eISSN 2500-0632
https://mst.misis.ru/

MINING ROCK PROPERTIES. ROCK MECHANICS AND GEOPHYSICS

Research paper

https://doi.org/10.17073/2500-0632-2023-01-75
UDC 691.21:553.89

Dolomite type nephrite processing wastes and their application

E. B. Kislov[1] ✉, **L. I. Khudyakova**[2], **A. G. Nikolaev**[3]

[1] *Dobretsov Geological Institute of Siberian Branch of the Russian Academy of Sciences (GIN SB RAS), Ulan-Ude, Russian Federation*

[2] *Baikal Institute of Nature Management of Siberian Branch of the Russian Academy of Sciences (BIP SB RAS), Ulan-Ude, Russian Federation*

[3] *Kazan (Privolzhsky) Federal University (KFU), Kazan, Russian Federation*

✉ *evg-kislov@ya.ru*

Abstract

The demand for ornamental stone material has led to an increase in the amount of rock mass being processed. However, the production of lapidary works and jewelry result in a significant amount of waste. This study aims to investigate the material composition and physical and mechanical properties of the solid wastes generated during the processing of dolomite type nephrite in the Vitim region. The accumulation of such waste leads to increased costs of transportation, storage, security, and negative environmental impact. The majority of dolomite type nephrite deposits are located in the Northwest, Northeast, and South of China, in South Korea, Australia, Italy, and Poland, with a large deposit in the Vitim region of Russia. In this study, the waste from the Kavoktinsky deposit, the most productive in Russian, was used. A visual and petrographic examination of nephrite, skarn and amphibolite which are components of the solid waste, was conducted. The macro- and microchemical composition of nephrite of different colors was studied, and X-ray phase analysis was performed. The decorative properties of the waste were determined. A radiation and hygienic certificate was obtained. The waste has a crushability grade of 1200, abrasion grade of I1, and frost resistance of F400. The study has shown that the waste does not contain grains of incompetent rocks, clay, dust, and clay particles. The solid waste form the Vitim nephrite processing is of high quality and meets the requirements of GOST 8267-93, except for an increased content of flagstone (flattened) and large size fragments. It can be used for the production of ordinary, decorative, and mosaic concrete, decorative plates, interior decoration of premises, bathrooms, and saunas, and the manufacture of souvenir products. However, further research is needed to investigate the application of the waste as a raw material for stone casting and a slow-release fertilizer. The utilization of this waste not only solves the problem of waste disposal but also improves economic performance of mineral extraction.

Keywords

nephrite, processing; processing waste, the Vitim region, mineral composition, chemical composition, decorative properties, physical and mechanical properties, utilization

Acknowledgments

The manuscript has been greatly improved thanks to remarks made by the reviewer of the editorial board. The authors would like to express their gratitude to Oriental Way Ltd. for providing stone material, to the Geospectr Center (TsKP) of the Institute of Geology of SB RAS, Ulan-Ude, and to the Geoanalitik of the Institute of Geology and Geochemistry, UB RAS, Yekaterinburg, for the analyses performed. The research was supported by grant No. 22-27-20003 form the Russian Science Foundation, https://rscf.ru/project/22-27-20003.

For citation

Kislov E.B., Khudyakova L.I., Nikolaev A.G. Dolomite type nephrite processing wastes and their application. *Mining Science and Technology (Russia)*. https://doi.org/10.17073/2500-0632-2023-01-75

СВОЙСТВА ГОРНЫХ ПОРОД. ГЕОМЕХАНИКА И ГЕОФИЗИКА

Научная статья

Отходы переработки аподоломитового нефрита и направление их использования

Е.В. Кислов[1] ✉, **Л.И. Худякова**[2], **А.Г. Николаев**[3]

[1] *Геологический институт им. Н.Л. Добрецова Сибирского отделения Российской академии наук (ГИН СО РАН), г. Улан-Удэ, Российская Федерация*

[2] *Байкальский институт природопользования Сибирского отделения Российской академии наук (БИП СО РАН), г. Улан-Удэ, Российская Федерация*

[3] *Казанский (Приволжский) федеральный университет (КФУ), г. Казань, Российская Федерация*

