ISSN 2518-170X (Online)
ISSN 2224-5278 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ
Satbayev University

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ
НАУК РЕСПУБЛИКИ
КАЗАХСТАН
Satbayev University

N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF
KAZAKHSTAN
Satbayev University

SERIES

OF GEOLOGY AND TECHNICAL SCIENCES

2 (458)

MARCH – APRIL 2023

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

«ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).
Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ39VPY00025420** мерзімдік басылым тіркеуіне қойылу туралы куәлік. Тақырыптық бағыты: *геология, мұнай және газды өңдеудің химиялық технологиялары, мұнай химиясы, металдарды алу және олардың қосындыларының технологиясы.*
Мерзімділігі: жылына 6 рет.
Тиражы: 300 дана.
Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19 http://www.geolog-technical.kz/index.php/en/

Типографияның мекен-жайы: «Аруна» ЖК, Алматы қ., Мұратбаев көш., 75.

«Известия НАН РК. Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ39VPY00025420,** выданное 29.07.2020 г.

Тематическая направленность: *геология, химические технологии переработки нефти и газа, нефтехимия, технологии извлечения металлов и их соеденений.*

Периодичность: 6 раз в год.

Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19

http://www.geolog-technical.kz/index.php/en/

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).
The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ39VPY00025420,** issued 29.07.2020.
Thematic scope: *geology, chemical technologies for oil and gas processing, petrochemistry, technologies for extracting metals and their connections.*
Periodicity: 6 times a year.
Circulation: 300 copies.
Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19
http://www.geolog-technical.kz/index.php/en/

Address of printing house: ST «Aruna», 75, Muratbayev str, Almaty.

NEWS of the National Academy of Sciences of the Republic of Kazakhstan
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 2, Number 458 (2023), 168–176
https://doi.org/10.32014/2023.2518-170X.292
UDC 662.673.13
IRSTI 67.09.91

© M.B. Nurpeissova[1*], Z.A. Yestemesov[2], A.A. Век[1], V.S. Kim[3], G.K. Syndarbekova[3], 2023
[1]Kazakh National Research Technical University named after K.I. Satpayev, Almaty, Kazakhstan;
[2]Central laboratory for certification testing of building materials – TseLSIM LLP, Almaty, Kazakhstan;
[3] Plant № 1 for production of reinforced concrete products – Zhenis LLP, Almaty, Kazakhstan.
E-mail: tselsim@mail.ru

MAIN CHARACTERISTICS OF FLY ASH FROM EKIBASTUZ SRPP–2

Nurpeisova Varzyan Baisanovna — Doctor of Technical Sciences, professor Satbayev University
Yestemesov Zatkali Airanbaevich — Doctor of Technical Sciences, Professor, Headmaster of "Central Laboratory of Tests and Certification Construction Materials", Almaty
Bek Aiman Askarkyzy — Lecturer, Department of Building Materials, Satbayev University
Kim Vyacheslav Sergeevich — senior researcher, deputy director of plant No. 1 for the production of reinforced concrete products, Almaty, Kazakhstan
Syndarbekova Gulim Kasymbekkyzy — senior researcher, engineer of plant No. 1 for the production of reinforced concrete products, Almaty, Kazakhstan
https://orcid.org/0000-0001-5290-4296. E-mail: tselsim@mail.ru.

Abstract. *Purpose* of this work is to study physicochemical characteristics of fly ash from the Ekibastuz SRPP -2, which is the most powerful thermal power plant in Kazakhstan, in terms of its formation and accumulation. This will make it possible to use it more rationally and efficiently during obtaining CEM II/A-3, CEM II/B-3, CEM V/A and CEM V/B. *Methodology.* XRF and XPSA were used to identify chemical and phase compositions, and standard methods were used to determine physical properties. *Results.* Studied fly ash is a low-active material, in order to increase its effectiveness as an additive for Portland cements, it is recommended to activate it. Fly ash from Ekibastuz SRPP – 2 has following physical and chemical characteristics: specific surface – 290 m^2 /kg, true density – 21 g/cm^3, bulk density – ~780 kg/m ^{3}, specific effective activity of radionuclides – 72 Bq/kg. Chemical composition is represented mainly by SiO2 (56.7 %) and Al_2O_3 (28.6 %), phase composition – mullite (38 %), quartz (32 %), sillimanite (12 %), hematite (5 %), glass phase (10 %) and unburned carbon (3 %); basicity modulus is 0,02 and the activity modulus is 0,5. It follows from the above that this fly ash is super acidic, among its components only the glass phase (10 %) can have increased activity, another part of silica (26 %) is reactive. Results of particle size distribution showed that:

– unburned carbon is mainly concentrated in the composition of large fractions, and glass phase is mainly among the smallest particles;

– particles of mullite, sillimanite and quartz are approximately equally distributed in fractions

Urgency and significance of this problem is intensified with the fact that technogenic wastes of CHPP are not sufficiently processed, current ash wastes accumulate and occupy vast areas, which takes them out of land use. Utilization of ash dumps makes it possible to reduce technogenic load on the environment and ensure rational use of secondary raw materials. *Scientific novelty.* For the first time, reasons for low activity of fly ash from the Ekibastuz CRPP-2 are shown; in order to increase efficiency, as an additive, it must be ground together with cement. Before grinding cement with the addition of fly ash, it is carried out on disintegrator mill. *Practical value.* Waste-free technology for processing of technogenic materials is being created, and activity of cements will increase.

