gas emissions, energy consumption, air pollution, and hazardous waste generation, necessitate mitigation measures such as improving energy efficiency, promoting alternative fuels, and adopting new technologies.

The Indian cement industry has made progress in adopting low-carbon technologies, surpassing some emissions reduction targets due to increased use of alternative fuels, reduced clinker factors, and blended cement production. However, ambitious goals for halving carbon dioxide emissions by 2050 still require significant effort and addressing challenges like technical limitations, high costs, and policy barriers [4]. Beyond environmental concerns, the social impacts of the cement industry on local communities, including changes in living patterns, household displacement, and loss of social adjustment, have also been noted. Studies emphasized the need for an Environmental Management Plan to mitigate these effects [9], a study in Coimbatore, Tamil Nadu, India, specifically identifies issues such as changes in living patterns, household displacement, and loss of social adjustment [10]. These studies collectively emphasize the need for a balanced approach to the industry's development, considering its economic benefits alongside its social and environmental costs.

Further, the cement industry's operations contribute to various pollutants, including Sulphur oxides, nitrogen oxides, carbon monoxide, and particulate matter, affecting both human health and ecosystems, [11] Contamination of soil with heavy metals also poses risks to soil chemistry and biodiversity [12]. In Jharkhand, the cement industry faces concerns regarding air pollution (particulate matter, SO_2, NOx, VOCs), with Jharkhand rank as one of top 10 most polluted state in India for PM2.5 concentration [13]. Water pollution is also an issue, as cement plants discharge effluent containing heavy metals and other pollutants, impacting water bodies. Furthermore, land degradation due to limestone mining is a major environmental problem, with over 50% of Jharkhand's geographical area affected. Cement production is highly energy-intensive, relying on fossil fuels, which contribute significantly to CO_2 emissions; Jharkhand's cement plants emitted over 4.3 million tons of CO_2 in FY 2018-19 [2]. The industry also generates significant waste, including dust, ash, and sludge, which can contaminate soil and water if improperly disposed.

While existing studies provides a general overview of the Indian cement industry, detailed studies specifically focusing on the performance and impacts of cement plants in Jharkhand remain scarce. This gap highlights the need for a targeted examination of the issues facing this critical regional sector. Overall, the literature highlights that while the cement industry is vital for economic growth, its environmental and social responsibilities are paramount. Research continues to explore strategies for improving energy efficiency, reducing emissions, and promoting sustainable practices, acknowledging the unique regional challenges faced by areas like Jharkhand.

III. METHODOLOGY

This study utilizes a mixed-methods research design to thoroughly analyze the performance of selected cement plants in Jharkhand and investigate their socio-economic and environmental impacts. This approach allows for a comprehensive exploration of complex interrelationships within regional industry.

III. A. Data Sources and Collection

Quantitative data for the analysis of Jharkhand's cement industry performance and its environmental impact were primarily sourced from publicly available secondary data. Key sources included the Jharkhand State Pollution Control Board (JSPCB) and the Indian Minerals Yearbook, covering data up to 2023 where available.

For our objective, focusing on the performance analysis of Jharkhand's cement industry, the following variables were collected:

- **Company/Plant Names**: Essential for identifying specific operational units within Jharkhand.
- **Capacity (million tonnes)**: Data on the potential output of each plant, crucial for assessing utilization.
- **Production (million tonnes)**: Actual output figures, indicating operational performance.
- **Production per Capacity**: A key performance indicator (KPI) calculated as the ratio of production to installed capacity, reflecting operational efficiency.
- **Carbon Dioxide Intensity**: The ratio of carbon dioxide emissions from cement production to the cement output, measuring environmental performance per unit of production.
- **Coal Production (in million tonnes)**: Data related to energy consumption and associated emissions.

Qualitative insights into socio-economic and broader environmental impacts were synthesized from various reports, policies, and existing literature, including the Jharkhand Economic Survey and industry analyses and questionnaire from industries expert and locals.

