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

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ
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

**1 (445)**

**JANUARY – FEBRUARY 2021**

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

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**«ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы».**

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

Меншіктенуші: «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 және техникалық ғылымдар бойынша мақалалар жариялау.***

Мерзімділігі: жылына 6 рет.
Тиражы: 300 дана.

Редакцияның мекенжайы: 050010, Алматы қ., Шевченко көш., 28, 219, 220 бөл.,
тел.: 272-13-19, 272-13-18,
http://www.geolog-technical.kz/index.php/en/

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Типографияның мекенжайы: «NurNaz GRACE», Алматы қ., Рысқұлов көш., 103.

**«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:** ***публикация статей по геологии и технических наукам.***

Периодичность: 6 раз в год.
Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, ком. 219, 220, тел.: 272-13-19, 272-13-18,
http://www.geolog-technical.kz/index.php/en/

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Адрес типографии: «NurNaz GRACE», г. Алматы, ул. Рыскулова, 103.

**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:** ***publication of papers on geology and technical sciences.***

Periodicity: 6 times a year.
Circulation: 300 copies.

Editorial address: 28, Shevchenko str., of. 219, 220, Almaty, 050010, tel. 272-13-19, 272-13-18,
http://www.geolog-technical.kz/index.php/en/

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Address of printing house: «NurNaz GRACE», 103, Ryskulov str, Almaty.

**N E W S**
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
**SERIES OF GEOLOGY AND TECHNICAL SCIENCES**
ISSN 2224-5278
Volume 1, Number 445 (2021), 114 – 120 **https://doi.org/10.32014/2021.2518-170X.16**

UDC 556.543.32

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# HYDROCHEMISTRY OF THE PYANJ TRANSBOUNDARY RIVER UPSTREAM, MIDDLE AND DOWNSTREAM AND THE CRITERION ITS USE FOR IRRIGATION

**Abstract.** The water quality of the transboundary Pyanj River in the formation zone and along the riverbed before merging with another tributary of the transboundary Amu Darya River-the Vakhsh River was studied. The water quality on the upstream river corresponds to the very soft class (> 1.5 mmol/dm$^3$) and in the middle and the downstream to the soft class (1.5-3.0 mmol/dm$^3$). At the upper, middle and lower reaches of the Pyanj river the concentration of alkaline earth exceeds alkali metals ($Ca^{2+}$ + $Mg^{2+}$> $Na^+$ + $K^+$) at $HCO_3^-$ > $SO_4^{2-}$ + $Cl^-$ and according to the Handa classification they are characterized by temporary rigidity. To assess the criterion of applicability of the Pyanj river water for irrigation the coefficient of sodium adsorption (SAC) was calculated for water samples from the upstream (Khorog), middle (Darvaz) and the downstream (Lower Pyanj) of the Pyanj river that were equal to 0.88; 1.07; 1.71, respectively. The SAC values for all water samples (from the upper, middle and lower reaches) of the Pyanj river indicate their good qualities for irrigation of agricultural land. The concentration of heavy metals in the Pyanj river is significantly lower than the maximum permissible concentration (MPC).

**Key words:** agriculture, underground water, solubility of cations, adsorbtion, irrigation.

**Introduction.** The problem of water quality of river systems and providing the population with safe drinking water, preventing the transfer of water pollutants through crops are one of the Millennium Priority Goals. Solving these problems requires an integrated approach to monitoring water quality from the formation zone to downstream. River systems are polluted mainly in the middle reaches and in the downstream dispersion zone. To determine the sources of river pollution and establish a balance of polluting chemicals, it is necessary to determine the quantitative values coming from the upstream river pollutants.

The formation of the quality of natural waters depends on their physical, chemical, biological and radiological characteristics that are greatly influenced by the geological structures, climate and topography of the zone of formation of water resources [1-5]. However, anthropogenic pressure is a major factor in the pollution of water bodies and arteries [1,2,8,9,10]. A wide and comprehensive review of the literature on the selection of optimal indicators for a comprehensive assessment of surface water quality was done in [6,7,11,12]. The importance of systematic monitoring of water quality is determined by the fact that pollutants in the aquatic environment, due to the occurrence of appropriate physicochemical processes, can transform into more toxic components or generate the appearance of other compounds that are dangerous to the environment and living organisms [13,14].

It is worth mentioning, the problem of water quality is especially relevant for Transboundary Rivers when the formation and dispersal zone of river is located in two or more countries.

For example, the water quality problem of the Zeravshan River the Transboundary River between Tajikistan and Uzbekistan has long been the subject of heated debate and mutual claims arising from the operation of the Anzob mining and processing plant in the middle reaches of the Zeravshan River on the territory of Tajikistan [15,16].

The database on transboundary freshwater disputes (DBTFW) at Oregon State University (OSU) has identified 263 water basins that cross national borders and cover more than 40% of the world's population. Now, humanity is faced with the cataclysms of global climate change manifested in the reduction of water resources and areas of glaciation, water scarcity and significant changes in the water cycle and increases of emergencies [17-20].

A reliable and effective way to solve water quality problems of Transboundary rivers and prevent conflicts and disagreements between neighboring countries is to create a database of real data on water quality indicators in the formation and dispersion zone of river and their quantitative value in the border-crossing zone.

