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ENVIRONMENTAL PROTECTION ISSUES IN QUARRY MINING OF SHELL ROCK

G.K. Mutalibova
Moscow Timiryazev Agricultural Academy, Moscow, Russian
e-mail: cirhe@mail.ru

Abstract: This article presents a comprehensive environmental impact assessment of sawn limestone quarrying in the Mangistau region, a key industrial area of Kazakhstan. The study focuses on the ecological consequences of quarry operations, particularly the emission of dust and other pollutants that contribute to air contamination. These emissions are shown to have a detrimental effect not only on the natural environment but also on the health and well-being of both quarry workers and nearby populations.

The research includes detailed analysis of air quality degradation caused by quarrying activities, identifying primary sources of pollution such as rock cutting, transportation, and material handling. It also explores the cumulative and long-term health risks faced by individuals working in the quarrying sector, as well as those residing in close proximity to the industrial sites. The study emphasizes the importance of monitoring particulate matter and airborne contaminants, which are linked to respiratory and cardiovascular diseases.

In addition to identifying environmental and health hazards, the article proposes practical and scientifically grounded mitigation strategies aimed at minimizing ecological damage. These include the implementation of dust suppression technologies, modernization of equipment, and development of green buffer zones around quarry sites. Furthermore, recommendations are provided to enhance occupational safety and improve the overall working conditions for employees in the limestone extraction industry. The findings of this study can serve as a foundation for future policy development and regulatory measures in Kazakhstan's mining sector.

Keywords: Mangistau, limestone, quarry, air pollution, ecology, mining, public health.

Introduction. The main limestone reserves in Kazakhstan are primarily concentrated in the Mangystau region, which is renowned for its unique geological characteristics. These deposits stand out due to their remarkable diversity, considerable thickness, and ease of extraction. Such features make these limestone formations exceptional, with no known analogues anywhere else in the global geological landscape. The limestone shell rock extracted here possesses distinct physical and chemical properties, making it highly valued in construction. As a result, it is widely used not only within the Commonwealth of Independent States (CIS) countries but also finds demand in international markets abroad, demonstrating its broad applicability and significance in the construction industry.

According to official data provided by the Land Relations Department of the Mangystau region, there are currently 25 active quarries dedicated to the extraction of construction stone within the region. These quarries are strategically important for the local economy and supply substantial quantities of raw materials. However, the region faces environmental challenges related to quarrying activities. Intense and persistent wind loads common to the Mangystau region play a significant role in dispersing fine particulate matter. These fine fractions are primarily generated as waste during the mechanical processing of stone. The dispersion of such dust particles leads to an increased concentration of airborne dust in the atmosphere. In some cases, these levels exceed the maximum allowable concentrations established by environmental safety standards. This excessive dust contamination contributes to the pollution of pasture lands, which negatively impacts agricultural productivity and local ecosystems.

Moreover, the settling of dust particles on the mechanical components of renewable energy infrastructure, such as the bearings of wind turbines and the surfaces of photovoltaic solar panels, poses additional problems. The accumulation of dust impairs the operational efficiency of these renewable energy sources by reducing aerodynamic performance and light absorption, respectively. This, in turn, decreases the overall productivity and reliability of the region's energy infrastructure, creating challenges for sustainable energy development efforts.

Scientific studies conducted in the region have revealed a concerning health impact on quarry workers exposed to limestone dust. These workers exhibit respiratory problems at rates significantly higher than those observed in the general population [1-3]. The inhalation of fine limestone dust over prolonged periods is associated with increased incidences of respiratory ailments, including chronic bronchitis, asthma, and other pulmonary conditions.

Continuous exposure to these fine dust particles can lead to their accumulation and deposition deep within the workers' lungs, which can cause or exacerbate various pulmonary diseases, sometimes leading to irreversible lung damage [4]. Furthermore, the elevated concentrations of suspended particulate matter in the air across the Mangystau region, particularly PM2.5 and PM10 fractions, when combined with other industrial and vehicular pollutants, represent a serious threat to the health and well-being of the local population. This environmental pressure necessitates urgent attention and the implementation of effective mitigation strategies.

Materials and Methods. Given the complex environmental situation involving significant dust pollution and declining air quality, the methods aimed at both quantitative and qualitative analysis of factors affecting atmospheric pollution levels, as well as determining the relationship between quarry activities and public health status.