✉ *evg-kislov@ya.ru*

Аннотация

Камнесамоцветное сырье пользуется повышенным спросом, что приводит к возрастающему объему перерабатываемой горной массы. Обогащение исходного сырья, изготовление камнерезных и ювелирных изделий сопровождаются образованием большого количества отходов. Представленное исследование направлено на изучение вещественного состава и физико-механических свойств твердых отходов переработки аподоломитового нефрита Витимского региона. Образование отходов в значительном количестве приводит к затратам на перевозку, хранение и охрану, ухудшает экологическую обстановку. Месторождения аподоломитового нефрита находятся в Витимском регионе России. Наибольшее их количество сосредоточено на Северо-Западе, Северо-Востоке и Юге Китая, в меньшей мере – в Южной Корее, Австралии, Италии и Польше. В работе использованы отходы переработки наиболее продуктивного российского месторождения аподоломитового нефрита – Кавоктинского. Проведено визуальное и петрографическое изучение нефрита, скарна и амфиболита твердых отходов. Изучен макро- и микрохимический состав нефрита различного цвета, выполнен рентгенофазовый анализ. Определены декоративные свойства. Получен радиационно-гигиенический сертификат. Отходы имеют марки по дробимости 1200, по истираемости – И1, по морозостойкости – F400. Проведенные исследования показали, что в их составе не содержатся зерна слабых пород, а также глина, пылевидные и глинистые частицы. Твердые отходы переработки нефрита Витимского региона имеют высокое качество, соответствуют требованиям ГОСТ 8267–93, за исключением повышенного содержания фрагментов лещадных (уплощенных) и повышенного размера. Они могут использоваться в производстве обычного, декоративного и мозаичного бетонов, декоративных плит, внутренней отделки помещений, бань и саун, для изготовления сувенирной продукции. Использование в качестве сырья для каменного литья и пролонгированного удобрения требует дополнительного рассмотрения. Все это позволит не только решить проблему утилизации отходов, но и улучшить экономические показатели добычи минерального сырья.

Ключевые слова

нефрит, обогащение; отходы переработки, Витимский регион, минеральный состав, химический состав, декоративные свойства, физико-механические свойства, утилизация

Благодарности

Замечания рецензента редколлегии позволили значительно улучшить рукопись статьи. Авторы признательны ООО «Ориентал Вэй» за предоставление каменного материала, ЦКП «Геоспектр» ГИН СО РАН, Улан-Удэ, и «Геоаналитик» ИГГ УрО РАН, Екатеринбург, за проведенные анализы. Исследование выполнено за счет гранта Российского научного фонда № 22-27-20003, https://rscf.ru/project/22-27-20003.

Для цитирования

Kislov E.B., Khudyakova L.I., Nikolaev A.G. Dolomite type nephrite processing wastes and their application. *Mining Science and Technology* (*Russia*). https://doi.org/10.17073/2500-0632-2023-01-75

Introduction

The demand for ornamental stone material has led to an increase in the amount of rock mass being processed. This processing, which includes the production of lapidary works and jewelry, results in the generation of two types of waste: hard fragments and scraps of host rock and substandard nephrite, which are produced during the extraction of grade stone and manufacturing of products, as well as the slime formed during cutting and processing. This slime is a mixture of water, abrasive material, and small stone particles. The volume of these wastes can range from 10 to 35 % of the primary stone material. The increasing amount of waste generated has resulted in higher costs associated with transportation, storage, and security. Moreover, it has a negative impact on the environment and human health [1–4]. Therefore, recycling of such waste to obtain marketable products is essential.

The slime generated from ornamental stone processing is mainly used for the production of cement, concrete, and ceramics, which enhances their performance. Slimes from granite [5], marble [6–8] are utilized in the production of cements. They replace natural sand in cement mortars [9]. The addition of slime to the clay mixture is beneficial for the production of ceramic materials [10–13]. Solid waste from marble processin is mostly used to produce lime [14]. Granite waste is employed for stabilizing loose grounds [15], whereas marble dustis suitable for clay grounds [16]. Additionally, chips and fragments are used in the production of artificial decorative stones for pedestrian sidewalks [17] and floors of residential and industrial buildings [18].

All of the aforementioned examples are related to the processing waste of granite and marble. While some studies have been devoted to the possibility of utilizing substandard serpentinite type nephrite [19, 20], the processing waste of dolomite type nephrite has not yet been considered, despite its intensive use.

As of January , 2022, 26 nephrite deposits were in the register of the State Balance of Reserves of Russia. In 2021, seven deposits in Buryatia were developed, including Kavoktinsky, Nizhne-Ollominsky, Sergeevsky, and Khaitinsky dolomite type nephrite deposits. As for other dolomite type nephrite deposits, the Voymakansky in Buryatia was being prepared for extraction, while the Udokan in the Trans-Baikal Territory, and Buromsky in Buryatia were being explored. There are no deposits of dolomite type nephrite in the non-licensed stock of prospects/areas. All the deposits are located in the Vitim nephrite-bearing region, with the largest deposit being the Kavoktinsky which had 346.81 tons of C2 category reserves as of January 1, 2022. In 2021, 70.36 tons of nephrite were extracted, amounting to 28.58 % of the Russian production.

