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Case Study

BALANCING INDUSTRIAL GROWTH AND ENVIRONMENTAL RESPONSIBILITY: A CASE STUDY OF POLLUTION MANAGEMENT AT UDAYAPUR CEMENT INDUSTRY, NEPAL

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ABSTRACT

The cement industry in Nepal is crucial for infrastructure development and economic growth, but its operations raise environmental concerns due to air pollution, dust emission and mining activities. The objective of this study was to evaluate the pollution management and the environmental effects of the Udayapur Cement Industry Limited (UCIL), Nepal, and to determine the ways of balancing industry development with environmental sustainability. Primary and secondary data sources were used and a qualitative case study approach was used. Primary data were gathered using site observation, semi-structured interviews with 10 plant officials and a survey of 20 local residents residing around the industry. Secondary data was collected from operational report, government environmental standards, policy documents and related literature. Thematic analysis was used to analyse the collected data. The results indicated a number of serious operational deficiencies in the pollution control system such as the Electrostatic Precipitator chamber which was not operating, low maintenance and lack of continuous emission monitoring, which made it more dangerous for the environment. Mining operations were identified to produce large volumes of dust, noise and vibration which resulted in detrimental impacts to the surrounding ecosystems and communities. Residents complained of respiratory discomfort, eye irritation, loss in agriculture production, and concerns about contaminating their water. The study concludes that the following measures would be helpful to achieve environmentally responsible industrial development to operate the UCIL sustainably: Technological modernization, rigorous regulatory enforcement, frequent monitoring of the environment and enhanced community involvement.

Keywords: Cement Industry, Environmental Pollution, Pollution Control, Sustainable Development, Udayapur Cement Industry

INTRODUCTION

It is a big industry sector, existing all over the world, having shown great advantages to Nepal. Nepal has a number of companies, like Udayapur Cement Limited (UCL), which are key contributors in socio-economic development of Nepal, but in the process of production, they also emit particulate matters and release toxic gases which cause environmental degradation in Nepal Singh and Shakya (2016). Cement industry is one of the most energy-intensive anthropogenic CO_2 emitters with a high CO_2 emission volume during clinker production and fossil fuel combustion which accounts for approximately 5-8 % of the total anthropogenic CO_2 emissions in the world Andrew (2019), Cheng et al. (2023). Similarly, as per the studies conducted by Thakuri et al., 2021, the cement industry is also a huge emitter of carbon emission in Nepal, where higher production of cement leads to higher CO_2 emissions in Nepal and vice versa. There are other industries such as Udayapur Cement Limited (UCL), which are also facing similar

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environmental issues due to their energy use in production and the emissions. The rapidly changing emissions trends during the study period clearly reflecting the importance of using cleaner technologies, proper emission monitoring and sustainable industrial practices in Nepal's cement industry.

As a consequence of urbanisation and infrastructure development, the demand for cement has grown up in Nepal and environmental issues have intensified. Some operational deficiencies, especially in the fields of maintenance, monitoring and pollution control are observed in Udayapur Cement Industry, which can lead to negative environmental and health impacts on people living in the nearby communities Pandeya et al. (2021). In spite of introduction of regulatory standards in terms of emission, disposal of the waste, noise and continuous monitoring by the Department of Environment since 2082 BS (Bikram Sambat), the situation is still critical. In practice, however, there are problems, as plants find it difficult to comply and have resulted in gaps in implementation of environmental performance and environmental regulation.

Figure 1

Figure 1 Udayapur Cement Industry, Nepal

LITERATURE REVIEW

ENVIRONMENTAL IMPACTS OF CEMENT INDUSTRIES

The extensive studies have indicated harmful environmental effects in the surrounding areas due to the production of cement. The main sources of air pollution are dust from kiln processes as well as dust from the raw material handling. This impacts human well-being along with natural systems Emetere et al. (2019). The use of pollution management tools, like electrostatic precipitators, is usually undertaken. Their effectiveness is largely dependent upon the attention and technology they receive. Unfortunately, older equipment and maintenance routines, if not followed properly, can allow fugitive emissions to increase Soni and Dandge (2023). This poses health risks to the people living in the vicinity.

A new theme that is emerging in recent publications in Toxics and other journals is the importance of properly maintaining pollution control systems, or risking them to emit higher concentrations of pollutant particulate matter (PM) and other odorous gases. It has a direct impact on people's health and the environment Mohamad et al. (2021).