Environmental monitoring was conducted based on regular measurements of airborne particulate matter PM2.5 and PM10 near active quarries. The main methods included:

Instrumental measurements of dust concentration in the air using mobile monitoring stations in the Zhanozen, Kuryk, Shetpe, and Aktau areas.

Comparative analysis of data from the platforms airkaz.org and iqair.com to identify pollution peaks during the cold months and compare them with the maximum allowable concentrations established by the World Health Organization (WHO).

To more accurately represent the spatial distribution of dust and assess its impact on agricultural lands and settlements, geospatial analysis was employed. This method enabled the creation of dust emission spread models based on cartographic data, identifying zones of the most intense pollution and tracing potential pathways of its impact on surrounding areas:

Geographic Information Systems (GIS) were used to create pollution maps, allowing visualization of PM2.5 and PM10 pollution levels in each district most affected by mining activities.

Concentration maps were obtained from satellite monitoring data and mobile stations, providing temporal and spatial analysis capabilities.

To assess the impact of dust pollution on public health and vegetation, statistical analysis was applied, including determining the correlation between particulate matter concentration and the frequency of respiratory diseases among the local population (based on data from the central hospital of Shetpe village).

For forecasting future consequences of limestone deposit development, a dust particle dispersion model was constructed, taking into account climatic data on wind loads and directions characteristic of the Mangystau region.

Results

PM2.5 is an air pollutant consisting of both solid microparticles and tiny liquid droplets. These particles have a diameter of less than 2.5 micrometers, which allows them to penetrate deeply into the lungs and even enter the bloodstream. PM2.5 often forms as a result of fossil fuel combustion, as well as from industrial processes, traffic, and natural phenomena such as forest fires. Limestone dust also falls into this category.

The short-term (24-hour) PM2.5 level recommended by the World Health Organization (WHO) is 15 μg/m³, while according to the air pollution map data from airkaz.org, the average daily

concentration of PM2.5 in the atmospheric air in Zhanaozen, Kuryk, and Shetpe was: Aktau – 70 μg/m³, Shetpe – 55 μg/m³, Zhanaozen – 54 μg/m³, Kuryk – 404 μg/m³.

According to iqair.com, the PM2.5 concentration in Aktau is currently 3.5 times higher than the WHO's recommended annual average air quality level [5].

In recent years, there has been a significant increase in respiratory diseases in the Mangystau region [6].

The situation is particularly critical in the village of Shetpe, surrounded by 19 quarries for extraction of building stone, gravel, and sand. The main problem in Shetpe is limestone dust, carried by wind from the dumps around the quarries, which contain limestone waste from the sawing of shell rock limestone [7].

Residents complain about poor air quality and frequent dustiness, which affects both people and vegetation.

Dust from the quarries blankets the settlement, creating a foggy haze. The sparse vegetation is unable to improve air quality. Dust also settles on garden plants and grass, which serves as livestock feed [8].

Local residents report worsening health. The proximity of the quarries (the nearest one is only 500 meters from the village) and the use of primitive mining methods without adhering to safety standards and quality control exacerbate the situation. Insufficient regulation and lack of inspections by the local administration (akimat) also remain serious problems.

According to data from the central hospital, the number of people with allergic diseases, chronic bronchitis (increasing from 39 to 42 patients), asthma (from 145 to 149 patients), and chronic obstructive pulmonary disease (COPD) (from 20 to 25 patients) has risen in Shetpe [9].

Data from iqair.com shows that the current average daily concentration of PM2.5 in Shetpe is 2 to 5 times higher than the WHO's recommended air quality standards for populated areas [10].

According to airkaz.org, as of April 19, 2024, the air quality index (AQI) for suspended particles PM2.5 and PM10 in Shetpe is generally rated as satisfactory to unhealthy for sensitive groups. However, last year, according to airkaz.org, the AQI for suspended particles PM2.5, PM1, and PM10 in December, January, and February 2023 was extremely hazardous, exceeding the recommended limit by more than 200 times.