III. B. Statistical Tools and Software

The following statistical tools were applied for quantitative analysis:

- **Descriptive Statistics**: Used to summarize the distribution and nature of data for production per capacity and utilization rates, as well as coal production and carbon dioxide intensity.
- **One-way ANOVA**: Employed to assess differences in production capacity among different cement plants in Jharkhand.
- **T-test**: Utilized to compare the mean production per capacity of Jharkhand's cement industry with India's national average and to assess the significance of differences from the industry benchmark.
- **Wilcoxon Signed-Rank Test**: A non-parametric test used to compare the median of the sample (Jharkhand plants' performance) to an average benchmark (70% utilization rate), particularly useful when data may not meet parametric assumptions.

- Software tools included JMP Software for statistical analyses, Excel for data management, and Origin Pro Software for advanced data visualization.

III. C. Hypotheses Formulation

To analyze the performance of the cement industry in Jharkhand, the following hypotheses were formulated:

Hypotheses for Cement Plants in Jharkhand:

- **Null Hypothesis (H0):** There is no significant difference in the performance (production per capacity and utilization rate) of the cement plants in Jharkhand compared to the average industry benchmark of 70% (or 0.7).

- **Alternative Hypothesis (H1):** The performance (production per capacity and utilization rate) of the cement plants in Jharkhand is significantly different from the average industry benchmark of 70% (or 0.7). The industry benchmark for capacity utilization in the Indian cement industry is generally accepted around 70-72%.

Hypotheses for India vs. Jharkhand:

- **Null Hypothesis (H0):** There is no difference between the means of production per capacity for India and Jharkhand in 2019.

- **Alternative Hypothesis (H1):** There is a difference between the means of production per capacity for India and Jharkhand in 2019. These hypotheses are crucial for evaluating the efficiency and competitiveness of cement companies in Jharkhand relative to national standards and their peers.

IV. RESULTS AND DISCUSSION

The analysis of the performance of cement plants in Jharkhand reveals a complex landscape characterized by varying production capacities, utilization rates, and significant socio-economic and environmental impacts.

IV. A. Performance of Cement Plants in Jharkhand

An examination of production per capacity and utilization rates for selected plants in 2019 (Table 1) shows diverse performance.

Table 1: Capacity and production, production per capacity of cement plants in Jharkhand (2019).

Plant/Company Name	**Year**	**Capacity (in million tonnes)**	**Production (in million tonnes)**	**Production per Capacity**
ACC Ltd - Chaibasa	2019	0.9	0.9	1
ACL, Jaypee Group - Durga Cement Works	2019	2.31	0.4	0.17
BJCL, Jaypee Group - Bhilai Jaypee	2019	1.3	0.8	0.62
Shree Cements - Shree Jharkhand	2019	2.27	0.57	0.25
ACC Ltd - Sindri	2019	3	0.53	0.18
Total	-	**9.78**	**3.2**	**0.33**

Source Indian Minerals year book [14-19]

ACC Ltd - Chaibasa demonstrated optimal efficiency with a production per capacity of 1, indicating 100% capacity utilization. In stark contrast, ACL, Jaypee Group - Durga Cement Works, had the lowest production per capacity at 0.17 (17% utilization), signifying substantial underutilization. Other plants like BJCL, Jaypee Group - Bhilai Jaypee (0.62), Shree Cements - Shree Jharkhand (0.25), and ACC Ltd - Sindri (0.18) also showed moderate to low utilization rates, suggesting operational inefficiencies or challenges in market demand Fig.1.