Keywords: fly ash; chemical and phase compositions, mullite, sillimanite, quartz, glass phase, unburned carbon, particles and fractions, physical and chemical properties

© М.Б. Нұрпейісова[1], З.А. Естемесов[2], А.А. Бек[1], В.С. Ким[3], Г.Қ. Сындарбекова[3], 2023
[1]Қ.И. Сәтбаев атынлағы Қазақ ұлттық зерттеу техникалық университеті (ҚазҰТЗУ), Алматы, Қазақстан;

[2]Құрылыс материалдарын сертификациялап сынаудың орталық зертханасы (ЦелСИМ) Алматы, Қазақстан;
[3]Темір-бетон бұйымдарын шығаратын №1 зауыт – «Жеңіс» Алматы, Қазақстан.

ЕКІБАСТҰЗДЫҢ 2–ГРЭС-НЕН АЛЫНҒАН ҰШУ КҮЛІНІҢ НЕГІЗГІ СИПАТТАМАСЫ

Аннотация. Бұл жұмыстың *мақсаты* — Қазақстандағы ең қуатты жылу электр станциясы болып табылатын Екібастұз ГРЭС-2 күлінің түзілуі мен жинақталуы бойынша физика-химиялық сипаттамаларын зерттеу. Бұл ЦЕМ II/А-3, ЦЕМ II/В-3, ЦЕМ V/А және ЦЕМ V/В алу кезінде оны ұтымды және тиімді пайдалануға мүмкіндік береді. *Әдістеме.* Химиялық және фазалық құрамдарды анықтау үшін РФА және РФСА, ал физикалық қасиеттерді анықтау үшін стандартты әдістер қолданылды. *Нәтижелер.* Зерттелген ұшу күлі белсенді материал емес,бірақ оны портландцемент қоспалары ретінде қолдану үшін, басқа белсенді емес материалдарды алып тастап, оның тиімділігін арттырып белсендіру ұсынылады. Екібастұз ГРЭС-2 күлі келесі физикалық-химиялық сипаттамаларға ие: меншікті беті – 290 м2/кг, нақты тығыздығы – 2,1 г/см3, үйінді тығыздығы - ~780 кг/м3, радионуклидтердің меншікті тиімді белсенділігі – 72 Бк/кг. Химиялық құрамы негізінен SiO2 (56,7 %) және Al2O3 (28,6 %), фазалық құрамы – муллит (38 %), кварц (32 %), силлиманит (12 %), гематит (5 %), шыны фазасы (10 %) және жанбаған көміртегі (3 %); негізгі модуль 0,02, ал белсенділік модулі 0,5 тұрады. Жоғарыда айтылғандардан бұл күл өте қышқыл болып табылады, оның құрамдас бөліктерінің ішінде тек шыны фазасы (10 %) белсенділігі жоғарылауы мүмкін, кремний диоксидінің тағы бір бөлігі (26 %) реактивтілікке ие.

Бөлшектердің мөлшері бойынша таралу нәтижелері мынаны көрсетті:

–жанбаған көміртек негізінен ірі фракциялардың құрамында шоғырланған, ал шыны фазасы негізінен ұсақ бөлшектердің қатарына жатады;

–муллит, силлиманит және кварц бөлшектері фракцияларға шамамен бірдей бөлінеді

Бұл мәселенің өзектілігі мен маңыздылығы ЖЭО-ның техногендік қалдықтары жеткілікті түрде өңделмейтінін, күлдің ағымдағы қалдықтары жиналып, орасан зор аумақтарды алып жатқанын мойындау фактісімен күшейе түседі, бұл оларды жер пайдаланудан шығарады. Күл үйінділерін кәдеге жарату қоршаған ортаға техногендік жүктемені азайтуға және қайталама шикізатты ұтымды пайдалануды қамтамасыз етуге мүмкіндік береді. *Ғылыми жаңалық.* Алғаш рет Екібастұз ГРЭС-2 ұшу күлінің аз белсенділігінің себептері көрсетілді, тиімділікті арттыру үшін қоспалар ретінде оны цементпен бірге ұнтақтау керектігі және де цементті күл-қоқыспен ұнтақтамас бұрын, ол диірмен-ыдыратқышта жүзеге асырылады. *Практикалық маңызы.* Техногендік материалдарды қайта өңдеудің қалдықсыз технологиясы құрылуда, цементтердің белсенділігі артады.

Түйін сөздер: үлу-күлі; химиялық және фазалық құрамдар, муллит, силлиманит, кварц, шыны фазасы, жанбаған көміртек, бөлшектер мен фракциялар, физика-химиялық қасиеттері

© М.Б. Нурпеисова[1], З.А. Естемесов[2], А.А. Бек[1], В.С. Ким[3], Г.К. Сындарбекова[3], 2023
[1]Казахский национальный исследовательский технический университет – КазНИТУ им. К.И. Сатпаева, Алматы, Казахстан;
[2]Центральная лаборатория сертификационных испытаний строительных материалов – ТОО «ЦеЛСИМ», Алматы, Казахстан;
[3]Завод №1 по производству железобетонных изделий — ТОО фирмы «Женис», Алматы, Казахстан.