Most of the dolomite type nephrite deposits abroad are located in China. The largest known deposits are located in the northwestern provinces of Chin, in the Hetian nephrite-bearing belt located in Xinjiang Uygur autonomous region. This region has been being developed for 6,000 years, both for primary nephrite deposits [21–23], among which the best known and studied is Alamas [24–25], and for famous placer nephrite deposits, Yurungkash ("the river of white nephrite") and Karakash ("the river of black nephrite") [26–28]. The Hetian belt is adjoined from the east by the Altyn Tagh [29, 30] and Southern Altyn Tagh [31, 32] nephrite-bearing districts. Further eastward, the Golmud and other deposits in Qinghai Province are located [33, 34]. A number of deposits are located in the northeastern provinces of China such as Tieli in Heilongjiang Province [35–37], Panshi in Girin Province [38], and Xiuyan and Sangpiyu in Liaoning Province [39, 40]. In East China, the Xiaomeiling deposit in Jiangsu Province is known [41, 42]. In South Central China, the Luanchuan deposits in Henan Province [43, 44] and Dahua deposits in the Guangxi Zhuang Autonomous Region are presented [45–47]. In Soutwest China, the Longxi deposit in Sichuan Province [48] and Luodian deposit in Guizhou Province [49] are known.

In addition, the Chuncheon deposit in South Korea [50, 51], the Cowell area on the Eyre Peninsula in South Australia [52, 53], the Alpe Mastabia deposit (Val Malenco) in Lombardy, Italy [54], and the Zloty Stok deposit in Lower Silesia, Poland [55–57] are noteworthy.

The aim of this study is to investigate the physical and mechanical characteristics of solid wastes generated during dolomite type nephrite processing and determine potential areas of their utilization.

Research Materials and Methods

This research focuses on the solid waste generated during processing of dolomite type nephrite in the Vitim region, specifically the Kavoktinsky. Oriental Way LLC provided the waste for this study.

Sampling for laboratory analysis was conducted using the point method. A square grid was overlaid onto the batch of waste laid out horizontally, and samples were taken from the center of each grid cells. To ensure the maximum representation of all types of nephrite processing waste, a total of 20 sample weights, weighing 200 kg, were collected from the batch. These representative samples were then used for a detailed examination of the materia (Fig. 1).

Fig. 1. Nephrite processing waste

The study examined the waste generated from the processing of nephrite to assess its conformity with the technical requirements specified in GOST 8267–93 "Crushed stone and gravel of solid rocks for construction works. Technical conditions" and GOST 8269.0–97 "Crushed stone and gravel of solid rocks and industrial waste for construction works. Methods of physical and mechanical tests".

The research methodology comprised of a mineralogical-petrographic analysis, chemical testing, evaluation of decorative properties, physical and mechanical tests of the waste, and a comparison of the obtained results with the stipulated GOST parameters.

A visual petrographic and mineralogical analysis was conducted on the solid waste samples by obtaining representative samples, measuring their size, and describing their shape using a measuring tape. The samples were then weighed using portable electronic scales, and their fracture and Mohs scale were determined. The presence of fractures and carbonate minerals was identified through of fracturing and diagnosis of carbonate minerals 5 % hydrochloric acid solution, respectively. Petrographic analysis of thin sections was carried out using a polarizing microscope POLAM L-213 in the Geological Institute in Ulan-Ude, Russia.

Silicate analysis was conducted at Geospectr TsKP of GIN SB RAS, Ulan-Ude, using a UNICO 1201 spectrophotometer (United Products and Instruments, USA) that operated in the spectral range of 315–1000 nm. Additionally, we employed a SOLAAR-6M atomic-absorption spectrophotometer (Unicam, England) with appropriate software. We utilized various methods including atomic absorption, flame photometric, gravimetric, and titrimetric methods. For weighing, we used VSL-200/0,1A electronic scales (CJSC VES-SERVICE, St. Petersburg, Russia) with a weighing range of 0.01 to 205 g.

