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STUDY OF THE IMPACT OF LIMESTONE MINING AND PROCESSING ON ECOSYSTEMS

Abstract. The paper considers the importance of the extracted limestone of the southern region of our country as a necessary building material based on the analysis methods. Limestone as a non-metallic building material is an important resource for Kazakhstan, providing raw materials not only for the domestic market, but also for foreign trade. However, during the extraction of limestone and its processing into lime or cement, experimental work has established the release of dust particles and harmful gases such as carbon dioxide (***CO_2***), which is a greenhouse gas. These emissions negatively affect the quality of atmospheric air, as well as human health, leading to respiratory diseases. In order to reduce emissions of ***CO_2*** and other polluting gases during limestone firing, technologies aimed at reducing carbon emissions are being introduced, using alternative energy sources or carbon capture and storage.
Key words: *limestone, non-metallic material, ecology, emissions, microcalcite, quarry, mineral.*

Әктасты алу және өңдеу процесінің экожүйеге әсерін зерттеу

Аңдатпа. Жұмыста еліміздің оңтүстік аймағындағы өндірілген әктастың талдау әдістері негізінде қажетті құрылыс материалы ретінде маңыздылығы қарастырылады. Әктас кенді емес құрылыс материалы ретінде Қазақстан үшін ішкі нарықты ғана емес, сыртқы сауданы да шикізатпен қамтамасыз ететін маңызды ресурс болып табылады. Алайда, әктас өндіру және оны әк немесе цементке өңдеу процесінде эксперименттік жұмыстарға сүйене отырып, парниктік газ болып табылатын көмірқышқыл газы (***CO_2***) сияқты шаң бөлшектері мен зиянды газдардың бөлінуі анықталды. Бұл шығарындылар атмосфералық ауаның сапасына, сондай-ақ адамдардың денсаулығына теріс әсер етеді тыныс алу органдарының ауруларына әкеледі. Әктасты күйдіру процесінде ***CO_2*** және басқа ластаушы газдар шығарындыларын азайту үшін көміртегі шығарындыларын азайтуға бағытталған технологиялар енгізілуде, баламалы энергия көздерін пайдалану немесе көміртекті ұстау және сақтау.
Түйінді сөздер: *әктас, кенді емес материал, экология, шығарындылар, микрокальцит, карьер, минерал.*

Изучение воздействия процесса добычи и переработки известняка на экосистемы

Аннотация. В работе рассматривается значимость добываемого известняка южного региона нашей страны в качестве необходимого строительного материала на основе проведенных методов анализа. Известняк в качестве нерудного строительного материала является важным ресурсом для Казахстана, обеспечивая сырьем не только внутренний рынок, но и внешнюю торговлю. Однако, в процессе добычи известняка и его переработки в известь или цемент на основе экспериментальных работ установлено выделение пылящих частиц и вредных газов, таких как углекислый газ (***CO_2***), который является парниковым газом. Эти выбросы негативно влияют на качество атмосферного воздуха, а также на здоровье людей приводя к респираторным заболеваниям. Для уменьшения выбросов ***CO_2*** и других загрязняющих газов в процессе обжига известняка внедряются технологии, направленные на снижение углеродных выбросов, с использованием альтернативных источников энергии или улавливания и хранения углерода.
Ключевые слова: *известняк, нерудный материал, экология, выбросы, микрокальцит, карьер, минерал.*

Introduction

There are several large lime deposits in Kazakhstan that meet the needs for construction and industrial materials such as lime, dolomite and other minerals. One of the most famous limestone mining areas is the South Kazakhstan region. In the Republic of Kazakhstan, lime deposits are particularly important: deposits in the South Kazakhstan region. one of the major regions where limestone is mined, used for the production of lime and other building materials.; deposits in the Karaganda region, significant reserves of limestone are also concentrated in this region, which is used in the metallurgical industry, as well as for the production of building materials [1]; deposits in the Pavlodar region, limestone quarries are located, which provide the region with industrial reserves of limestone. These deposits are important for Kazakhstan's industry, as lime is used in metallurgy, chemical industry, construction and agriculture.