ОСНОВНЫЕ ХАРАКТЕРИСТИКИ ЗОЛЫ-УНОСА ЭКИБАСТУЗСКОЙ ГРЭС–2

Нурпеисова Маржан Байсановна — доктор технических .наук, профессор, профессор Satbayev University Алматы, Казахстан
ORCID: ttps://0000-0002-3956-5442. E-mail: marzhan-nurpeissova@rambler.ru;
Естемесов Заткали Айранбаевич — доктор технических наук, профессор. Центральная лаборатория сертификационных испытаний строительных материалов, Алматы, Казахстан
https://orcid.org/0000-0001-8725-3735. E-mail: tselsim@mail.ru;
Бек Айман Аскаркызы — преподаватель кафедры строительных материалов Satbayev University
Ким Вячеслав Сергеевич — с.н.с., Директор звода №1 по производству железобетонных изделий, Алматы, Казахстан
https://orcid.org/0000-0002-2802-5459. E-mail: tselsim@mail.ru;

Сындарбекова Гулим Касымбекқызы — с.н.с., инженер звода №1 по производству железобетонных изделий, Алматы, Казахстан
https://orcid.org/0000-0001-5290-4296. E-mail: tselsim@mail.ru.

Аннотация. *Целью* данной работы является исследование физико-химических характеристик золы-уноса Экибастузской ГРЭС-2, являющейся наиболее мощной тепло-энергетической станцией в Казахстане, по ее образованию и накоплению. Это даст возможность более рационально и эффективно использовать ее при получении ЦЕМ II/А-З, ЦЕМ II/В-З, ЦЕМ V/А и ЦЕМ V/В. *Методика.* Для идентификации химического и фазового составов применены РФА и РФСА, а для определения физических свойств использованы стандартные методы. *Результаты.* Исследованная зола-унос малоактивный материал, чтобы повысить ее эффективность как добавки для портландцементов рекомендуется ее активизировать. Зола-унос Экибастузской ГРЭС-2 имеет следующие физико-химические характеристики: удельная поверхность – 290 м^2/кг, истинная плотность – 2,1 г/см^3, насыпная плотность – ~780 кг/м^3, удельная эффективная активность радионуклидов – 72 Бк/кг. Химический состав представлен в основном SiO_2 (56,7 %) и Al_2O_3 (28,6 %), фазовый состав – муллитом (38 %), кварцом (32 %), силлиманитом (12 %), гематитом (5 %), стеклофазой (10 %) и несгоревшим углеродом (3 %); модуль основности составляет 0,02, а модуль активности – 0,5. Из сказанного следует, что эта зола-унос сверх кислая, среди ее составляющих только стеклофаза (10 %) может иметь повышенную активность, еще часть кремнезема (26 %) обладает реакционной способностью.

Результаты распределения частиц по размерам показали, что:

-несгоревший углерод в основном сосредоточен в составе крупных фракций, а стеклофаза, преимущественно, находится среди мельчайших частиц;

- частицы муллита, силлиманита и кварца примерно одинаково распределены по фракциям.

Актуальность и значимость данной проблемы усиливаются с фактом признания, что техногенные отходы ТЭЦ недостаточно перерабатываются, текущие отходы золы накапливаются и занимают огромные площади, что выводит их из землепользования. Утилизация золоотвалов позволяет снизить техногенную нагрузку на окружающую среду и обеспечить рациональное использование вторичного сырья. *Научная новизна.* Впервые показаны причины малоактивности золы-уноса Экибастузской ГРЭС-2 для повышения эффективности как добавки, ее надо совместно размалывать с цементом и до измельчения цемента с добавкой золы-уноса осуществляется на дезинтеграторной мельнице. *Практическое значение.* Создается безотходная технология переработки техногенных материалов, повысится активность цементов.

Ключевые слова: зола-унос; химический и фазовый составы, муллит, силлиманит, кварц, стеклофаза, несгоревший углерод, частицы и фракции, физико-химические свойства

Introduction

Currently, more than 500 million tons of ash and slag waste have been accumulated in Kazakhstan, which by 2030 will increase to one billion tons. The lion share of these technogenic materials is formed during combustion of Ekibastuz coals, which are hard, low- caking, high-ash, small-grained, but cheap. Therefore, they are used as fuel in many thermal power plants in Kazakhstan and Russia.

In the process of combustion of Ekibastuz coals in the boilers of thermal power plants, complex chemical and phase transformations of their mineral components occur as follows (Potapov et al., 2016: 14; Reference manual, 1985: 288):

− high-temperature processes associated with clay:

• at temperatures of 450…650°C, kaolinite ($Al_2O_3·2SiO_2·2H_2O$ transforms into chemically active anhydrous metakaolinite ($Al_2O_3·2SiO_2$);

• at temperatures above 900°C, mullite ($3Al_2O_3·2SiO_2$) is formed;

− processes associated with decomposition of carbonates:

• iron carbonate ($FeCO_3$) decomposes at 400…500°C;

• at 600…1000°C, dicarbonization of calcite ($CaCO_3$), magnesite ($MgCO_3$) and dolomite ($CaCO_3·MgCO_3$) occurs;

− processes at 540…573°C associated with phase transformations of quartz (SiO_2);

− at 400…700°C pyrite (FeS_2) is oxidized with formation of iron oxides (Fe_2O_3) and sulfur (SO_3);

− at high temperatures (1200°C), eutectic mixtures appear, which are a glass phase, including a microsphere.