The trace elements grades were determined using a high-resolution HR ICP-MS ELEMENT2 (ThermoFinnigan) mass spectrometric system for multi-element analysis of geological material at the TsKP Geoanalitik of the Institute of Geology, Ural Branch of the Russian Academy of Sciences, Yekaterinburg. Quality control of the results was ensured through parallel analyses of internal control samples and standard rock samples, including SG-1A, SGD-1A, BCR-2. Standard samples BCR2 (U.S. Geological Survey) were included in the normal sample flow for analysis at frequency of 1:5–1:10.

Optical properties such as transparency, color, optical effects, and inclusions were investigated using a MBS-10 binocular and a 20x magnification gemological magnifying glass at KFU in Kazan. The GIA color scale and the requirements of TU 117-3-0761-7-00 were utilized for determining color, color hue, tone, and saturation. The studies were carried out by optical absorption spectroscopy method, and a standardized MSFU-K spectrophotometer was used to record optical absorption spectra in the wavelength range of 400–800 nm in increments of 1 nm. The method of calculating chromaticity coordinates according to the XYZ international colorimetric system was used to measure and describe the coloration of samples. The colorimetric results were placed on the standard color triangle of the Commission International d'Eclairage (ICE-1931), and color coordinates were converted into the GIA systems used for color evaluation. The "Spectrum" specialized program was employed to calculate colorimetric parameters of the minerals according to the CIE Lab international system. All experimental studies were carried out at room temperature, and five spectra were taken from each sample.

The physical and mechanical properties were determined in BIP SB RAS, Ulan-Ude, following the requirements of GOST 8267–93 "Crushed stone and gravel of solid rocks for construction works. Technical Specifications" and GOST 8269.0–97 "Crushed stone and gravel of solid rocks and industrial waste for construction works. Methods of physical and mechanical tests". A fraction of 40–70 mm was selected from the waste to determine the grain composition, while the fraction over 70 mm was crushed using a jaw crusher. The samples were brought to a constant weight, and the moisture content was determined using a ShSU-M1 drying cabinet (JSC Electropribor, St. Petersburg, Russia), with a heating temperature ranging from 50 to 300 °C and the time of heating to the maximum temperature not exceeding 120 minutes. Particle size distribution testing was conducted using a standard set of sieves, and weighing was carried out on MK-15.2-A22/10540 electronic scales (CJSC "Massa-K", St. Petersburg, Russia). X-ray phase analysis was performed using a D8 Advance powder automatic diffractometer of BrukerAXS (Germany) with appropriate software at a rate of 2° per minute in the range from 5 to 70°. For mechanical tests, a PGM-500 hydraulic test press (LLC "SKB Stroypribor", Chelyabinsk, Russia) with a load range up to 50 tons and a speed of plate movement of 10 ± 1 mm min^{-1} was used. To determine abrasion, an abrasion testing machine KP 123 ("Novoe Delo" LLC, St. Petersburg, Russia) with a diameter of 700 mm, length of 500 mm, and a shelf 100 mm wide on the inner surface was employed.

A radiation and sanitary audit was conducted in compliance with the requirements of GOST 30108–2016 "Materials and products for construction. Determination of specific effective activity of natural radionuclides". The specific effective activity of natural radionuclides found in nephrite processing waste was measured in the Test Laboratory Center of the Federal Public Health Institution "Center for Hygiene and Epidemiology in the Republic of Buryatia" using an integrated universal spectrometer, USK "Gamma-plus".

Findings

The batch of solid waste consists of angular, isometric to flattened fragments, and irregularly shaped pieces of light-colored raw nephrite. The largest dimension of 75 % of the fragments ranges from 4 to 12 cm, while 25 % of the fragments range from 12 to 15 cm. The coloring of the stone varies from uniform to heterogeneous, sometimes spotted or banded, and includes light-green, grayish-white, often with a bluish tint, light gray, dark gray, brown (honey). The fragments may occasionally contain light green patches and brown margins staining on fractures and surfaces. Visually distinguishable isometric grains of tremolite, calcite, epidote, chlorite, black and emerald-green phenocrysts, dendrites of black manganese hydroxides, and flaky aggregates of brown iron hydroxides may be present in some fragments. The fragments are covered with white matte crusts with dendrites of black manganese hydroxides, and dendrites of black manganese hydroxide, white films of calcite, and brown films of iron hydroxides may also be observed along fractures. Some fragments consist of areas of white matte tremolite-calcite skarns and variously colored metasomatized amphibolite., while others are entirely composed of skarn and amphibolite.

Under binocular microscope magnification, the nephrite includes inclusions of individual crystals and aggregates of calcite and broad-prismatic tremolite, dendrites of manganese hydroxides, flaky aggregates of iron hydroxides, and veins of calcite-tremolite skarn. Fresh chips show uneven, splintered, conchoidal fractures.

