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Assessment of Environmental Pollution Caused by Marble Mining in District Buner, Pakistan

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Abstract: *Marble mining is a major economic activity in District Buner, Khyber Pakhtunkhwa, Pakistan, contributing to employment, income generation, and regional development. However, the extraction and processing of marble have also led to significant environmental degradation and social challenges. This study aimed to assess community perceptions of the environmental and social impacts of marble mining in the district. Primary data were collected from mine workers, mine owners, and local residents using structured questionnaires, semi-structured interviews, and field observations. The data were analyzed using descriptive and inferential statistical techniques. The findings indicate that marble mining has considerable adverse effects on the environment and the well-being of local communities, with water and land pollution, along with health-related issues, emerging as the most prominent concerns. The study concludes that while marble mining plays an important role in regional economic development, the adoption of effective environmental management practices, improved waste management systems, regular environmental monitoring, and stronger regulatory enforcement is essential to promote sustainable mining in the region.*

Introduction

Mining is a vital sector that contributes significantly to economic growth through the provision of raw materials for industrial development, infrastructure expansion, and employment generation. In Pakistan, the mining industry plays an important role in the national economy, particularly in Khyber Pakhtunkhwa (KP), which is endowed with abundant mineral resources such as marble, granite, and gemstones (Ozcelik, 2023; Salem, 2021). Among these resources, marble is one of the most valuable dimension stones because of its extensive applications in construction, flooring, architectural decoration, and monument production (Celik & Sabah, 2008).

District Buner is one of the leading marble-producing regions in Pakistan and makes a substantial contribution to local employment, household income, and regional economic development. The extraction, processing, and transportation of marble provide livelihood opportunities for thousands of people and support several associated economic activities. Despite these economic benefits, marble mining has become a source of growing environmental and social concern due to the intensive extraction and processing practices employed in the region (Mulk et al., 2015; Ahmad et al., 2022).

Marble quarrying, blasting, cutting, and polishing operations generate considerable amounts of dust, slurry, and solid waste, which have adverse effects on the surrounding environment. Previous studies have reported that these mining activities contribute to air pollution, deterioration of water quality, soil degradation, loss of agricultural productivity, and increased health risks for nearby communities (Iqbal et al., 2022; Noreen et al., 2019). Furthermore, the discharge of untreated marble slurry into streams and rivers alters water quality, increases turbidity, and disrupts aquatic ecosystems (Mulk et al., 2015; Fawad et al., 2021). Similarly, the disposal of marble waste on agricultural land has been associated with declining soil fertility and reduced crop yields (Tazzini et al., 2024; Tercan & Dereli, 2021).

Several studies have investigated the environmental impacts of marble mining in different districts of Khyber Pakhtunkhwa, including Mardan, Malakand, Swat, and Buner (Noreen et al., 2019; Iqbal et al., 2018; Khan et al., 2022). However, most of these studies have focused primarily on environmental pollution, waste generation, or ecological degradation, while relatively limited attention has been given to understanding the perceptions of local communities regarding both the environmental and social impacts of marble mining in District Buner. Since local communities are directly affected by mining activities, their perceptions provide valuable insights for identifying priority issues and formulating effective environmental management strategies. Therefore, further investigation is required to bridge this knowledge gap and support evidence-based decision-making for sustainable mining development.

The present study contributes to the existing body of knowledge by assessing community perceptions of the environmental and social impacts of marble mining in District Buner. Specifically, it identifies the major environmental impacts perceived by local communities, ranks these impacts to facilitate policy prioritization, and proposes practical recommendations for promoting sustainable marble mining practices. The findings of this study are expected to provide useful evidence for policymakers, environmental protection agencies, mining authorities, and other stakeholders in designing effective environmental management policies that balance economic development with environmental conservation and community well-being.

Methodology

Research Design

This study adopted a descriptive and analytical research design to investigate community perceptions of the environmental and social impacts of marble mining in District Buner, Khyber Pakhtunkhwa, Pakistan. The descriptive approach was used to summarize respondents' perceptions, while the analytical component facilitated the statistical examination of the reported impacts.

Study Area and Study Population

The research was conducted in the active marble mining areas of District Buner, Khyber Pakhtunkhwa, Pakistan. District Buner is one of the major marble-producing regions of the province, where mining activities constitute an important source of employment and economic development. The target population comprised mine workers, mine owners, and local residents living within a 3 km radius of the marble quarries, as these groups are directly exposed to the environmental and social consequences of mining operations.

Sampling Technique and Sample Size

A purposive sampling technique was employed to select respondents with direct knowledge and experience of marble mining activities. A total of 50 participants were included in the study, consisting of 25 mine workers, 5 mine owners, and 20 local residents. This sampling approach ensured that the collected information was obtained from individuals who were well informed about the impacts of marble mining in the study area.

Data Collection

The study utilized both primary and secondary sources of data to obtain a comprehensive understanding of the environmental and social impacts of marble mining in District Buner. Primary data were collected through field surveys conducted between May and June 2026 in the major marble mining areas of Bampokha, Gagra, Chagharzai, Jowar, and Torwarsak.