And:

• most of the fuel boilers mode is designed in such a way that most of mineral constituents of coals pass into ash, and smaller part into slag;

• in addition to specified ash composition can include all elements of the Periodic Table of D. I. Mendeleev;

• chemical composition of ash can vary widely when same fuel is burned at TPPs.

Let's add to what has been said:

• now there are more than 300 technologies for the processing of ash and slag waste, depending on their chemical and phase composition;

• the most ash-and-slag-intensive technology is their use in construction, including road construction.

Table 1 shows negative consequences arising from impact of ash dump on ecosystem, which these technogenic wastes have on the biogeocenosis.

From ecotope system lithosphere experiences the greatest anthropogenic load from impact of technogenic waste. Peculiarity of anthropogenic impact of ash dumps components on the lithosphere system is:

– suppression of biochemical processes occurring in soil system as a result of occurrence of accompanying silicate-forming physical and chemical processes;

– change in the pH of reaction medium (pH of soil medium is neutral, i.e. is about 7), both downward (with acid reaction) and upward (with alkaline reaction), which leads to violation of redox reaction occurring in soil system;

– formation of various soluble and insoluble salts that depress soil components and adversely affect biochemical soil processes;

− centers emergence of cementation by formation of aluminosilicate systems on the surface of the earth, as a result of which vegetation is destroyed.

All this ultimately leads to erosion, pollution, salinization, desolation, dusting, alienation and other negative consequences in the lithosphere.

By and large, ash is not a waste, but a valuable raw material - technogenic mineral formation. Therefore, in England and Germany, ash and slag is completely used in the national economy (100 %), in Japan - 82%, in the USA and China – 65 %, in Russia – 15 %.

However, for various reasons, ash dumps are not used in Kazakhstan, since physical and chemical properties are very poorly studied, in addition, during their processing, other wastes are obtained from these wastes or ash dumps are unsuitable for use, since they contain a lot of unburned coal.

Table 1- Negative consequences arising from impact of ash dump on ecosystem

Ash dump	Buildings and structures	Reducing conditions of archophytomeliorative measures
		Reducing degree of biopositivity of buildings and structures
	Biocenosis [Flora (F_2), fauna (F_n), man (H_s)]	Decreased strength characteristics and durability of buildings and structures
		Oppression and deterioration of human condition, flora and fauna
		Occurrence of various diseases
	L – Lithosphere	Depression of a vast territory and violation of natural landscape
		Depression of soil biota (earthworms, wood lice, earth mites, nematodes) and flora (fungi, bacteria, algae, etc.)
		Violation of the functional properties of soils (turf, forest cover, meadow felt, humus horizon)
	A – Atmosphere	Ambient temperature rise and climate change
		Formation of technogenic systems in the form of acid rain, greenhouse effect, ozone holes, etc.
		Change in the natural functional properties of the air basin
	H- Hydrosphere	Anthropogenic impact of precipitation in the form of acid rain
		Increase in the amount of polluted ground and surface water
		Changes in the functional natural, physico-chemical properties of water systems

Therefore, ash dumps in storage facilities in Kazakhstan are increasing from year to year, causing, as mentioned above, environmental, economic and socio-economic damages amounting to a billion tenge:

• World experience shows that fly ash can be used in various areas of the national economy;

• However, the most gold-intensive and environmentally-economically efficient areas, as already mentioned, are the construction and road industries.

During using fly ash as a mineral additive for cements and concrete mixtures, their physical, mechanical and operational properties are significantly improved. In connection with the foregoing, relevance of using fly ash as a component for cement and concrete mixtures is beyond doubt.

Methodology

To determine phase composition of material under study, a modernized DRON-3M diffractometer based on CuKα radiation with software was used. X-ray patterns of sample were obtained in the range of 2Θ(angles) from 10 to 70°. Chemical composition was determined using energy dispersive spectrometer «EDX–8000».

Micrograph of fly ash was taken on a Superprob-733 scanning electron microscope.

Results and discussions

Chemical and phase compositions. Figure 1 shows an X-ray diffraction pattern of ash, from which it can be seen that reflections with interplanar distances, d/n, Å, are recorded:

• mullite ($3Al_2O_3{\cdot}2SiO_2$) – 5.4246; 3.41; 2,2009 and others;

• quartz (SiO_2) – 4.2678; 3.41; 2.2852 and others;

• sillimanite ($2Al_2O_3{\cdot}SiO_2$) – 5.4246; 3.41; 1.5233 etc.

At the same time, values of some peaks of minerals coincide with each other, especially between mullite and sillimanite. In addition, there is also a glass phase in the ash, as evidenced by a halo on the X-ray pattern in the region of 16° ... 28° and unburned carbon, which is not fixed on the X-ray pattern. In quantitative terms, ash components are distributed as follows, %: mullite – 38; quartz – 32; sillimanite –12; hematite – 5; glass phase –10; unburned carbon –3.