Under a petrographic microscope, nephrite is observed to be a practically monomineral aggregate of crystals and the finest fibers of mainly tremolite amphibole with a tangled-fibrous (fibroblast) structure characteristic of nephrite, with individual fibers ranging from a few microns to 0.1 × 0.5 mm. The shape of the aggregates is mostly parallel-fibrous, fan-shaped, and felt-like. Inclusions of individual crystals and aggregates of calcite, broad-prismatic tremolite of isometric or elongated shape with grain size up to 1–10 mm may be observed in places in nephrite. The nephrite is heterogeneously polished, with significant shagreening in places. The areas of nephrite with the inclusions of other minerals and their aggregate clusters do not take a polish; they are matte and rough. Transparency along the edge of a hand specimen is to a depth of 5 cm.

In the skarn, tremolite is represented by several varieties, including solid porcelain-like tremolite, consisting of tiny, shapeless radiated aggregates with slices, fuzzy aggregates of finely dispersed calcite, and traces of prismatic tremolite crystals. Large shapeless aggregates with relics of split prismatic tremolite replaced by thin-fibrous tremolite, and fine-grained multioriented tremolite with grain sizes ranging from 0.01 × 0.03 to 0.6 × 1.3 mm are also present. Lenticular aggregates of fine-grained calcite in various proportions with tremolite are found, and in another case, numerous single grains, panicle-like, radial-beam aggregates of tremolite with apatite alternate with nephrite-like areas composed of micro- and fine-grained tremolite. Diopside and plagioclase are also present.

The predominant mineral found in amphibolite is tremolite, with the occasion presence of actinolite. Tremolite is commonly observed in large calcite grains, where it appears as thin, elongate needle-like prisms that penetrate the host mineral parallel to one another. Actinolite is typically inequigranular, forming aggregates with rare calcite and intergrowths of prismatic epidote. These aggregates may form radial fibrous intergrowths, with potassium feldspar occasionally present in small angular interstices. The calcite grains contain inclusions of dolomite, epidote, chlorite, and quartz which can occupy up to 30 % of the host mineral area. Zoisite grains and fine-scaly chlorite, and they can form unusual spot-like aggregates among calcite grains. Xenomorphic quartz grains are often found saturated with rhombic, needle-like crystals of tremolite and/or epidote, which can occupy up to 25 % of the host mineral area. In some cases, plagioclase is more abundant and can be partially replaced by granular aggregates of epidote and clinozoisite, sometimes forming independent interstitial aggregates that may also contain potassium feldspar. Finally, apatite, sphene, and zircon are present as well.

Tables 1 and 2 provide a detailed breakdown of macro- and micro-components found in nephrite of various colors that were extracted from the solid waste.

The solid waste mineral composition is confirmed by the results of X-ray phase analysis (Fig. 2).

The X-ray diffraction pattern revealed that the primary reflexes of the studied samples corresponded to the minerals tremolite, diopside, chlorite, talcum and calcite.

eISSN 2500-0632
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The visual description of the samples included color characteristics such as primary color, hue, tone, saturation. Based on these characteristics, two main varieties were identifed. The first variety is referred to as white nephrite, which ranges from pure white to slightly saturated grayish or yellowish-brown, and may appear brown (honey-colored) due to iron oxidation, as illustrated in Fig. 3. The second variety is known as light-green (greenish) nephrite, which ranges from bluish to yellow-greenish and may appear brown (honey-colored) due to oxidation, as depicted in Fig. 4.

The primary color types of the nephrite include white as well as gray with a pale green hue, bright light bluish-green, and bluish-green tones occur. The the pattern of the nephrite is uniform, with brown staining edges, and may contain inclusions of prismatic tremolite, calcite and white-colored diopside, which are noticeable due to cleavage.

Table 1

Chemical composition of nephrite

Sample	Grade															
	%													g/t		
	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total	F	Cr	Co	Ni
KS-6	58.2	<0.02	0.3	<0.1	0.2	0.04	25.77	12.5	0.08	0.06	<0.1	2.72	99.87	0	<5	6	9.5
KS-7	57.5	<0.02	0.6	<0.1	0.16	0.02	24.98	12.92	0.08	0.04	<0.1	2.9	99.2	0	<5	9.5	8
KS-8	56.8	<0.02	0.7	<0.1	0.22	0.03	25.36	13.15	0.1	0.07	<0.1	2.28	98.71	0.32	9	9.8	8

Note: hereinafter, the analyses of nephrites refer to: KS-6 – brown, KS-7 – light-green, and KS-8 – white nephrite.