The purpose of the study is to study the process of the lime industry's environmental impact on environmental components. The objectives of the study are: to determine the chemical and physical properties of the extracted limestone as a building material; to identify emerging environmental problems due to the extraction and production of a non-metallic natural resource.

The limestone of the Big Karatau ridge is one of the largest limestone deposits in Kazakhstan, located in the southeastern part of the country. The Big Karatau ridge is part of a geological structure rich in various minerals, including limestone, which is used in various industries. Features of limestones found in Big Karatau:

1. Quality and composition: Limestones are characterized by high strength and whiteness, which makes them suitable for the production of building materials such as cement, lime, as well as for use in the chemical and metallurgical industries.

2. Geological significance: The limestones here were formed in different geological epochs and have different compositions, which may affect their use in industry. Limestones containing impurities of organic residues can be used for more specific purposes.

3. Mining: Limestone deposits are actively being developed and meet the needs of local businesses, as well as exports to neighboring countries. It is an important source of raw materials for cement, construction and other industries [2].

Thus, limestone from the Big Karatau ridge is an important resource for Kazakhstan, providing raw materials not only for the domestic market, but also for foreign trade. The chemical composition of limestones may vary depending on the deposit and type of limestone, but in general, limestones from domestic deposits contain the following components. Calcium oxide (***CaO***) is the main component of limestone, which makes up the bulk of its composition. Calcium in the form of calcium oxide (***CaO***) is a key element used for the production of lime and cement. Its content in limestones usually varies from 40% to 55%, depending on the deposit. Carbonates (***$CaCO_3$***) – limestones are predominantly composed of calcite (***$CaCO_3$***), which is a form of calcium carbonate. It can make up 80–90% of the rock composition. Magnesium oxide (***MgO***) – some types of limestones contain magnesium in the form of dolomite (***$CaMg(CO_3)_2$***). The magnesium content in Kazakhstan's limestones can vary from 1% to 10%, depending on geological conditions. Iron oxides (***Fe_2O_3***) – Iron in the form of oxides can be present in amounts up to 2–4%. It gives limestone a dark shade and can be used in the metallurgical industry. Aluminum oxide (Al_2O_3) – Aluminum in the form of various compounds (alumina) is found in known rocks of Kazakhstan in small quantities (up to 1–2%).Silicates (SiO_2) – Silicate impurities such as quartz (SiO_2) can also be present in limestones, but usually in small amounts (up to 10%). Other elements: Limestones may contain phosphorus (P_2O_5), sodium (Na_2O), potassium (K_2O), as well as organic substances in small quantities. Thus, the chemical composition of Kazakhstan's limestones has a fairly wide range, which affects their use in various industries such as construction, metallurgy and the chemical industry [3].

Limestone mining usually takes place in an open-pit manner (quarries developed using blasting), which leads to significant changes in the landscape [4]. The mining process destroys natural ecosystems, destroys vegetation, and disrupts natural bodies of water [5]. Open pits can occupy large areas, leading to land degradation, especially if remediation activities are not carried out properly after the completion of mining. During the extraction of limestone and its processing into lime or cement, dusty particles (limestone dust) and harmful gases such as carbon dioxide (CO_2), which is a greenhouse gas, are released. Floating dust can negatively affect air quality, as well as the health of people working in such areas. Such pollution often leads to a deterioration in the health of local residents, including respiratory diseases [6].