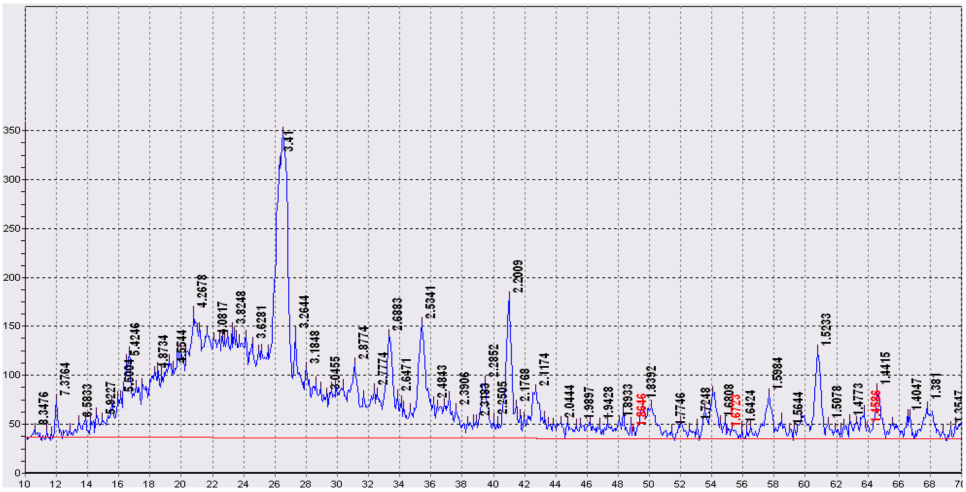

Fig.1 - Radiograph of fly ash

Chemical composition, %: SiO_2 – 57,7; Al_2O_3 – 29,6; (Fe_2O_3+ FeO) – 6,4; CaO – 1,1; MgO – 0,35; SO_3 – 1,3; K_2O – 0,03; Na_2O – 0,52; ппп – 3,0.

Analyzing phase composition of fly ash, it can be stated that only glass phase, which contains a microsphere, has its pozzolanic and hydraulic activity, and rest is mullite ($3Al_2O_3{\cdot}2SiO_2$), quartz (SiO_2), sillimanite (Al_2O_3), hematite (Fe_2O_3) and carbon (C) do not have pozzolanic and hydraulic activity.

In addition, following micro elements are present in the ash: P, Sc, Mn, Pb, Ti, As, Zr, Ge, Ga, W, Ni, Cr, which do not exist independently in ash, do not form independent compounds, but are part of minerals and glass phase.

Specific surface – 290 m^2/kg; true density – 2.1 g / cm^3, bulk density – 780 kg / m^3.

Fig. 2 shows electromicroscopic image of fly ash, which shows:

• that particles are spherical, vitreous and hollow, ranging in size from 1 µm to 50 µm;

• that large particles contain smaller spherical particles in their cavities (shown by arrow);

• that on the surface of large particles there are, as a rule, tightly "glued" tiny granular balls.

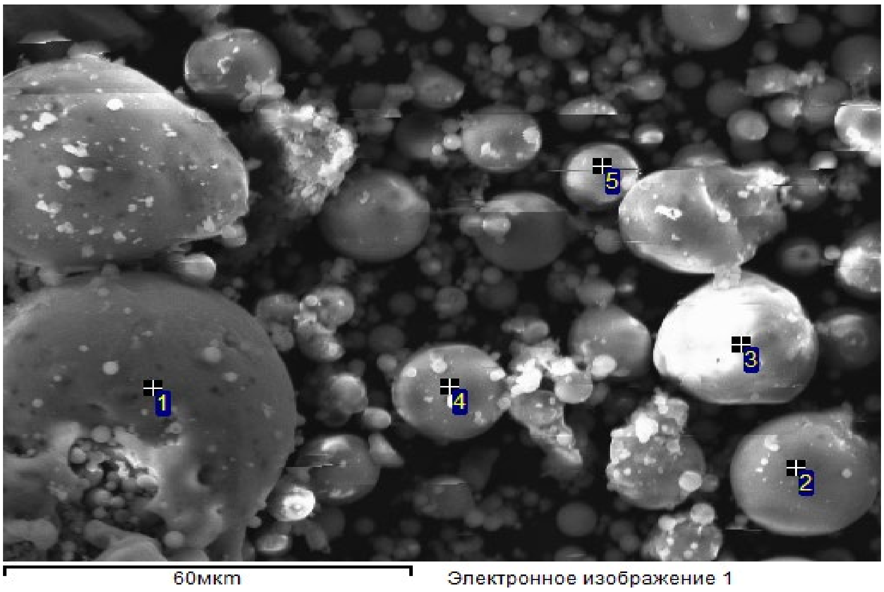

Fig. 2 - Micrograph of ash fractions in a scanning electron microscope

Mechanism of particle formation can be represented as follows:

• under conditions of hydraulic removal from furnace, ash with elevated temperature comes into contact with water, resulting in the formation of small glass balls;

• after a moment, large melts due to action of water begin to turn into balls, during which small balls are captured by them into their cavity;

• «massive balls» cool down more slowly, so already cooling small balls stick to their surface;

it is possible to form relatively large balls, inside which there are small balls, according to the following mechanism: small balls are clustered in one place, attracted to each other, then during rotational movement, outer balls still stick together tightly, thereby creating a continuous outer surface; by the way: small balls located in the cavity of a large ball, as a rule, are mullite and α-quartz (Kokubu et al., 1996: 11; Entin et al., 1976: 5).