Table 2

Concentration of trace elements in nephrite, g/t

Element	KS-6	KS-7	KS-8	Element	KS-6	KS-7	KS-8
Li	4	7	6	Te	< 0.01	< 0.01	0.026
Be	11	17	9	Cs	1.8	2.1	0.7
Sc	1	1	0.6	Ba	6	5	8
Ti	50	80	18	La	0.2	0.4	0.35
V	8	17	8	Ce	0.47	0.8	0.59
Cr	2.4	4.7	15	Pr	0.06	0.1	0.07
Mn	180	80	140	Nd	0.25	0.41	0.3
Co	4	6	5	Sm	0.06	0.09	0.07
Ni	11	6	9	Eu	0.01	0.02	0.018
Cu	4.1	6	50	Gd	0.065	0.094	0.069
Zn	14	20	14	Tb	0.01	0.014	0.01
Ga	0.8	2.4	0.9	Dy	0.07	0.09	0.06
Ge	0.5	0.5	0.6	Ho	0.015	0.02	0.012
As	90	86	80	Er	0.043	0.058	0.033
Se	0.2	0.17	0.15	Tm	0.006	0.009	0.0036
Rb	2.4	2.9	2.3	Yb	0.04	0.05	0.02
Sr	70	60	60	Lu	0.006	0.008	0.0028
Y	0.4	0.6	0.5	Hf	0.041	0.06	0.06
Zr	2.1	2.7	2.8	Ta	0.019	0.06	< 0.001
Nb	0.06	0.37	0.12	W	16	30	40
Mo	0.22	0.16	0.6	Tl	0.013	0.012	0.005
Ag	< 0.0004	0.027	0.079	Pb	4	8	12
Cd	0.05	0.05	0.09	Bi	< 0.0005	0.057	0.065
Sn	0.11	0.2	0.28	Th	0.008	0.14	0.03
Sb	0.08	0.18	0.24	U	0.026	0.6	0.047

eISSN 2500-0632
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One common feature observed in the optical absorption spectra of the nephrite is the presence of a broad absorption band in the near-infrared region, located near 990 nm, as shown in Fig. 5. Further investigation into configuration of this line, combined with chemical analyses of the nephrite, suggests that this band is associated with the spin-allowed transitions $^5T_2$ (^5D) → ^5E (^5D) in Fe^{2+} ions that occupy positions M1, M2, M3, replacing Mg^{2+}. In addition, the absorption bands observed around 440 nm and 650 nm in the spectrum of the nephrite are attributed to the spin-allowed transitions from the basic state $^4A_{2g}$ (^4F) to higher energy levels, $^4T_{1g}$ (^4F) and $^4T_{2g}$ (^4F), respectively [58, 57].

The specific effective activity of natural radionuclides present in the nephrite processing waste was found to be less than 50 Bq/kg.

As the waste is composed of remnants from sawing larger than 40 mm, only the fraction within the range of 40–70 mm can be used as ballast stone, while the remaining material must undergo crushing. The distribution of grain size in the resulting crushed waste is presented in Fig. 6.

The data obtained indicate that the majority of crushed waste (62 %) ranges from 5 to 15 mm in size, whereas 21.5 % of the waste falls under to the fraction – 5 mm.