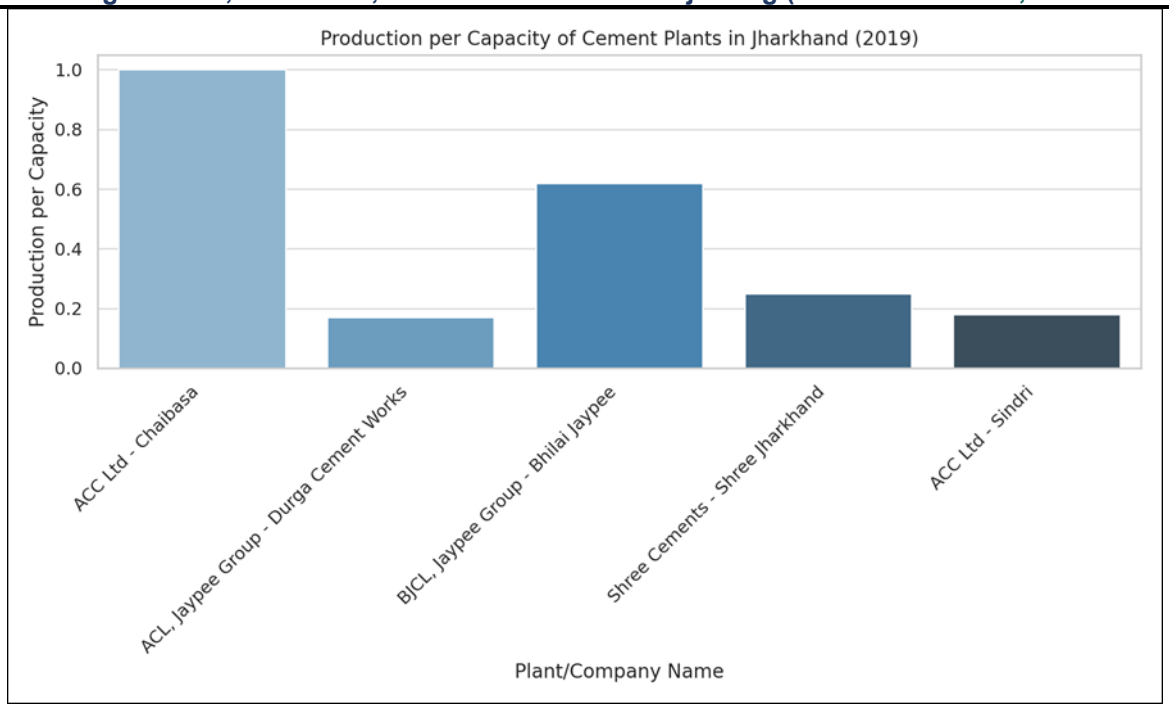

Figure 1: variation in production per capacity of cements plants in Jharkhand.

Despite these observed lower average utilization rates (mean production per capacity of 0.444 and utilization rate of 44.93%) compared to the average industry benchmark of 70%, the statistical tests did not find a significant difference at either the 0.05 or 0.01 significance levels (Wilcoxon Signed-Rank Test p-value: 0.187500; One-sample t-test p-value: 0.188). This outcome implies that while Jharkhand's plants generally operate below the benchmark, the observed deviation is not statistically significant given the sample data, though it still highlights areas for potential improvement in efficiency and consistency.

A one-way ANOVA analyzing production capacity by plant/company name showed no significant difference among the selected plants in Jharkhand (Prob > F = 0.5284). This suggests that plant/company name alone does not explain significant variations in production capacity among the studied units (Table 2; Fig. 2).

Table 2: Analysis of Variance of variables used in the study.

Source	**DF**	**Sum of Squaṛės**	**Mean Square**	**F Ratio**	**Prob > F**
Plant/Company Name	5	4.809111	0.96182	0.8709	0.5284
Error	12	13.252400	1.10437		
C. Total	17	18.061511			