Structured Questionnaire

A structured questionnaire was designed to collect quantitative data regarding respondents' perceptions of the impacts of marble mining. The questionnaire focused on six major impact categories: air pollution, water pollution, land pollution, noise pollution, land degradation, and health-related issues. The instrument consisted primarily of close-ended questions to ensure consistency and facilitate statistical analysis.

Semi-Structured Interviews

Semi-structured interviews were conducted with mine workers, mine owners, local residents, community leaders, and business owners to obtain qualitative information regarding the environmental and social consequences of marble mining. These interviews provided detailed insights that complemented the quantitative findings obtained through the questionnaire survey.

Field Observations

Field observations were undertaken to assess the existing mining practices and their environmental consequences. Particular attention was given to slurry disposal, dust emissions, noise generation, land degradation, waste accumulation, and the overall environmental condition of the mining sites. Field notes and photographic records were maintained to support and validate the survey findings.

Secondary Data

Secondary information was collected from peer-reviewed journal articles, government reports, environmental impact assessment reports, books, and other reliable academic sources. These materials provided the theoretical foundation of the study and were used to compare and validate the primary data.

The combination of questionnaires, interviews, field observations, and secondary data enhanced the reliability and comprehensiveness of the study by allowing the findings to be verified through multiple sources of evidence.

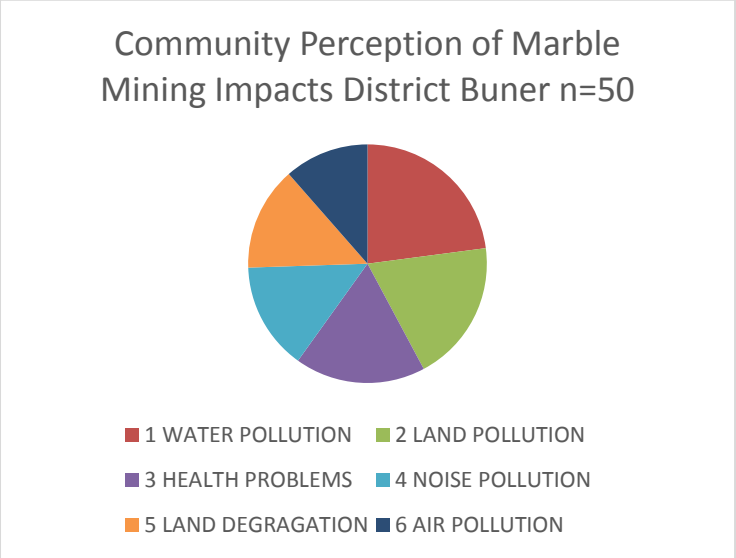
Statistical Analysis

The collected data were coded, entered, and analyzed using Microsoft Excel 2021 and R statistical software. Descriptive statistics, including frequencies and percentages, were computed to summarize respondents' perceptions of the environmental and social impacts of marble mining.

To examine whether the reported environmental and social impacts differed significantly across the six impact categories, the Chi-square Goodness-of-Fit test was employed. Statistical significance was assessed at the 5% significance level ($\alpha = 0.05$). In addition, bar charts were generated using Microsoft Excel to present the distribution of respondents' perceptions in a clear and interpretable graphical format.

Analysis

Descriptive Analysis



The distribution of community perceptions regarding the environmental impacts of marble mining is presented in Table 1. Multiple responses were allowed because respondents could identify more than one environmental concern.

Table 1: Community perception of marble mining impacts, n=50

Impact category	Frequency	Percentage	95% CI
Water pollution	38	76.0	64.1 - 87.9
Land pollution	32	64.0	50.6 - 77.4
Health problems	29	58.0	44.3 - 71.7
Noise pollution	22	44.0	30.3 - 57.7
Land degradation	18	36.0	22.7 - 49.3
Air pollution	12	24.0	12.1 - 35.9