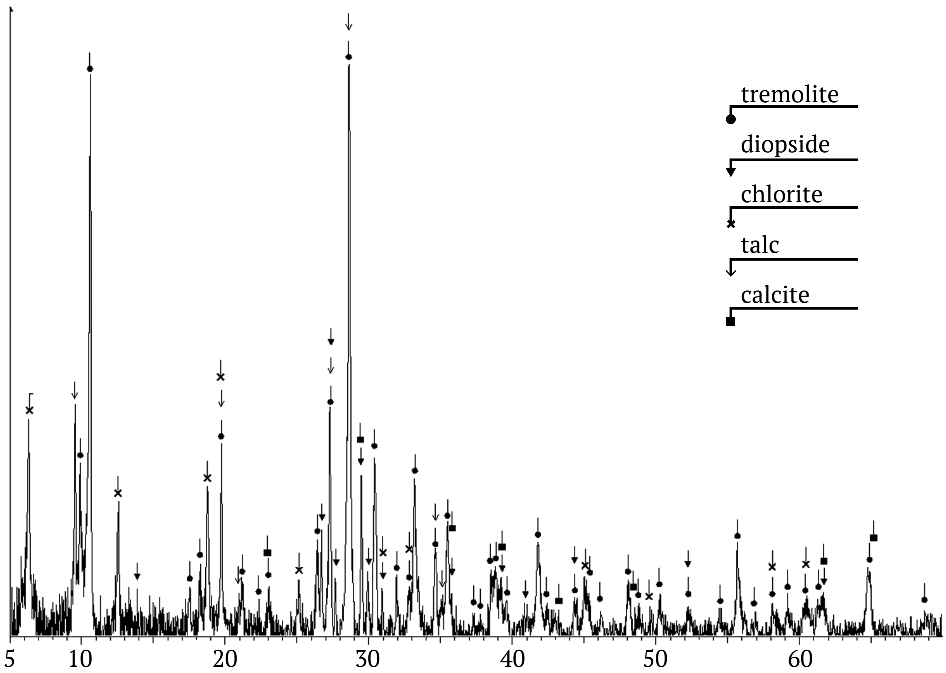

Fig. 2. X-ray diffraction pattern of nephrite processing waste

Fig. 3. Nephrite H9 white w with brown edges br and weathering crust with black manganese hydroxides

Fig. 4. Nephrite H11 bluish-green bG (light l, moderately strong light saturation mst), brown staining crust Brn (light l to extremely dark exdk with strong light saturation st)

eISSN 2500-0632
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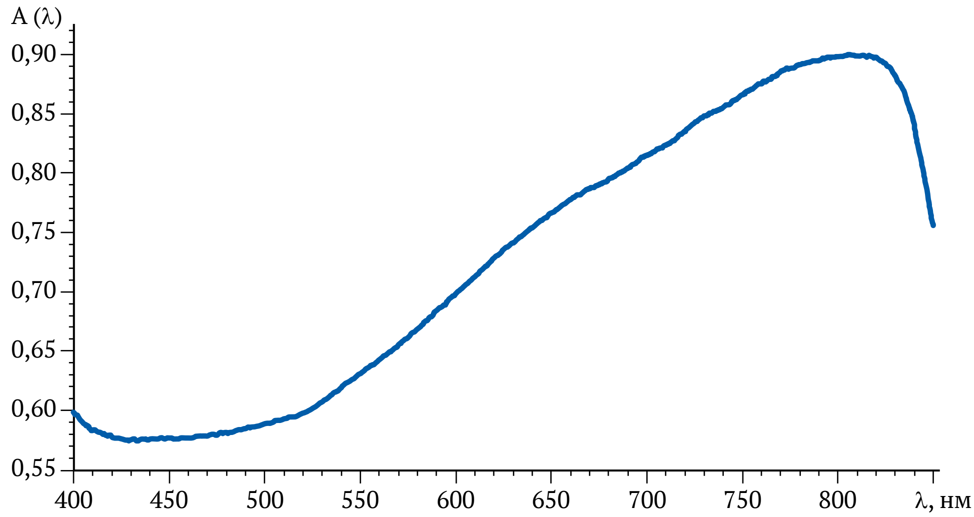

Fig. 5. Optical spectrum of white nephrite H9. Lab 55.0938: −5.4096: −5.7374 (CIE Lab)

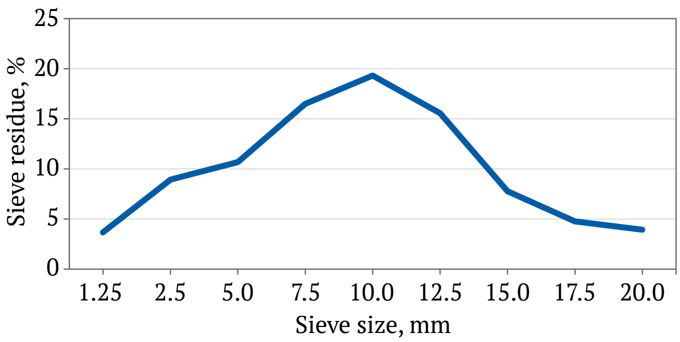

Fig. 6. Crushed stone grain size distribution

Nephrite, due to its tangled-fibrous microstructure and high viscosity, is challanging to crush. Consequently, a significant percentage of needle-shaped and flaky grains are observed, accounting for 23.4 % of the crushed stone from nephrite processing waste. This categorizes the waste into the third group of crushed stone according to GOST 8267–93.

The waste has a crushability grade of 1200, abrasion grade of I1, and frost resistance of F400. The studies reveals that the waste does not contain grains of incompetent rocks, clay, dust, or clay particles. Table 3 summarizes the study results and demonstrate that the solid nephrite processing waste from the Vitim region adheres to the requirements of GOST 8267–93.