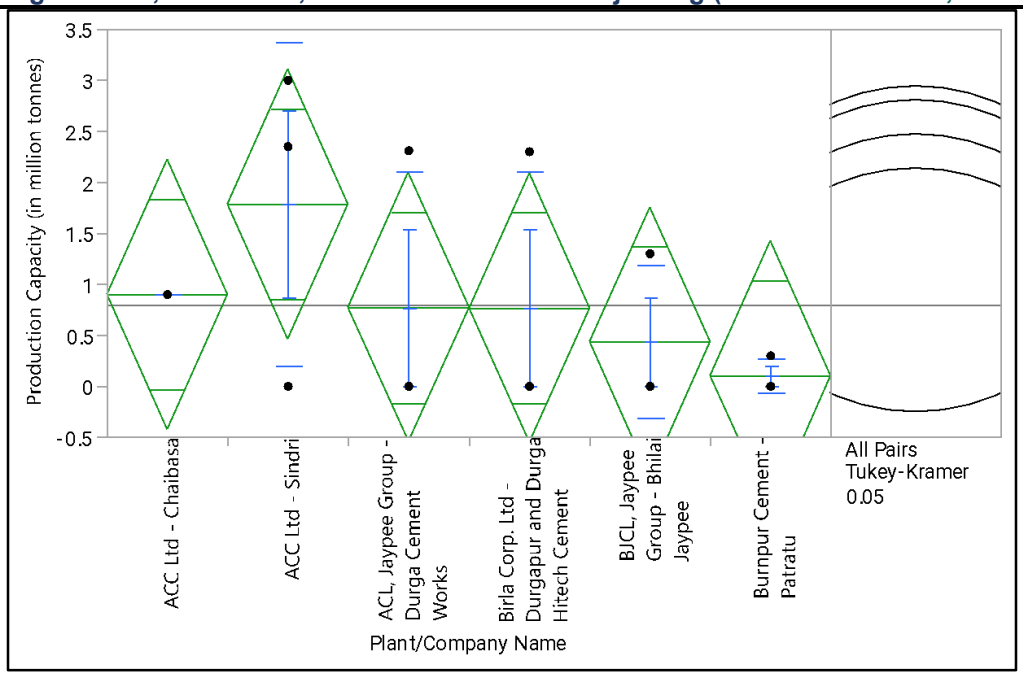

Figure 2: One-way Analysis of Production Capacity (in million tonnes) By Plant/Company Name.

When comparing Jharkhand's cement industry performance with the national average in 2019, a significant difference was observed (Table 3).

Table 3: Analysis of Production per capacity for India and Jharkhand in 2019.

State/Region	Production Capacity (million tonnes)	production (million tonnes)	Production per Capacity in 2019 (million tonnes)
India	480	329	0.69
Jharkhand	9.78	3.2	0.33

Source Indian Minerals year book [14-19]

The t-test comparing the mean production per capacity for India (0.69) and Jharkhand (0.33) in 2019 yielded a highly significant result ($t(487.78) = 36.36$, $p < 0.001$). This decisively rejects the null hypothesis, indicating that the production efficiency of cement plants in India overall was significantly higher than those in Jharkhand in 2019.

Table 4: Analysis of Production per capacity for India and Jharkhand in 2019 with T test.

State/ Region	Production Capacity (million tonnes)	Production (million tonnes)	Production per Capacity in 2019 (million tonnes)
India	480	329	0.69
Jharkhand	9.78	3.2	0.33
t-test	$t(487.78) = 36.36$, $p < 0.001$		

IV. B. Environmental Impact and Sustainability Efforts

The study also assessed environmental performance through coal production and carbon dioxide intensity.

Table 5: shows Coal production (in million tonnes), Carbon dioxide intensity of Jharkhand's cement industries variation along the year.

year	Coal production (in million tonnes). Jharkhand *(a)*	Carbon dioxide intensity of Jharkhand's cement industries *(b)*
2001	33.5	0.0405
2002	76.8	0.0409
2003	78.6	0.0312
2004	79.5	0.0261
2005	78	0.0211
Annual average	69.28	0.032

Source: (20) Economic Intelligence Service, (2008); (21) Mandal, (2010).

Table 6: Analysis showing Statistical Summary for Coal production (in million tonnes), Carbon dioxide intensity of Jharkhand's cement industries variation along the year.

Variable	Mean	Standard Error	Median	Standard Deviation	Range	Minimum	Maximum
Coal production (in million tonnes). Jharkhand	69.28	8.955747	78	20.02566	46	33.5	79.5
Carbon dioxide intensity of Jharkhand's cement industries. (Jh)	0.03196	0.00391	0.0312	0.008742	0.0198	0.0211	0.0409

A linear regression analysis revealed a strong negative linear relationship between year and carbon dioxide intensity in Jharkhand's cement industries (Figure 3). This significant decreasing trend indicates that Jharkhand's cement industries have become more energy-efficient and less polluting over time, which is a positive sign for their environmental performance. This improvement can be attributed, in part, to key initiatives by the state government, such as the Jharkhand Industrial and Investment Promotion Policy 2021–

22. This policy offers incentives like capital investment subsidies, interest subsidies, and tax benefits for new and expanding cement plants, reducing initial costs and improving viability. It also streamlines regulatory processes through a Single Window Clearance system and promotes investment opportunities through summits and campaigns.