It should be especially noted that on microscope screen, balls and fly ash balls have shiny and white (light) surface, which is typical for texture of glass. Color fades in the picture. Particles of unburned carbon here and there give a black background.

Comparing data of X-ray phase and electron microscopy, one can detect, at first glance, some contradictions:

• X-ray shows that fly ash mainly consists of individuals with a crystalline structure, and content of amorphous glass phase does not exceed 10 %;

• in a scanning microscope, ash is represented mainly by glass phase in the form of spheres and balls.

These contradictions are removed if we represent fly ash particles as a glass phase with a crystalline structure. Therefore, mullite ($3Al_2O_3 \cdot 2SiO_2$), quartz (SiO2), sillimanite ($Al_2O_3 \cdot SiO_2$) and others are minerals with a glassy-crystalline structure, having neither hydraulic nor pozzolanic properties.

Grading. These properties of fly ash entering system of hydraulic ash removal channels depend on many factors, main ones being:

• design of boiler furnaces;

• operating conditions of boilers;

• system of dust preparation and supply of coal dust for combustion;

• type of mills and their operational condition;

• device with which fly ash is fed into hydroash removal system of TPP

Granulometric composition of the Ekibastuz SRPP by fractions is distributed as follows: till 0,5 mm – 0,14 %; 0,45 mm – 2,26 %; 0,25 mm – 3,6 %; 0,1 mm – 25,8 %; 0,09 mm – 0,84 %; 0,08 mm – 12,12 %; 0,06 mm – 4,5 %; 0,05 mm – 21,46 %; 0,045 mm – 21,38 %; 0,04 mm – 7,9 %.

Table 2 - Distribution of phase composition of fly ash depending onfrom its fraction

			Distribution of phase composition depending on the fraction, %

Mesh sieve number	Particle sizes, µm	Content of the fraction on sieve, %	mullite	α- quartz	sillimanite	carbon	glass phase (occupied by halo square, sm^2)
0,5	500	0,14	28	54	–	18	6
045	450	2,26	44	21	24	11	14
025	250	3,36					
01	100	25,8	46	18	28	8	14,5
009	90	0,84					
008	80	12,12	42	20	31	7	18
0063	63	4,5	47	17	29	7	20
005	50	21,46	50	21	29	–	22
0045	45	21,38	47	25	28	–	23
004	40	7,9	51	14	35	–	23

Table 2 shows distribution of phase composition of fly ash depending on its fractional composition. Analyzing data in this table, we can say following:

fly ash is mainly represented by a fraction consisting of a particle with a size of 100 microns – 25.8 %, a size of 80 microns – 12,12 %, a size of 50 microns – 21,46 %, a size of 45 microns – 21,38 %; in total they reach 80,76 %;

• composition of a particle with a size of 500 µm stands apart, which is represented by mullite (28 %), α-quartz (54 %), carbon (18%) and small amount of glass phase (occupying a halo area on the X-ray pattern reaches 6 cm ^{2}; their content from the total fly ash is small – only 0.14 %;

• content of unburned carbon on x-rays is fixed only in composition of large fractions - from 500 microns to 63 microns; moreover, within these fractions, its content naturally decreases: 18 %–7 % – from coarse fraction to a fine one;

• area of the halo on X-ray patterns (Fig. 3), representing glass phase, increases with a decrease in dispersion of fly ash; so, for example, halo area on the x-ray pattern of particles with a size of 500 microns reaches 6 cm^2, its intensity is 105 pulses/sec, and the size of 40 microns is 23 cm^2, respectively; consequently, in the last composition of fly ash there are more (almost 3.8 more and 140 pulses / sec) glass phase, therefore, small particles can have the highest activity;

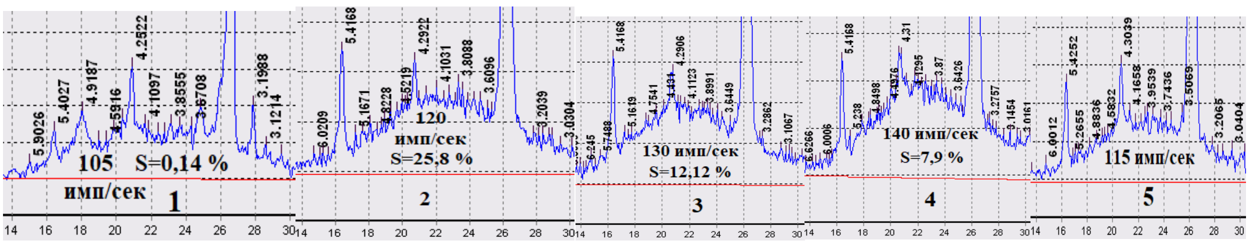

Fig. 3 - Distribution of glass phase in fly ash fractions: 1 ... 4, respectively, fraction 500, 100, 80 and 40 microns; 5 - the content of the glass phase in the original fly ash

• in particles of fly ash with a size of less than 450 microns, mullite content varies within 41...51 %, α-quartz – 14...25 % and sillimanite – 24...35 %. 1 ... 4, respectively, fraction 500, 100, 80 and 40 microns; 5– glass phase content in the original fly ash.