Discussion

The investigation of the composition of the nephrite processing waste from the Vitim region revealed the absence of harmful components and impurities, including minerals, macro- and micro- chemical components). The decorative properties, including coloring, pattern, translucency, polishability, and defects, meet the existing standards.

The specific effective activity of natural radionuclides of the waste is bellow 50 Bq/kg, which ccomplies with the NRB–99/2009, GOST 8267–93, and the 1st safety class norm, allowing its use as ornamental and facing stone for all types of construction work.

The waste material has a crushability grade of 1200, abrasion grade of I1, and frost resistance of F400. The studies revealed that the waste does not contain grains of incompetent rocks or clay particles. The solid waste of Vitim nephrite processing meets the requirements of GOST 8267–93, except for the increased content of flagston and iand large fragments, which can be sold as crushed stone is possible by mutual agreement.

After crushing, the nephrite processing waste can be used as crushed (ballast) stone for construction works, including the production of ordinary concrete, decorative and mosaic concrete for finishing and lining walls and floors, as well as decorative floor slabs using cement and polymer binder compositions. The waste material is compliant with the requirements of GOST 9479–2011 “Blocks of rocks fo r the production of facing, architectural and construction, memorial and other products” and GOST 24099–2013 “Decorative plates based on natural stone. Technical Specifications”.

Furthermore, the nephrite processing waste can be utilized as a facing material for interior decoration, such as hallways and bathrooms, owing to its high density (2,900 kg/m^3), durability (M1200), low water absorption (0.2 %), resistance to corrosive environments, temperature differences, high melting point (approximately 1,250 °C) and low thermal conductivity.

Table 3

Physical and mechanical parameters of nephrite processing waste

Item No.	Indicator	Nephrite processing waste	Requirements (GOST 8267–93)
1	Total residue on check sieves, % by weight	98.73	d 90 to 100
		48.34	0.5(d+D) 30 to 60
		6.10	D to 10
		0.32	1.25D to 0.5
2	Contents of lamellar (flaky) and needle-shaped grains, % by weight	36.6	
3	Crushability grade	1,200	
4	Abrasion grade	I1	
5	Content of grains of incompetent rocks, % by weight	0	Less than 5
6	Frost resistance	F400	
7	Content of dust and clay particles, % by weight	0	Less than 1
8	Clay content in clumps, % by weight	0	< 0.25
9.	Presence of harmful components and impurities	None	
10	Resistance against all types of decay (mass loss on decay, %)	0	Less than 3
11	True density, g/cm^3	2,8426	
12	Average density, g/cm^3	2,8995	
13	Bulk density, kg/m^3	1314,29	
14	Moisture content, %	0,083	
15	Water absorption, %	0,1937	

Nephrite processing waste is a valuable for souvenir production, as a raw material for stone casting and slow-release fertilizer, particularly in areas with low calcium and magnesium due to the predominant development of granite, such as Buryatia.

Conclusion

The processing waste form nephrite has high quality and, with few exceptions, meets Russian standards. This waste can be utilized in the production of crushed stone for various purposes such as ordinary, decorative, and mosaic concrete. It is also suitable for the production of decorative slabs when corporated into cement and polymer binder compositions. Moreover, as an independent material it has potential for interior decoration and serves a valuable raw material for souvenir production. Furthermore, this waste can be used as a raw material for stone casting and slow-release fertilizer, especially in areas with unsufficient calcium and magnesium due to the predominance of granite, as in Buryatia. These multiple application not only solve the waste disposal problem but also enhance the economic viability of mineral extraction.

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Information about the authors

Evgeniy V. Kislov – Cand. Sci. (Geol. and Min.), Associate Professor, Leading Researcher, Dobretsov Geological Institute of Siberian Branch of the Russian Academy of Sciences, Ulan-Ude, Russian Federation; ORCID 0000-0003-2266-0942; e-mail evg-kislov@ya.ru

Liudmila I. Khudyakova – Dr. Sci. (Eng.), Leading Researcher, Baikal Institute of Nature Management of the Siberian Branch of the Russian Academy of Sciences, Ulan-Ude, Russian Federation; ORCID 0000-0003-1423-410X; e-mail lkhud@binm.ru

Anatoly G. Nikolaev – Cand. Sci. (Geol. and Min.), Associate Professor, Kazan (Volga Region) Federal University, Kazan, Russian Federation; ORCID 0000-0002-8082-6536, ResearcherID F-7024-2017

Received 24.01.2023
Revised 15.02.2023
Accepted 14.03.2023