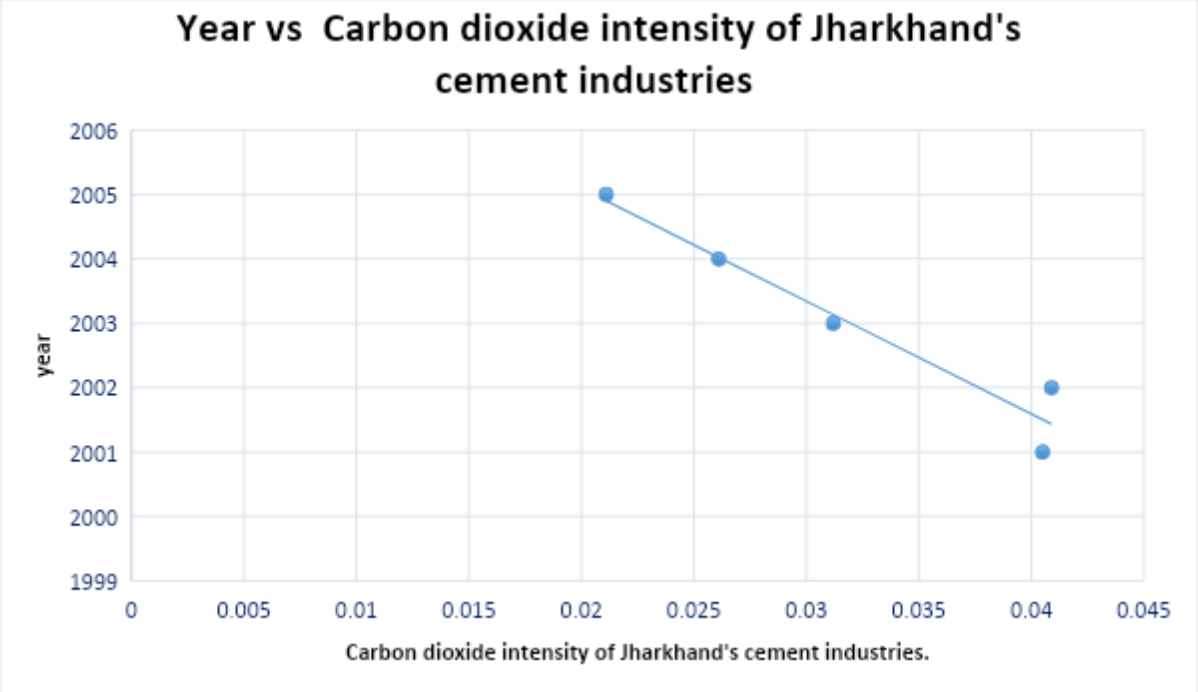

Figure 3: shows variation in Carbon dioxide intensity of Jharkhand's cement industries overtime period

IV. C. Socio-economic Impact

The cement industry in Jharkhand has made a significant socio-economic contribution.

- **Employment Generation**: The industry directly and indirectly employs around 15,000 people across various skill levels, contributing to a reduction in unemployment and strengthening growth in allied sectors like transportation, logistics, and construction. This also stimulates the growth of small and medium enterprises (SMEs) providing support services.

- **Revenue Generation**: The sector generated approximately Rs. 1,847.82 crore in revenue through taxes and other charges in 2020-21, and attracts substantial domestic and foreign investments, leading to plant expansion and new developments.

- **Infrastructure Development**: Quality cement supply has been instrumental in building highways, bridges, dams, airports, railways, housing projects, and industrial infrastructure, significantly driving the state's development.

- **Rural Development**: Many cement factories are located in remote areas, providing employment and boosting local economies. Their presence has led to improved connectivity through road development, promoted sustainable farming practices, and fostered SMEs in rural areas.

- **Social Welfare**: Cement companies actively engage in corporate social responsibility (CSR) initiatives. These include establishing and supporting schools (e.g., Dalmia Vidya Mandir, ACC Public School, Birla Institute of Technology), establishing hospitals and healthcare centers (e.g., ACC Limited hospital in Chaibasa, Birla Corporation centers), and community development projects (e.g., building roads, community halls, skill development centers, micro-enterprise programs). Furthermore, initiatives promote women's empowerment through employment, skill development, education, and healthcare access.

While these contributions are significant, the industry must continuously address environmental concerns to ensure its growth remains sustainable.