Recent research has shown that PM emitted from cement production can cross industrial boundaries Bajuri (2023). It subsequently impacts nearby communities land used for farming and plant life. Dust can negatively impact crop yields and alter local environmental conditions through sedimentation. The results highlight the importance of effective methods of emission containment and continued ecological monitoring.

MINING AND ITS ENVIRONMENTAL EFFECTS

Extraction of raw material, which requires blasting and excavation, creates high noise levels, blasts and generates much dust damaging infrastructure, affecting local flora and fauna, also creating pollution in air, soil and water Ganapathi and Phukan (2020) and (Nepal's standards, 2082 BS). These negative impacts may be minimised through green mining. Green mining uses blasting practices which are environmentally friendly while also using resource efficient sustainable mining Soni and Nema (2021). The problem of damaging environments and local assets by unregulated and uncontrolled quarrying are discussed for Sri Lanka (Nepal's standards, 2082 BS). In addition to physical effects, it also aggravates land degradation as quarries affect erosion of surrounding areas. Thus, correct planning of mines and subsequently rehabilitation activities are major components of sustainable cement production.

MOVING TOWARD SUSTAINABLE PRACTICES

Worldwide, industries are opting for cleaner production techniques such as dry process cement for manufacturing, in-situ leaching and zero-waste mining to lower environmental footprint Sharma and Bhagowati (2024). Furthermore, use of modern dust suppression systems and real time environmental monitoring and engaging with the community proactively are also seen as crucial to sustainable industrial use Naranje et al. (2021).

International best practice stresses embedding environmental management of systems, real time emission monitoring and development of green belts around industrial facilities to minimize environmental impacts while preserving efficiency of production.

NEPAL'S POLLUTION STANDARDS FOR CEMENT INDUSTRIES

As per the environmental standards applicable in Nepal Department of Environment. (2082 BS), cement plants must limit the level of particulate matter, sulfur dioxide (SO_2), nitrogen oxides (NO_x) and other pollution through pollution-control devices like EPs, bag filters and scrubbers and are required to treat and handle wastewater and solid waste adequately and must monitor their emission levels regularly and submit emission reports to the authorities. But inconsistent and erratic carry out of environmental regulations on cement plants has led to several problems and many cements plant are in violation of environmental policies either due to poor enforcement, technological limitations or malfunctioned equipment which has caused severe environmental harm Chauhan and Shrestha (2022) but studies shows that strengthening the enforcement of policies and up gradation of technology will improve the environmental and health outcomes Firdissa et al. (2024).

Furthermore, according to the 2082 BS standards, cement industries must employ pollution-control devices such as Electrostatic Precipitators (ESP) or bag filters, establish sufficient chimney heights and adopt various dust-control measures, such as water spraying, paved internal roads and green belt development, to reduce fugitive dust emissions and ensure proper environmental performance within industrial premises.

RECENT POLLUTION CONTROL STANDARDS FOR CEMENT INDUSTRIES IN NEPAL (2082 BS)

Since emissions from cement production are an extensive issue on environmental pollution, Government of Nepal enforced regulations of ' Standards for Dust, Smoke and Chimney Height Emissions from the Cement Industry, 2082 BS'. The main objective of the standards was to enforce regulation of air emissions; air quality within the industry area; wastewater, solid waste from the cement industry; noise level control and monitoring emissions.

The limit on Total Suspended Particulates within the industry premises was 500 $\mu g/m^3$ during operation while cement dust emissions were 35 mg/m^3 in rotary kiln system with fabric filter and 50 mg/m^3 for vertical shaft kiln system. Similarly, Sulfur Dioxide (SO_2) emissions must not exceed 1000 mg/m^3 and Nitrogen Dioxide (NO_x) emission should be 800 mg/m^3. Besides, the cement factories must have Electrostatic Precipitators (ESP) or bag filter as pollutant control devices.

The other rules were a chimney over 30-meter height, provide space and inspection facilities, control dust by spraying water over paved road, making of a green belt around the industry premises. These norms were created in the perspective of diminishing environmental pollution and maintain sustainable industrial development in Nepal Department of Environment. (2082 BS).