Table 1 – Air Quality Index (AQI) Scale According to U.S. Environmental Protection Agency (EPA) Standards

AQI Range	Air Quality Level	Health Effects	Precautions
0 - 50	Good	Air quality is considered satisfactory, and air pollution poses little or no risk.	None
51 - 100	Moderate	Air quality is acceptable; however, some pollutants may pose a moderate health concern for a very small number of people who are unusually sensitive to air pollution.	Active children and adults, and people with respiratory diseases such as asthma should limit prolonged outdoor exertion.
101 - 150	Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is unlikely to be affected.	Active children and adults, and people with respiratory diseases such as asthma should limit prolonged outdoor exertion.
151 - 200	Unhealthy	Everyone may begin to experience health effects; members of	Active children and adults, and people with respiratory diseases such as asthma should avoid prolonged outdoor

AQI Range	Air Quality Level	Health Effects	Precautions
		sensitive groups may experience more serious health effects.	exertion; everyone else, especially children, should limit prolonged outdoor exertion.
201 - 300	Very Unhealthy	Health alert: everyone may experience more serious health effects.	Active children and adults, and people with respiratory diseases such as asthma should avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion.
300+	Hazardous	Health warning of emergency conditions: the entire population is more likely to be affected.	Everyone should avoid all outdoor physical activity.

To assess the level of hazard posed by pollutants, Table 1 presents the Air Quality Index (AQI) scale based on the standards of the United States Environmental Protection Agency (EPA).

As seen in Figure 1, the level of air pollution in the village of Shetpe for the PM2.5 indicator was very high during December, January, and February. The highest Air Quality Index (AQI) value was recorded in January, with results ranging from Q=3204 to 3367. High concentrations of particulate matter in the air were observed for 12 consecutive days. A similar situation was observed for the PM1.0 indicator.

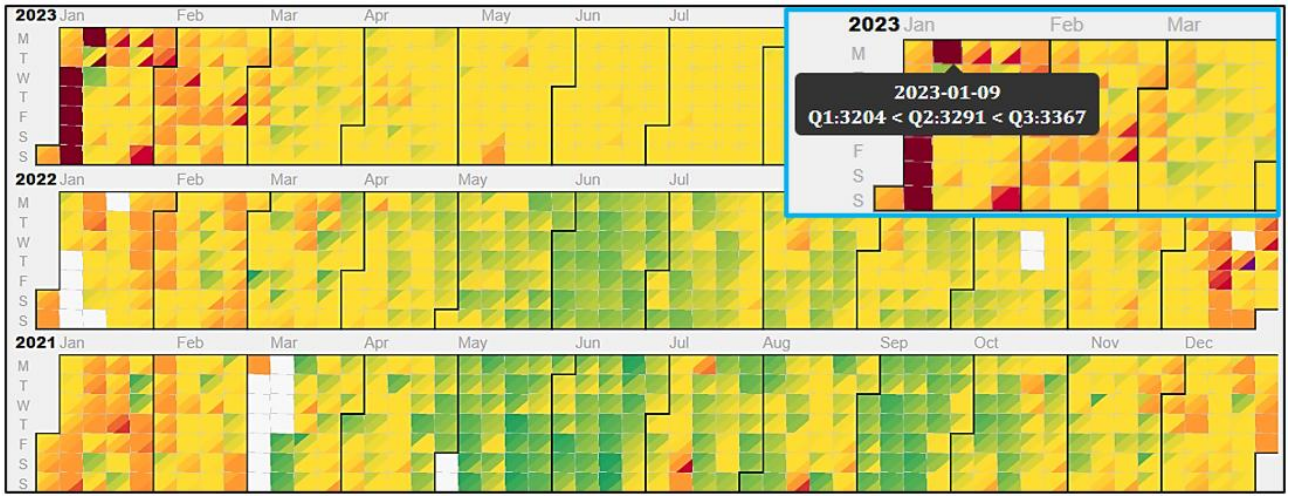

Figure 1 – Air Pollution Map of Shetpe Village by PM2.5 Pollutant

Discussion of Results

The analysis of the collected data clearly indicates significant health and environmental risks associated with the elevated levels of air pollution in the village of Shetpe, particularly affecting vulnerable population groups such as children, the elderly, and those with pre-existing respiratory conditions. During the winter months, when concentrations of fine particulate matter pollutants such as PM2.5 and PM1 reach their peak, pollution levels increase markedly. This rise is largely driven by adverse climatic conditions typical of the region, including persistently low temperatures and strong, frequent winds. These environmental factors contribute to the accumulation and concentration of airborne pollutants in the near-surface atmospheric layer, thereby worsening the overall environmental quality and significantly increasing the risk of negative health effects on local residents.