It is known that the above-mentioned components of the Ekibastuz fly ash have the following characteristics:

• *mullite and sillimanite* are representatives of andalusite group; have hardness within 6…7.5, density – 3.03…3.23 g/cm^3; optical characteristics in transmitted light - light refraction of sillimanite – Ng=1.677; Nm=1.658; Np=1.657; mullite − Ng=1.654; Nm=1.644; Np=1.642; have high refractoriness, extremely chemically inert and with high mechanical strength (Kuldeev et al., 2022:9; Bek et al., 2022:9);

• *α -quartz* is a low-temperature form of mineral; uniaxial, positive: Ng=1.553 and Np=1.544; density 2.65 g/cm3; hardness – 7; almost insoluble in H_2O, HCl and H_2SO_4H2SO4, soluble in HF, slightly soluble in alkalis.

Moreover, it should be noted that 26 % of α-quartz is reactive towards lime.

• *Hematite* – density 5.26 g/cm^3, hardness 5…6, uniaxial, negative; Ng>2.95, Ne=2.74. Insoluble in water, organic acids, soluble in concentrated HCl solution (Bek et al., 2022: 7; Aitkazinova et al., 2020: 11);

- *coal* – is amorphous carbon, density is within 1.8…2.1 g/cm ^{3}; consists of smallest crystals invisible even to microscope, having graphite structure; absolutely does not have astringent properties; decomposes from sun rays , does not create compounds with water; does not interact and has no bonding strength with minerals of Portland cement clinker, lime, gypsum, mineral components of crushed stone, gravel and sand, therefore its presence in composition of cement stone, mortar, concrete and reinforced concrete products and structures is highly undesirable;
- *glass phase* - occurs as a result of rapid cooling with water; has different densities: if it is lighter than water, then such a glass phase is called a microsphere with increased hydraulic and pozzolanic properties; therefore it is used as an active mineral supplement; if its density is higher than water, then it is known as a glass phase, which has latent hydraulic and pozzolanic properties.

Both types of glass phase actively interact (especially microsphere) with Portland cement hydration products, forming additional cementing agents in hardening systems.

According to the technical requirements of GOST 31108–2020, fly ash is introduced into the composition of the following types of cements:

• CEM II/A-3 in the amount of 6...20% by weight and CEM II/B-3 in the amount of 21...35% (Estemesov et al.,2020:9; Bek et al., 2022: 7);

• CEM V/A in the amount of 18…30 % and CEM V/B in the amount of 31…49 %.

At the same time, fly ash must meet technical requirements of the above-mentioned standard. Table 3 shows chemical parameters of standard and investigated fly ash.

Table 3 - Comparative data of chemical indicators of standard and fly ash

№	Name of indicator	ND on tests	Norm ND according to GOST 31108–2020	Actual value fly ash
1	Content of alkali oxides (R_2O) in terms of Na_2O, no more, %	ГОСТ 5382–2019, p.12	2,0	0,54
2	Content MgO, no more, %	ГОСТ 5382–2019, п.7.3	5,0	0,35
3	Weight loss on ignition (ppp), no more, %	ГОСТ 5382–2019, p4	5,0	3,0
4	Uniformity of volume change (expansion of cement with the addition of fly ash, no more, mm	ГОСТ 30744–2001, p.7	10	9,0
5	Содержание реакционноспособного SiO2, at least, %	ГОСТ 5382–2019, p.6; RFSA	25	26
6	Массовая доля реакционноспособного CaO, at least, %	ГОСТ 5382–2019, p.7	10	0,5
7	Mass fraction of free calcium oxide CaO, no more, %	ГОСТ 5382–2019, p.13	1	absent
8	Specific effective activity of natural radionuclides, bk/kg	ГОСТ 30108–94	До 370	72

Conclusions

1. Currently, Kazakhstan has accumulated more than 500 million tons of fly ash, which by 2030 will increase to one billion tons. Such an accumulation of fly ash in storage creates a powerful anthropogenic impact on biogeocenosis. In light of this, complex physical and chemical studies of fly ash from ash storage facility of the Ekibastuz CRPP-2 were carried out.

2. Following physical characteristics have been established: specific surface – ~200 m ^{2} /kg, true density – 2.1 g/cm ^{3}, bulk density – ~780 kg/m ^{3}. Fractional composition: the highest content of particles with a size of 100 microns (25,8 %), 80 microns (12,12 %), 50 microns (21,46 %) and 45 microns (21,38 %); in this case, unburned carbon is concentrated in large fractions, and glass phase is concentrated in small ones.