Figure 1. Community Perception of Marble Mining Impacts, District Buner, n=50

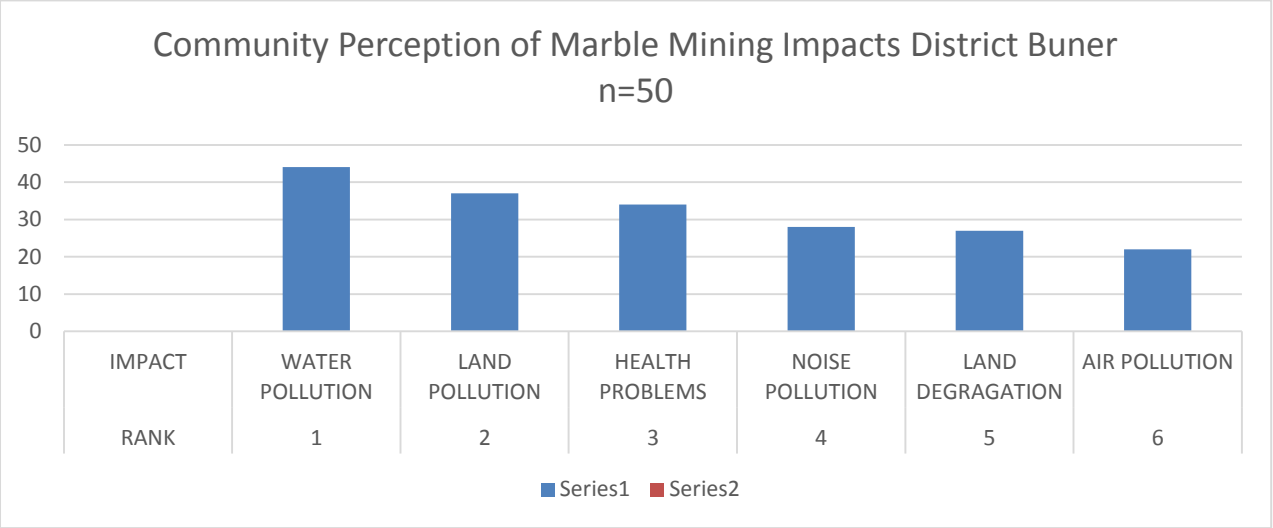
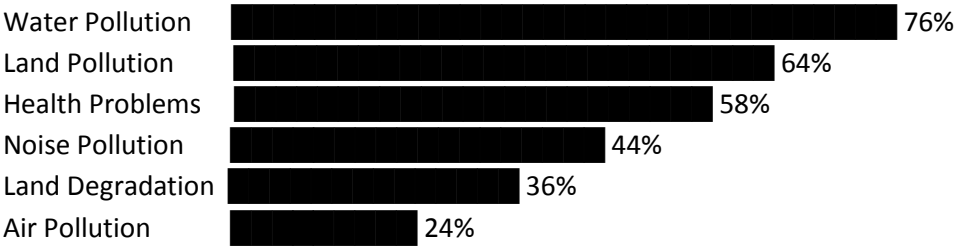


Figure 1. shows that water pollution was perceived as the most significant environmental impact of marble mining, reported by 76% of respondents. Land pollution (64%) and health-related problems (58%) were also frequently reported. Noise pollution (44%) and land degradation (36%) were considered moderate concerns, whereas air pollution (24%) received the lowest response rate. The results indicate that water-related environmental issues require immediate policy attention in the marble mining areas of District Buner.



The Chi-square Goodness-of-Fit test was employed to determine whether respondents reported the six environmental impact categories with equal frequency or whether certain impacts were perceived as more prominent than others. The null hypothesis assumed that there was no significant difference in the reporting frequencies across the six impact categories. The results revealed a statistically significant difference in respondents' perceptions $chi^2(5) = 18.96$; $p = 0.002$), leading to the rejection of the null hypothesis at the 5% significance level. These findings indicate that the perceived environmental impacts of marble mining are not uniformly distributed among the study participants. Instead, some impacts are considered substantially more severe than others, with water pollution emerging as the most prominent concern. Furthermore, the calculated Chi-square statistic exceeded the critical value at the 5% level of significance, confirming that the observed differences in reporting frequencies were unlikely to have occurred by chance and reflect genuine variations in community perception.

To further examine the prominence of water pollution, a Binomial test was performed using a hypothesized population proportion of 0.50. The analysis demonstrated that the proportion of respondents identifying water pollution as a major environmental issue was significantly greater than the hypothesized value ($p < 0.001$). The corresponding 95% confidence interval also supported this finding, indicating that a clear majority of the community regarded water pollution as the most serious environmental consequence of marble mining. Conversely, the proportion of respondents identifying air pollution as a major concern was significantly lower than the hypothesized proportion. The remaining

environmental impacts, including land pollution, health-related problems, and noise pollution, occupied an intermediate position in respondents' perceptions. Although these impacts were widely recognized by the community, the overlap among their confidence intervals suggests that their perceived severity did not differ significantly from one another at the 95% confidence level. Overall, the inferential analyses corroborate the descriptive findings and demonstrate that water pollution is the dominant environmental concern associated with marble mining in District Buner, followed by land pollution, health-related issues, and noise pollution.

Conclusion

Marble mining plays a significant role in the economic development of District Buner by providing employment opportunities and supporting the livelihoods of local communities. However, the findings of this study demonstrate that these economic benefits are accompanied by considerable environmental and social challenges. Community perceptions indicate that mining activities have adversely affected environmental quality, particularly through water and land pollution, while also contributing to health-related problems and other environmental concerns. The statistical analyses confirmed that these impacts are not perceived equally, with some environmental issues receiving substantially greater concern than others. The study highlights the importance of incorporating community perspectives into environmental planning and decision-making, as local residents are directly affected by the consequences of mining activities. Addressing these concerns requires the adoption of effective environmental management practices, including proper slurry treatment and disposal, improved waste management systems, regular environmental monitoring, and strict enforcement of environmental regulations. In addition, collaboration among government agencies, mining companies, and local communities is essential to ensure that economic development is achieved without compromising environmental sustainability and public well-being.

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