V. CONCLUSION

The cement industry in Jharkhand, while a powerhouse for regional economic growth, faces distinct challenges that necessitate a strategic and balanced approach for sustainable development. Our investigation highlights significant disparities in the operational performance of individual cement plants within the state. While some units, like ACC Ltd - Chaibasa, demonstrate exemplary efficiency with optimal capacity utilization, others like ACL, Jaypee Group - Durga Cement Works, exhibit considerable underperformance and untapped capacity. Furthermore, the production efficiency of Jharkhand's cement plants significantly lags behind the national average.

Despite these operational inconsistencies, the state's cement sector is actively working towards environmental sustainability. The observed decreasing trend in carbon dioxide intensity signifies a positive trajectory in environmental performance, aided by policy initiatives such as the Jharkhand Industrial and Investment Promotion Policy 2021–22. This policy, with its emphasis on investment incentives, streamlined clearances, land availability, infrastructure development, and skill enhancement, is crucial for fostering industrial growth while promoting responsible practices.

The socio-economic impact of the industry in Jharkhand remains undeniably positive, contributing extensively to employment, state revenue, and vital infrastructure development across both urban and rural areas. However, the environmental costs, including air and water pollution, land degradation, and greenhouse gas emissions, demand continuous and rigorous attention.

V. A. Future Directions and Recommendations

To realize the full potential of Jharkhand's cement industry and ensure its sustainable growth, the following recommendations are crucial:

- **Efficiency Enhancement**: Underperforming cement plants in Jharkhand must prioritize operational efficiency improvements, drawing lessons from high-performing counterparts. This involves investing in modern technologies, process optimization, and robust maintenance protocols to maximize production per capacity.

- **Performance Benchmarking**: Regular and transparent benchmarking of plant-level performance against national and international best practices should be mandated. Establishing industry-specific KPIs and sharing non-sensitive operational data can drive continuous improvement and foster healthy competition.

- **Targeted Capacity Utilization Initiatives**: For plants with significant underutilized capacity, specific strategies should be developed. This may include market expansion studies, addressing local demand-supply gaps, and evaluating investment in infrastructure to reduce logistical bottlenecks.

- **Strengthened Environmental Compliance**: While progress in reducing carbon intensity is evident, stricter enforcement of environmental regulations and continuous investment in pollution control technologies (e.g., advanced air scrubbers, water treatment plants, and responsible waste disposal) are paramount to mitigate ongoing air, water, and land pollution.

- **Promote Green Technologies**: Accelerated adoption of cleaner production technologies, alternative fuels, and waste heat recovery systems, beyond just coal combustion, should be incentivized. Government subsidies and R&D support can facilitate this transition.

- **Integrated Socio-Environmental Planning**: Industrial development policies should explicitly integrate socio-environmental impact assessments to ensure that economic benefits are balanced with community well-being and ecological preservation. This includes robust land reclamation policies for mined areas and support for local livelihoods adversely affected by industrial operations.

- **Skill Development and Local Engagement**: Continuous investment in vocational training and skill development programs tailored to the needs of the cement industry can enhance local employability and foster community engagement, ensuring that the benefits of industrial growth are shared equitably.

By addressing these facets, Jharkhand's cement industry can not only enhance its performance and competitiveness but also serve as a model for responsible industrial development, contributing significantly to the state's economic prosperity and the well-being of its communities.

REFERENCES

[1] Dutta, M., & Mukherjee, S. (2010). An outlook into energy consumption in large scale industries in India: The cases of steel, aluminium and cement. *Energy Policy*, *38*(11), 7286–7298. https://doi.org/10.1016/J.ENPOL.2010.07.056

[2] Jharkhand State Pollution Control Board. (2022) Retrieved from. https://jsac.jharkhand.gov.in/pollution/IndustryDetail.aspx?IList=Cement Accessed: 08 March 2023.