Figure 2

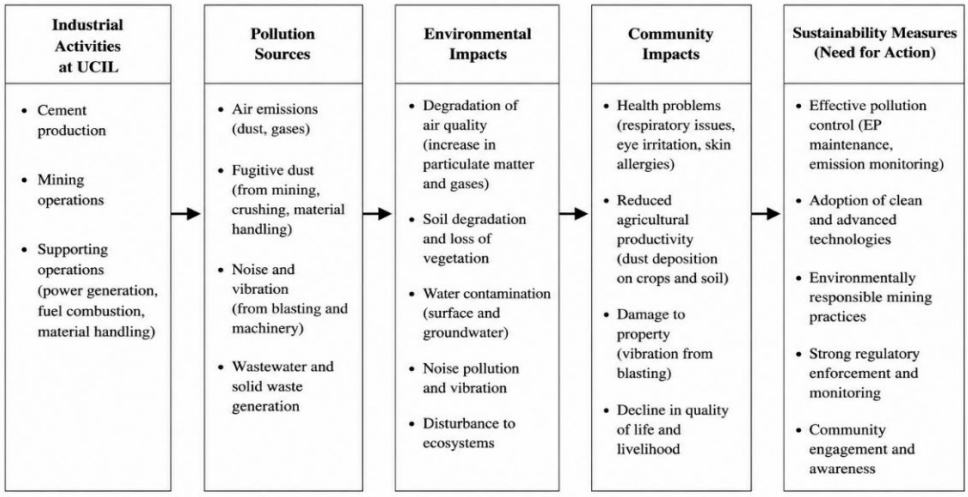

Figure 2 Conceptual Framework of Environmental Impact at UCIL

METHODOLOGY

This study used a qualitative case study approach to understand the pollution management practices and environmental issues of Udayapur Cement Industry Limited (UCIL) in Nepal. A qualitative approach was deemed suitable to allow an in-depth exploration of issues on the functioning of the system, including those of pollution control, mining impacts, environmental compliance and community concerns, in the context of the real industrial system. The case study design enabled the researcher to build up a fine-grained understanding of UCIL's environmental management, and the issues confronting its sustainable operation.

Both primary and secondary sources were used to gather the data so that there would be a complete understanding of the issue. The primary data were collected by using site observations, semi-structured interview and community survey. The operational state of the pollution-control systems, the mining activities and environmental conditions around the mining activity were observed during the site visits. Data collection was conducted between March and May 2026. 10 plant officials, who were selected by purposive sampling according to their direct involvement in the operation, maintenance and environmental management of the plant, were interviewed using a semi-structured interview. The interviews were conducted for about 30-60 minutes, and the questions centered on pollution control practices, maintenance issues, regulations and limitations of operations.

A survey was also carried out among 20 residents of nearby communities to learn about their perspectives on dust pollution, health and water pollution problems, and socio-economic impacts. The subjects included those who lived in the industrial area and were near the cement plant. Verbal informed consent was obtained from all participants prior to data collection.

Table 1

Table 1 Participant Profile

Participant Group	Number	Purpose
Plant Officials	10	Operational and environmental insights
Local Residents	20	Community perceptions and impacts
Total	30	Study participants

Secondary data comprised operational reports, government environmental regulations (2082 B.S), published articles in journals, policy documents and industry related documents. The following sources were utilized to provide context, and to compare UCIL's environmental performance with that of other countries and the world.

Thematic analysis was used for the analysis of the collected data. Interviews and field observations were analyzed and coded into themes and survey results were analyzed and coded into themes systemically. The analysis revealed four main themes: pollution control systems, environmental degradation related to mining activities, health and socioeconomic concerns of communities and sustainable development possibilities. The process of analysis identified major gaps in operation, risks to the environment and possible ways to improve pollution management and sustainable industrial operations at UCIL.

Data triangulation was used to validate the data results of the study to ensure the credibility of the research, which is done by cross checking the data from interviews, field observations, community responses and documentary sources. This increased the credibility of the results and thus the overall validity of the research.