Materials and Methods

Various methods were used to study limestones, which allowed us to obtain information about the composition, structure, physico-mechanical properties and other characteristics of these non-metallic rocks. X-ray fluorescence analysis (XFA) and X-ray diffraction (XD) are methods that have made it possible to study the crystalline structure of limestone and determine its mineralogical composition. This method has made it possible to accurately determine the content of various minerals such as calcite, dolomite, clay minerals, quartz, and others [7]. The analysis was carried out by a DRON-3 diffractometer. Chemical analysis determines the content of the main components of limestone, such as calcium (CaO), magnesium (MgO), carbon (CO_2), iron, aluminum and other elements. Geochemical analysis was also used, which includes the study of the distribution of chemical elements in limestones [8, 9]. It helps to understand the origin of the rock, as well as assess its suitability for various purposes (for example, for the production of cement or lime). According to the research topic, ecological methods were used in the study of limestones. They aim to assess their environmental impact and the impact of limestone extraction, processing and use on ecosystems. These methods include various approaches to study the effects on air, water, soil, and living organisms. In this study, the Gank-4 gas analyzer was used to measure the dust content, as well as emissions of pollutants such as carbon dioxide (CO_2), nitrogen oxides (NO_x), sulfur dioxide (SO_2), hydrogen sulfide (H_2S) and other components that are released into the atmosphere during the extraction and processing of limestone.

Results

X-ray diffractometric analysis was performed on an automated diffractometer DRON-3 with $Cu_{K\alpha}$ – radiation, β – filter. Diffractogram shooting conditions: U = 35 кВ; I = 20 мА; shooting θ-2θ; the detector 2 deg/min. X-ray phase analysis on a semi-quantitative basis was performed using diffractograms of powder samples using the method of equal weights and artificial mixtures. The quantitative ratios of the crystalline phases were determined. The diffractograms were interpreted using ICDD card file data: database of powder diffractometric data PDF 2 (Powder Diffraction File) Release 2022 and programs High Score Plus. The content was calculated for the main phases. Possible impurities, the identification of which cannot be unambiguous due to their low contents and the presence of only 1–2 diffraction reflections or poor crystallization. The experimental data are shown in tables 1–2 and in figure 1.

Table 1
Interplane distances and phase composition of the sample
Кесте 1
Жазықтықаралық қашықтық және үлгінің фазалық құрамы
Таблица 1
Межплоскостные расстояния и фазовый состав образца

d [Å]	I [%]	PDF Card number
3,85258	4,93	01-089-1304
3,35802	2,09	
3,03282	100,00	01-089-1304
2,84130	1,39	01-089-1304
2,49388	5,91	01-089-1304
2,28301	9,57	01-089-1304
2,09317	9,33	01-089-1304
1,91148	8,74	01-089-1304
1,87316	9,58	01-089-1304
1,62421	1,63	01-089-1304
1,60208	3,87	01-089-1304

Table 2
Results of semi-quantitative analysis of crystalline phases
Кесте 2
Кристалдық фазалардың жартылай сандық талдауының нәтижелері
Таблица 2
Результаты полуколичественного анализа кристаллических фаз

PDF Card number	Formula	The mineral	Concentration [%]
01-089-1304	$(Mg_{0.03}Ca_{0.97})(CO_3)$	Mg-containing calcide	100

Based on the experimental work carried out, it can be concluded that an admixture (< 1%) of helenite $Ca_2(Al_2SiO_7)$ is possible. It is usually found in sedimentary rocks and may be present as an admixture in limestones. Helenite occurs as glassy or translucent crystals, with a characteristic greenish-yellow hue, and is part of more complex aluminosilicate minerals [10].