[3] MAHASENAN, N., SMITH, S., & HUMPHREYS, K. (2003). The Cement Industry and Global Climate Change: Current and Potential Future Cement Industry CO2 Emissions. *Greenhouse Gas Control Technologies - 6th International Conference*, 995–1000. https://doi.org/10.1016/B978-008044276-1/50157-4

[4] International Energy Agency (IEA). Technology Roadmap - Low-Carbon Transition in the Cement Industry. 2020. Retrieved from https://www.iea.org/reports/technology-roadmap-low-carbon-transition-in-the-cement-industry. Accessed: June, 2023

[5] Ighalo, J. O., & Adeniyi, A. G. (2020). A perspective on environmental sustainability in the cement industry. *Waste Disposal and Sustainable Energy*, *2*(3), 161–164. https://doi.org/10.1007/S42768-020-00043-Y/FIGURES/2

[6] Dasgupta, D., & Das, S. (2021). Sustainability performance of the Indian cement industry. *Clean Technologies and Environmental Policy*, *23*(4), 1375–1383. https://doi.org/10.1007/S10098-020-01998-6/TABLES/3

[7] Kudtarkar, S. (2018). Indian cement industry on the path of environment sustainability through innovation and resource optimization. *Int J Latest Technol Eng Manag Appl Sci*, *7*(5), 236-244. https://www.researchgate.net/publication/332143068_Indian_Cement_Industry_on_Path_of_Environment_Sustainability_through_Innovation_and_Resource_Optimization#full-text

[8] Kukreja, K., Sharma, P., Mohapatra, B., & Saxena, A. (2020). Indian cement industry: A key player in the circular economy of India. *Sustainable Production, Life Cycle Engineering and Management*, 181–192. https://doi.org/10.1007/978-3-030-44248-4_18/TABLES/5

[9] Soni, S., & Dandge, K. P. (2023). Environmental and Health Impacts of Cement Industry. *International Journal of Scientific Research in Engineering and Management*. https://doi.org/10.55041/IJSREM17817

[10] Valan, R. P., & Muthukumar, P. K. A STUDY ON SOCIAL IMPACT CAUSED BY CEMENT INDUSTRIES IN COIMBATORE, TAMIL NADU, INDIA. *Turkish Journal of Physiotherapy and Rehabilitation*, *32*, 2. https://api.semanticscholar.org/CorpusID:237345281

[11] Mishra, U. C., Sarsaiya, S., & Gupta, A. (2022). A systematic review on the impact of cement industries on the natural environment. *Environmental Science and Pollution Research*, *29*(13), 18440–18451. https://doi.org/10.1007/S11356-022-18672-7,

[12] Ogunkunle, C. O., & Fatoba, P. O. (2014). Contamination and spatial distribution of heavy metals in topsoil surrounding a mega cement factory. *Atmospheric Pollution Research*, *5*(2), 270–282. https://doi.org/10.5094/APR.2014.033

[13] Bisoee, A. (2022, July 2). *Pollution | Jharkhand 8th most polluted state: Report - Telegraph India*. https://www.telegraphindia.com/jharkhand/jharkhand-8th-most-polluted-state-report/cid/1872770

[14] Indian Minerals yearbook (2015) IBM, Retrieved from. https://ibm.gov.in/writereaddata/files/08092017095128Cement2015(Final).pdf Accessed: 11 Dec, 2022

[15] Indian Minerals yearbook (2016) IBM, Retrieved from. https://ibm.gov.in/writereaddata/files/05152018161803Cement%202016.pdf Accessed: 12 Dec, 2022

[16] Indian Minerals yearbook (2019) IBM, Retrieved from. https://ibm.gov.in/writereaddata/files/05042022161127Cement_2019.pdf Accessed: 11 Dec, 2022

[17] Indian Minerals yearbook (2020) - IBM, Retrieved from. https://ibm.gov.in/writereaddata/files/12102021174214Cement_2020.pdf Accessed: 11 Dec, 2022

[18] Indian Minerals yearbook (Part- III: MINERAL REVIEWS) (2020) Retrieved from. https://ibm.gov.in/writereaddata/files/12102021174214Cement_2020.pdf Accessed: 26 Dec, 2022

[19] Indian Minerals yearbook (2021) IBM, Retrieved from. https://www.ibm.gov.in/writereaddata/files/01312023164746Cement_2021.pdf Accessed: 28 Dec, 2022

[20] Economic Intelligence Service (Energy), Center for Monitoring Indian Economy (CMIE). (2008). https://www.cmie.com/

[21] Kumar Mandal, S., & Madheswaran, S. (2010). Environmental efficiency of the Indian cement industry: An interstate analysis. *Energy Policy*, *38*(2), 1108–1118. https://doi.org/10.1016/J.ENPOL.2009.10.063