FINDINGS AND DISCUSSION

Table 2

Table 2 Themes Generated from Thematic Analysis

Major Theme	Subthemes
Pollution Control Systems	Non-functional EP chamber, poor maintenance, weak emission monitoring
Mining Impacts	Dust generation, blasting noise, vibration, land degradation
Community Health & Socioeconomic Concerns	Respiratory problems, eye irritation, crop damage, water concerns
Sustainable Development Pathways	Technology upgrade, stronger regulation, community engagement

POLLUTION CONTROL AT UDAYAPUR CEMENT INDUSTRY

Figure 3

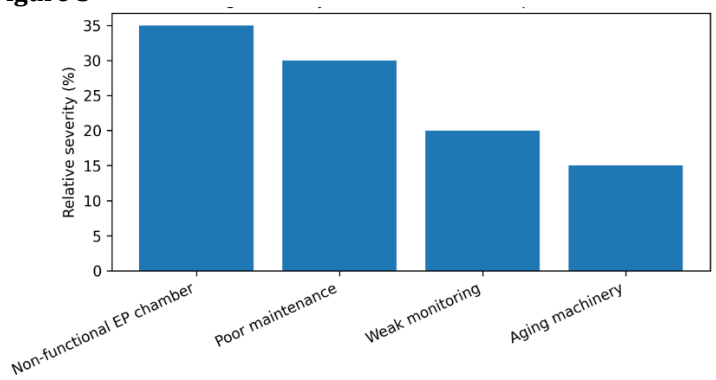

Figure 3 Major pollution control Gaps at UCIL

Figure 3 shows the critical areas of pollution in Udayapur Cement Industry Limited (UCIL). The top four challenges identified by the figure are problems with the Electrostatic Precipitator (EP) chamber (35%), sub-optimal maintenance of emissions equipment (30%), inadequate emission monitoring (20%) and old equipment (15%). The above results show that while such environmental regulations and pollution-control exist to some degree in written form, their actual implementation is still inadequate at UCIL.

On-site observations confirmed that one EP chamber had not been working for a long time thus the system's dust control efficiency was significantly reduced and the surrounding dust emission was increased. Poor performance of pollution-control equipment was reported as the main factors, including outdated equipment, inadequate maintenance, and delayed technical repairs related to the equipment at the plant. “This has been inoperable for a long time in one of the electrostatic precipitator chambers and has impacted the dust removal efficiency,” said one plant official. “Keeping them operational is the toughest part of the job, because there are technical problems along with the cosmetic and aesthetic issues that require repair, which would not allow the pollution control units to function at a maximum capacity,” the same official added.

It also revealed that the 2 working EP chambers that were available were not being optimally effective because of maintenance issues. Such operational inadequacies can lead to particulate emissions and impact air quality in nearby areas. The results may corroborate with the findings of Mohamad et al. (2021); Salman et al. (2025), which showed that poorly maintained pollution-control system directly causes increased dust emission and environmental risks.

In addition, persistent monitoring of emissions has not been established at UCIL due to a lack of implementing environmental standards (2082 B.S.) in the country. But, as one official put it, “We know what the new environment specs are but it's not fully implemented through continuous monitoring yet.” This reflects a distinct disconnect between what is being called for in policy and what is actually being done in industry. For this reason, regular maintenance, technological updates and increased rigour in regulation monitoring is vital to help enhance pollution-control efficiency, and reduce environmental risks.

MINING IMPACTS AND ENVIRONMENTAL DEGRADATION

Figure 4

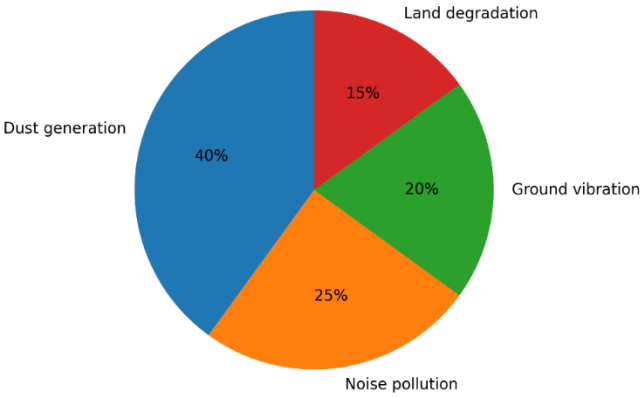

Figure 4 Major Environmental Impacts of Mining Activities

The major environmental impacts that can be determined in Udayapur Cement Industry Limited (UCIL) have been shown in Figure 4. The figure reveals that dust generation is still the largest environmental problem currently (40%), followed by noise pollution (25%), ground vibration (20%) and land degradation (15%). The results suggest that numerous environmental disturbances have resulted from cement production, particularly in the process of limestone extraction and mining.