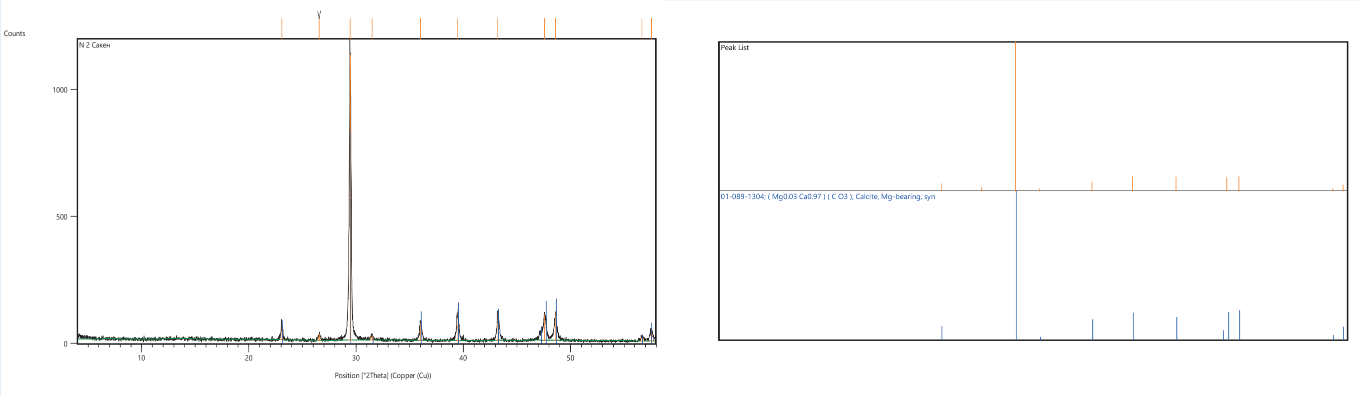

Figure 1. Diffractogram of the studied sample.
Сурет 1. Зерттелетін үлгінің дифрактограммасы.
Рис. 1. Дифрактограмма изучаемого образца.

When helenite is present in limestone, its role depends on the concentration and the specific conditions under which the limestone was formed. Next, a spectral analysis of limestone was performed for its applicability in the production of microcalcite (Tables 3–4).

The limestones also contained organic substances, such as remnants of vegetation or microscopic organisms (mollusk shells, corals). This makes limestone organogenic and affects its appearance and texture. The chemical composition of limestones can vary significantly depending on their origin and

Table 3

Indicators for the presence of chemical elements in the sample, %

Кесте 3

Сынамада химиялық элементтердің көрсеткіштері, %

Таблица 3

Показатели на наличие химических элементов в пробе, %

Spectrum	***O***	***Mg***	***Al***	***Si***	***Ca***	***Fe***	Total
Spectrum 1	52,74	0,37	0,11	0,21	46,26	0,31	100,00
Spectrum 2	52,60	0,32	0,12	0,21	46,59	0,15	100,00
Spectrum 3	52,70	0,30	0,21	0,63	45,94	0,23	100,00
Average	52,68	0,33	0,15	0,35	46,26	0,23	100,00
Standard. deviation	0,07	0,04	0,05	0,24	0,33	0,08	
Max.	52,74	0,37	0,21	0,63	46,59	0,31	
Min.	52,60	0,30	0,11	0,21	45,94	0,15	

Table 4

Indicators for the presence of oxides by stoichiometry, %

Кесте 4

Стехиометрия бойынша оксидтердің көрсеткіштері, %

Таблица 4

Показатели на наличие оксидов по стехиометрии, %

Spectrum	MgO	Al_2O_3	SiO_2	CaO	FeO	Total
Spectrum 1	0,91	0,32	0,66	97,47	0,63	100,00
Spectrum 2	0,80	0,35	0,66	97,89	0,31	100,00
Spectrum 3	0,73	0,59	2,01	96,22	0,45	100,00
Average	0,81	0,42	1,11	97,19	0,46	100,00
Standard. deviation	0,09	0,15	0,78	0,87	0,16	
Max.	0,91	0,59	2,01	97,89	0,63	
Min.	0,73	0,32	0,66	96,22	0,31	

environmental conditions. However, in general, the main components of limestone are calcite (***$CaCO_3$***), as well as various impurities.

Discussion

The use of limestone for the production of building materials (such as cement, concrete and lime) It is accompanied by a number of environmental problems related to the extraction, processing and use of this natural resource. Thus, although limestone is an important building material, its extraction and processing can have a significant impact on the environment, which requires taking measures to minimize damage.