The harsh winter conditions, characterized by cold temperatures and powerful wind activity, facilitate the settling and stagnation of dust particles and other airborne contaminants. This creates serious health risks, particularly for individuals suffering from respiratory diseases like asthma and chronic bronchitis. Extended exposure to outdoor air with high levels of pollution can aggravate these conditions, potentially leading to more frequent and severe exacerbations of chronic respiratory illnesses.

The primary sources of these elevated pollutant levels are twofold: the naturally strong winds that mobilize dust particles across the region, and the intensive quarrying activities related to building stone extraction, which generate substantial amounts of dust and particulate emissions. In 2022, it was reported that only 31% of quarry waste was processed or utilized effectively, underscoring the urgent need to address waste management practices and reduce the environmental footprint of these operations to improve regional air quality.

While the average Air Quality Index (AQI) values for Shetpe generally fall within a moderate range, there are episodic spikes in pollution levels at localized points that significantly exceed regulatory limits and safety thresholds. These transient but severe pollution events have a pronounced negative impact on public health, particularly among the sensitive groups mentioned earlier. Therefore, a comprehensive and multifaceted approach is imperative to mitigate the harmful effects of air pollution. This approach should include active public education and awareness campaigns to inform residents about pollution risks, the development and enforcement of programs aimed at reducing dust and particulate emissions, and the adoption of modern technological solutions designed to suppress dust generation during quarrying and stone extraction processes.

Despite the average AQI for Shetpe remaining within generally acceptable levels, the occurrence of periodic pollution peaks in certain areas represents a serious health hazard. This fact highlights the critical importance of ongoing, continuous environmental monitoring to detect and respond promptly to pollution events. Additionally, it calls for the implementation of further preventive and corrective measures to protect the health of the local population and improve the overall quality of the environment in the region.

Conclusions

The results of the comprehensive analysis regarding the impact of shell limestone quarrying on the environmental conditions in the Mangystau region clearly underscore the urgent necessity of implementing effective and sustainable measures to significantly reduce atmospheric pollution. Given the current state of environmental stress and degradation, it is notable that quarrying activities in approximately half of the region's extraction sites have been temporarily suspended. However, this suspension represents only a short-term response and does not adequately address the underlying and systemic issues that contribute to the region's environmental challenges.

To achieve a lasting and meaningful improvement in air quality and overall ecological health, it is essential to develop and implement a comprehensive, long-term strategy focused on the greening and environmental modernization of shell limestone production. Such a strategy should encompass the introduction and adoption of advanced, environmentally friendly technologies and equipment designed to minimize dust generation and emissions during quarrying and processing operations. Additionally, effective dust suppression methods must be applied consistently across all active extraction sites to reduce airborne particulate matter.

Furthermore, increasing green infrastructure by expanding vegetation cover and creating buffer zones around quarries can play a vital role in mitigating dust dispersion and enhancing local air quality. Alongside these measures, the development of efficient waste management and recycling programs is critical, particularly focusing on the transformation of accumulated quarry waste into valuable and innovative construction materials. This circular approach not only reduces environmental contamination but also contributes to resource efficiency and economic sustainability.

Implementing these measures will not only ensure strict compliance with existing environmental regulations and international standards but also safeguard the health and well-being of the local population, which is increasingly vulnerable to pollution-related health risks. At the same time, these initiatives will help preserve a key regional industry—the production of shell limestone

building materials—thereby supporting economic stability and securing employment opportunities for local communities. In this way, a balanced approach can be achieved that promotes both ecological integrity and socio-economic development in the Mangystau region.

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ҰЛУТАС КАРЬЕРЛІК ӨНДІРУ КЕЗІНДЕ ҚОРШАҒАН ОРТАНЫ ҚОРҒАУ МӘСЕЛЕЛЕРІ

Г.К. Муталибова
К.А. Тимирязев атындағы Мәскеу ауылшаруашылық академиясы, Москва, Ресей
e-mail: cirhe@mail.ru

Аңдатпа: Бұл мақалада Маңғыстау облысында, Қазақстанның негізгі өнеркәсіптік ауданында кесілген әктас өндіру бойынша карьерлердің қоршаған ортаға әсерін кешенді бағалау ұсынылған. Зерттеу карьерлер қызметінің экологиялық салдарын, атап айтқанда ауаның ластануына ықпал ететін шаң мен басқа ластаушы заттардың шығарындыларын қарастырады. Бұл шығарындылар қоршаған ортаға ғана емес, сонымен қатар мансап қызметкерлерінің де, жақын маңдағы халықтың да денсаулығы мен әл-ауқатына зиянды әсер ететіні дәлелденді.