The operations of blasting result in high amounts of dust, noise and ground vibration, with a negative impact on the ecosystems and the surrounding communities. Residents said blasting regularly interferes with their daily routine and that it causes a lot of discomfort. "And when they blow, the whole area vibrates and the dust can cover the entire area" said one citizen. Another resident explained, “The dust from mining and transportation becomes a more or less daily occurrence on our roads, crops and our homes.

The research also found the fact that infrastructure damage and land degradation is a concern. Multiple residents stated the possibility of vibration from blasting rupturing nearby buildings and structures over time. It was observed by one participant that the blasting vibration can have an impact on property located close to the blasting site, which is a concern for many families. From these results, it can be concluded that mining activities for an extended duration could have negative impact not only on environmental quality but also safety and property damage are becoming an increasing concern.

While mining is still a cornerstone in raw material extraction, plant officials have recognized its negative impacts on the environment. During both excavation and transport stages, dust was observed to spread, impacting on nearby human settlements and land used for agriculture, which had a negative effect on vegetation and livelihoods. The present results concur with the results reported by Ganapathi and Phukan (2020) which stated that mining of limestone is a major source of air pollution, ecological damage and soil disturbance. The study recommends the following ways to minimize these effects: controlled blasting, dust suppression methods and environmentally friendly mining practices like "dry" processing.

COMMUNITY HEALTH, SOCIO-ECONOMIC CONCERNS

Figure 5

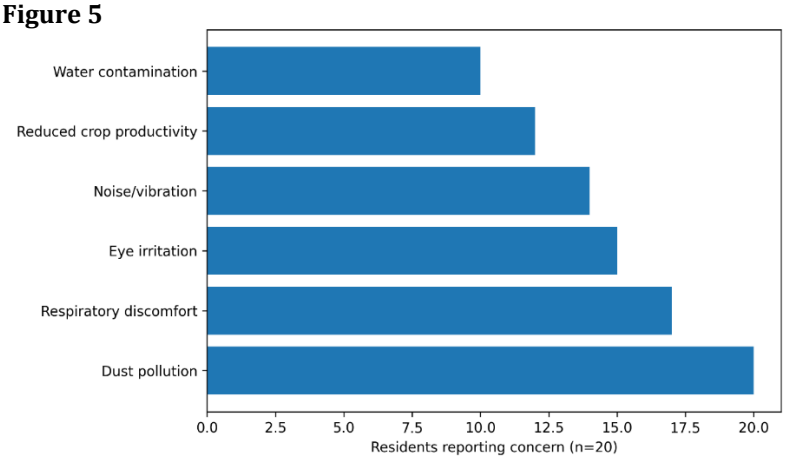

Figure 5 Community Concerns reported by residents

The significant community concerns reported by the residents of the vicinity of the Udayapur Cement Industry Limited (UCIL) are shown in Figure 5. As it can be seen the dust pollution issue (20 residents) ranks the highest and is the most common concern, followed by the eye irritation (15 residents), respirable discomfort (17 residents), noise and vibration disturbances (14 residents), concern about reduced crop productivity (12 residents), and water contamination concerns (10 residents). The results suggest that manufacturing of cement and mining operations have led to major health and social problems among the surrounding populations.

The research found that the local communities were very interested in the impact of prolonged exposure to cement dust on health. Typical complaints were respiratory discomforts, eye irritations, skin allergy and psychological stress. The West Chester resident commented, “We have to cough; itch our eyes; get short of breath, especially in the winter when the weather is dry and windy.” Many of those participating expressed these concerns, not least for vulnerable groups like children and elderly people. These results indicate the particulate matter has turned into a dominant health and environmental problem that impacts daily living and health.

The respondents also mentioned that there were considerable socio-economic effects, mostly on agriculture. Dust build-up on crops, trees and inside houses was often reported. “The dust impacts on our crops and vegetables, and no longer the same agricultural productivity before,” said one of the residents. This shows that industrial pollution has potential impacts not only on public health but on livelihoods and food production too in the local context.

In addition, there were some concerns about water quality among residents. Several of the participants were concerned about the possibility of contamination of local water sources by the untreated wastes from industries and effluents. One resident commented, "They are worried about the quality of the water because waste from the industry may endanger the local water supply." Water quality testing was not done for this study, but these perceptions are also signs of increased community concern for environmental contamination. The study aligns with Tian et al. (2019) and Biswas et al. (2024) who found industrial dust and mining pollution have detrimental effects on respiratory health, and agricultural output and community health.