Using the Gank-4 gas analyzer, it was found that limestone mining, as well as processing of many other natural resources, generates emissions into the atmosphere, which can have a significant impact on the environment (figure 2). The following are the main emissions that were generated during the extraction and processing of limestone. Limestone dust is one of the main emissions that occur during the extraction, crushing and transportation of limestone. The dust particles contain fine calcite (***$CaCO_3$***) particles, as well as other impurities such as clay minerals and quartz. Dust causes health problems for workers, as well as worsens the air quality in the surrounding areas. It penetrates the lungs and causes respiratory diseases, especially if the dust concentration is high. Dust also settles on vegetation and bodies of water, which affects the ecosystem. Carbon dioxide ***CO_2*** is also an emission from this production. Limestone itself (***$CaCO_3$***) is not a source of carbon dioxide during its extraction, co₂ is released during limestone firing. Calcining limestone for the production of lime or cement requires high temperatures at which calcite decomposes:

$$CaCO_3 \rightarrow CaO + CO_2$$

Thus, the main source of ***CO_2*** is the limestone refining process, not its extraction. But ***CO_2*** emissions from the combustion of fuels used to heat furnaces are also significant. In addition, No_x nitrogen oxides are released during the combustion of fuels during the extraction and processing of limestone. Nitrogen oxides are formed during high-temperature combustion processes, such as calcining limestone in furnaces for the production of lime or cement. These substances negatively affect air quality, contributing to the formation of acid rain and polluting water bodies. Also, sulfur dioxide ***SO_2*** is released during the processing of limestone if it contains sulfates such as gypsum (***$CaSO_4$***). Although ***SO_2*** is mainly released during

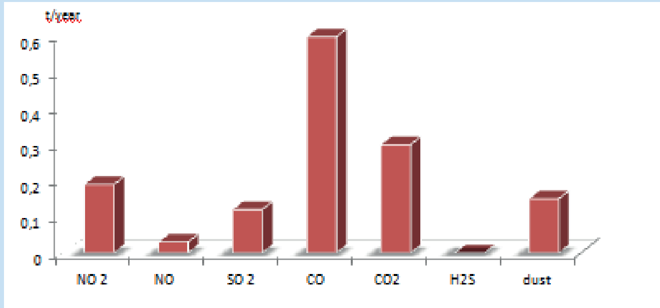

Figure 2. Emission of pollutants into the atmosphere.
Сурет 2. Атмосфераға ластаушы заттардың шығарылуы.
Рис. 2. Выброс загрязняющих веществ в атмосферу.

the combustion of fossil fuels, in some cases, when sulfur impurities are present in limestone, it can also be released.

Other industrial gases, such as hydrocarbons, including methane (***CH_4***), may be released during limestone mining if mining occurs in areas where there are coal or gas layers. This is due to the peculiarities of the geological composition of the deposits. The limestone mining process, especially when using heavy machinery and vehicles for transportation, emits carbon dioxide, nitrogen oxides, hydrocarbons, and dust particles. These emissions come from burning fuels (diesel, gasoline) and using equipment. In some cases, when trace amounts of toxic metals are present in limestone, such as lead (***Pb***), cadmium (***Cd***), or arsenic (***As***), its extraction and processing generates emissions with an admixture of these substances. Although this is rare, such emissions can pose an environmental threat to soil, water bodies, flora and fauna.

Conclusions

Limestone mining and processing can lead to emissions of various pollutants, including dust, carbon dioxide, nitrogen oxides, and sulfur dioxide. To minimize the environmental impact, it is important to introduce environmentally friendly technologies, regularly monitor emissions and take measures to reduce them. In order to reduce emissions of ***CO_2*** and other polluting gases during limestone firing, technologies aimed at reducing carbon emissions are being introduced, for example, using alternative energy sources or carbon capture and storage. The introduction of cleaner technologies in the mining process, such as the use of low-sulfur fuels, improved crushing and transportation methods, can also reduce pollutant emissions.

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