Зерттеуге тау-кен жұмыстарынан туындаған ауа сапасының нашарлауын егжей-тегжейлі талдау, тау жыныстарын кесу, тасымалдау және өңдеу сияқты негізгі ластану көздерін анықтау кіреді. Ол сондай-ақ тау-кен секторында жұмыс істейтін адамдар, сондай-ақ

өнеркәсіптік нысандарға жақын жерде тұратындар кездесетін жиынтық және ұзақ мерзімді денсаулық тәуекелдерін қарастырады. Зерттеу тыныс алу және жүрек-қан тамырлары ауруларымен байланысты ауадағы бөлшектер мен ластаушы заттарды бақылаудың маңыздылығын көрсетеді.

Қоршаған ортаға және денсаулыққа қауіп-қатерді анықтаумен қатар, мақалада экологиялық зиянды азайтуға бағытталған практикалық және ғылыми негізделген азайту стратегиялары ұсынылған. Оларға шаңды басу технологияларын енгізу, Жабдықты жаңарту және карьерлердің айналасында жасыл буферлік аймақтарды құру кіреді. Бұдан басқа, әктас өндіру саласы қызметкерлерінің еңбек қауіпсіздігін арттыру және жалпы еңбек жағдайларын жақсарту бойынша ұсыныстар беріледі. Бұл зерттеудің нәтижелері Қазақстанның тау-кен өндіру секторында реттеу саясаты мен шараларын болашақта әзірлеу үшін негіз бола алады.

Түйін сөздер: Маңғыстау, әктас, карьер, ауаның ластануы, экология, пайдалы қазбаларды өндіру, денсаулық сақтау.

ВОПРОСЫ ОХРАНЫ ОКРУЖАЮЩЕЙ СРЕДЫ ПРИ КАРЬЕРНОЙ ДОБЫЧЕ РАКУШЕЧНИКА

Г.К. Муталибова
Московская сельскохозяйственная академия имени К.А. Тимирязева, Москва, Россия
e-mail: cirhe@mail.ru

Аннотация: В данной статье представлена комплексная оценка воздействия на окружающую среду карьеров по добыче пиленого известняка в Мангистауской области, ключевом промышленном районе Казахстана. Исследование посвящено экологическим последствиям деятельности карьеров, в частности выбросам пыли и других загрязняющих веществ, которые способствуют загрязнению воздуха. Доказано, что эти выбросы оказывают пагубное воздействие не только на окружающую среду, но и на здоровье и благополучие как работников карьера, так и близлежащего населения.

Исследование включает в себя детальный анализ ухудшения качества воздуха, вызванного деятельностью по добыче полезных ископаемых, выявление основных источников загрязнения, таких как резка породы, транспортировка и погрузочно-разгрузочные работы. В нем также рассматриваются совокупные и долгосрочные риски для здоровья, с которыми сталкиваются люди, работающие в секторе добычи полезных ископаемых, а также те, кто проживает в непосредственной близости от промышленных объектов. В исследовании подчеркивается важность мониторинга твердых частиц и загрязняющих веществ в воздухе, которые связаны с респираторными и сердечно-сосудистыми заболеваниями.

В дополнение к выявлению опасностей для окружающей среды и здоровья, в статье предлагаются практические и научно обоснованные стратегии смягчения последствий, направленные на минимизацию экологического ущерба. К ним относятся внедрение технологий пылеподавления, модернизация оборудования и создание зеленых буферных зон вокруг карьеров. Кроме того, даются рекомендации по повышению безопасности труда и улучшению общих условий труда работников отрасли добычи известняка. Результаты этого исследования могут послужить основой для будущей разработки политики и мер регулирования в горнодобывающем секторе Казахстана.

Ключевые слова: Мангистау, известняк, карьер, загрязнение воздуха, экология, добыча полезных ископаемых, здравоохранение.