PATHWAYS TOWARD SUSTAINABLE DEVELOPMENT

Figure 6

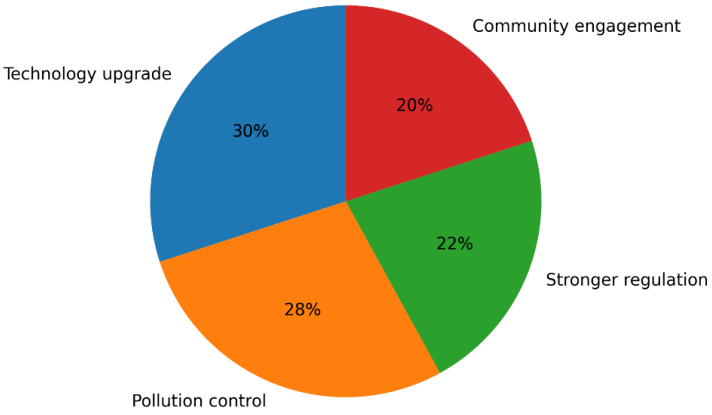

Figure 6 Priority Measures for Sustainable Development

The priority measures identified for promotion of sustainable development at Udayapur Cement Industry Limited (UCIL) is shown as in Figure 6. As seen in the figure technology upgrade (30%) became the most essential strategy, next to improvement of pollution-control system (28%), tighter regulation enforcement (22%) and community involvement (20%). The results indicate that sustainable industrial development of UCIL is multifaceted: technological, institutional and social interventions.

The results of the analysis revealed that dust filtration efficiency is poor, and showed the need of restoring and maintaining all Electrostatic Precipitator (EP) chambers which serves the purpose of better filter efficiency and meeting the environmental standards. Another key factor mentioned by respondents in lowering fugitive dust emissions was the use of modern equipment for dust suppression such as systems that spray water onto the dust and chemical suppressants. The biggest needs were seen as technology modernization for operation and environmental performance. Plant officials conceded that investing in outdated machinery that is less energy efficient and less environmentally friendly could substantially cut emissions but also lower production rates.

The use of controlled blasting and sustainable mining was also identified as being critical for reducing environmental damage caused by mining activities. Furthermore, there was a need for increased legal controls to comply with national environmental regulations. "Little work is done in policy and standards; there are gaps in capacity and enforcement when it comes to the implementation and monitoring," one official said. This is further evidence of the disconnect between policy and action.

Another key element for sustainable long-term solutions was the involvement of the community. Moreover, residents spoke about the necessity for increased communication between industry and neighboring communities in the form of awareness programs, periodic environmental monitoring and health support programs. A resident commented, "Pollution standards are set by the government, but we do not see regular monitoring and effective action to control pollution. In conclusion, the results indicate that sustainable development of the UCIL is a daunting task, which can be achieved in a long-term way only through collaborative activities based on technological modernization and the implementation of proper regulation, which must lead to active participation of the community in environmentally friendly and sustainable development of the industry.

CONCLUSION

This study identified the problem of pollution management, environmental compliance, and sustainable operational management in Udayapur Cement Industry Limited (UCIL), Nepal. The results indicated that the ineffectiveness of dust control and the potential environmental risks are due to the malfunctioning of the pollution-control systems, especially the non-operational Electrostatic Precipitator (EP) chamber, inadequate maintenance and lack of continuous emission monitoring. Also, the dust, noise and vibration caused by limestone mining activities were identified to be in excess, causing adverse impact on the neighboring

ecosystems and the communities. The research also identified the increasing community awareness of respiratory issues, eye irritation, decreased agricultural productivity, and potential water contamination related to emissions and waste from industries.

Nepal has enacted environmental norms for the cement sector (BS 2082) but it is observed that there is a significant gap between the enacted norms and the actual implementation. The results indicated that the implementation of these policies is not sufficient to make UCIL sustainable; it relies on policy presence, policy enforcement, monitoring and accountability. UCIL should focus on restoration and maintenance of pollution-control systems, implementing cleaner and energy-efficient technologies, establishing continuous emission monitoring, and environmentally responsible mining practices to minimize environmental impacts and enhance operational sustainability. Additionally, strengthening the regulatory oversight and the active participation of the community are both necessary. Overall, achieving a balance between industrial growth and environmental responsibility is crucial for ensuring sustainable development in Nepal's cement industry.

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