3. Chemical composition is presented SiO_2 (57,7 %), Al_2O_3 (29,6 %), Fe_2O_3+FeO (6,4 %), CaO (1,1 %), MgO (0,35), SO_3 (1,3 %), K_2O (0,03 %), Na_2O (0,52 %); pp= – 3,0 %. Composition still contains more than 13 micro elements that do not create independent compounds and do not remain in a free state, but are included in mineral phase composition of fly ash, which includes (rounded): mullite ($3Al_2O_3 \cdot 2SiO_2$) – 38 %; quartz (SiO_2) – 32 %; sillimanite ($Al_2O_3 \cdot SiO_2$) – 12 %; hematite (Fe_2O_3) – 5 %; glass phase – 10 %; unburned carbon – 3% among them, onlyglass phase has pozzolanic and hydraulic activity, and reactivity – 26 % SiO_2.

4. Modulus of basicity about 0.02; activity module – 0,5. From this it follows that studied fly ash has a superacid index.

According to its chemical properties, it can be used as an additive for Portland cements CEM II/A-3, CEM II/B-3, CEM V/A and CEM V/B. However, to increase efficiency of fly ash, it is strongly recommended to additionally grind it together with cement.

Studies were carried out within the framework of grant funding from Ministry of Science of Higher Education of the Republic of Kazakhstan AR14871694 «Development of technology for processing ash and slag waste from thermal power plant with production of demanded building materials».

REFERENCES

Aitkazinova Sh.K, A.A. Bek A.A., K.N. Derbisov K.N., Levin E., Nurpeissova M.B., 2020. Preparing solutions based on industrial waste for fractured surface strengthening. News of the National Academy of sciences of the Republic of Kazakhstan, Series of Geology and Technical sciences».

ISSN 2224–5278. Volume 5. Number 443 (2020). Pp.13–20. https://doi.org/10.32014/2020.2518-170X.99.

Bek A.A., Yestemesov Z.A., Baidzhanov D.O., Fedotenko N.A., 2022. Effective strengthening solutions for fractured rock masses using tailings// «Eurasian Mining» 1-2022. -Pp.64–74.

Bek A.A., Aitkazinova Sh.K., Nurpeisova M.B., Yestemesov Z.A., 2022. Assessment of the suitability of enrichment waste for the production of building materials //Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu. №3. 2022. Pp. 88–94.

Bek A.A., Yestemesov Z.A., Nurpeisova M.B., Suvorov A.S., Dadin A.D., 2022. Mortgage mixtures based on limestone tailings. Proceedings of the National Academy of the Republic of Kazakhstan - Series of Chemistry and Technology. № 1. 2022. Pp. 11–18.

Estemesov Z.A., Barvinov A.V., Sarsenbaev B.K. Tulaganov A.A., Estemesov M.Z., Khaidarov A.M., 2020. New method for disposal of granulated phosphoric slag from hazardous gases// News of the national academy of sciences of the Republic of Kazakhstan- Series chemistry and technology. Vol. 3. Number 441 (2020). Pp. 6–14. https://doi.org/10.32014/2020.2518-1491.37.

Entin Z.B., Yashina E.T., Lepeshenkova G.T., Ryazantseva N.Z., 1976. On hydration and hardening of cements with ash / In: Sixth International Congress on Chemistry of Cement; Volume III - Cements and their properties. - Moscow: Stroyizdat, 1976. – Pp. 95–99.

Kuldeev E.I., Nurpeisova M.B., Bek A.A., Ashimova A.A., 2022. Waste processing is one of the key areas for the development of the «green» economy //M.: Mine surveying and subsoil use. No. 6. 2022. Pp. 67–75.

Kokubu M., 1996. Yamada D. Ash-added cements (Main report) / materials Sixth International Congress on Cement Chemistry; Volume III – Cements and their properties. - Moscow: Stroyizdat, 1996. –Pp. 83–94.

Potapov S.O., Svirilova M.N., Tanutrov I.N., Toloknov M.N., 2016. Physical and chemical properties of fly ash from combustion of Ekibastuz coals. Butlerov Communications. № 3. Volume 45. Kazan. 2016. Pp.36–39.

Reference manual: Composition and properties of ash and slag from thermal power plants: Ed. V.A. Melentyeva. - Leningrad: Energoatomizdat, 1985. – 288 p.

CONTENTS

Publication Ethics and Publication Malpractice in the journals of the National Academy of Sciences of the Republic of Kazakhstan

For information on Ethics in publishing and Ethical guidelines for journal publication see http://www.elsevier.com/publishingethics and http://www.elsevier.com/journal-authors/ethics.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the described work has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see http://www.elsevier.com/postingpolicy, that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE, and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics.org/files/u2/New_Code.pdf). To verify originality, your article may be checked by the Cross Check originality detection service http://www.elsevier.com/editors/plagdetect.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of Sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of Sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайтах:
www:nauka-nanrk.kz
http://www.geolog-technical.kz/index.php/en/
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Заместитель директор отдела издания научных журналов НАН РК *Р. Жәлиқызы*
Редакторы: *М.С. Ахметова, Д.С. Аленов*
Верстка на компьютере *Г.Д.Жадыранова*

Подписано в печать 14.04.2023.
Формат 70x90$^{1}/_{16}$. Бумага офсетная. Печать – ризограф.
20,0 п.л. Тираж 300. Заказ 1.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-19