The Pyanj river is one of the tributaries of the Transboundary Amu Darya river with the basin areas 113.6 thousand $km^2$ that about 73% (82.9 thousand $km^2$) is located in Tajikistan, 27% (30.6 thousand $km^2$) in Afghanistan.

The average long-term runoff of the Pyanj River is 7.0 $km^3$ at the upstream and increase up to 39.8 $km^3$ in downstream. The norm of the average annual maximum discharge of the Pyanj River is 3670 $m^3/s$ and minimum water discharge (193 $m^3/s$) is observed in December-February.

Water resources formed in the Aral Sea basin are 148.5 $km^3$/year (116.5 $km^3$/year – natural river flow and about 32.0-33.0 $km^3$/year-return water) and their distribution between the countries of the basin is as follows: Uzbekistan – about 53%, Turkmenistan – 20%, Tajikistan and Kazakhstan – 10%, Kyrgyzstan – less than 5% and Afghanistan – about 2% [21]. According to the World Bank, from 400 thousand ha irrigated in northern Afghanistan of land about 100 thousand ha irrigated directly from the Pyanj and Amu Darya Transboundary Rivers. The growth potential of irrigated lands in the Afghan territory in the basin of these rivers is huge and the irrigation area of fertile lands can reach, according to various estimates, about 500 thousand ha.

Consequently, after the stabilization of the political situation, Afghanistan will claim additional water from the water resources of the Amudarya river basin, and Afghanistan's water withdrawal will reach 9.0 $km^3$/year by the middle of the XXI$^{st}$ century that will lead to a runoff decrease in the downstream of the Amu Darya.

This means that when the full potential of agricultural land in the north of Afghanistan is developed, it is likely that the anthropogenic pressure on the water resources of the Pyanj River will increase with the influx of municipal sewage and return water from agricultural land. The issue of water quality will appear on the agenda – which country of the basin, in what quantities pollutes the waters of the Pyanj River. The statement that in the mountainous territories of the river catchment in Tajikistan anthropogenic pollution is minimized will not be sufficient to solve the problem. This will require evidence of river water quality in the relevant sections of the river.

The aim of this work is to monitor the water quality of the Pyanj Transboundary River – the main tributary of the Amu Darya.

**Objects and Methodology.** Water sampling in the Pyanj river upstream, middle and downstream was performed at the Khorog (37º30'N 71º30'E) Darvaz (38º28'N 70º53'E) and Nijniy Pyanj (37º11'N 68º35'E) hydrological stations, respectively (figure 1). The physical and chemical analyses of the waters samples were carry out by use of the «TaLab» spectrophotometer according corresponding state standards.

At chemical analyses and interpretation of results was guided by the normative document «Sanitary and epidemiological requirements to water sources, water intake sites for drinking purposes, drinking water supply and places of cultural and domestic water use and security of water facilities» (Order of the Minister of national economy of the Republic of Kazakhstan, March 16, 2015 No. 209). In addition, state standards were relevant: $Na^+$ (State standart 26449.1-85, п.17.1), $K^+$ (State standart 26449.1-85, п. 18.1), $Ca^{2+}$ (State standart 26449.1-85, п. 11.1), $Mg^{2+}$ (State standart 26449.1-85, п.12), $NO_3^-$ (State standart 33045-2014).


Figure 1 – Sampling points of water from the Pyanj river (Khorog Darvaz, Nizhniy Pyanj)

**Results and discussion.** The World Health Organization (WHO) has developed international water quality standards in the form of guidelines that are used as basic rules and standards in developing and developed countries. According to these standards, the maximum permissible concentration of the total hardness of drinking water is 15 mmol/dm$^3$ and the most favorable is 3.0 mmol/dm$^3$.

The results of chemical analyses of water samples from the formation zone (Gunt), the middle (Darvaz) and the downstream (Nijniy Pyanj) of the Pyanj river are presented on the Table.

From the Table it follows that the water in all three section (upstream, middle and downstream) of the Pyanj river meet the requirements for drinking water. In addition, the water of the Pyanj river in the upstream corresponds to the very soft class (>1.5 mmol/dm$^3$), in the middle reaches and downstream to the soft class (> 1.5-3.0 mmol/dm$^3$).

At the upper, middle and lower reaches of the Pyanj river the concentration of alkaline earth exceeds alkali metals ($Ca^{2+}$ + $Mg^{2+}$> $Na^+$ + $K^+$) (figure 2) at $HCO3^-$ > $SO_4^{2-}$ + $Cl^-$ (figure 3) and according to the Handa classification they are characterized by temporary hardness.

The chemical indicators of water in the upstream (Khorog), middle (Darvaz) and the downstream (Nijniy Pyanj) of the Pyanj river

| Indicators | Unit | Value | | |
|---|---|---|---|---|
| | | Khorog | Darvaz | Nijniy Pyanj |
| Hydrogen index | pH | 6.4 | 7.86 | 7.88 |
| Total mineralization | mg/dm$^3$ | 86 | 257 | 286 |
| Dry residue | mg/dm3 | 22 | 190 | 224 |
| Total hardness | mmol/dm$^3$ | 1.34 | 2.35 | 2.65 |
| Permanganate oxidability | mgO$_2$/dm$^3$ | 0.32 | 1.04 | 0.98 |

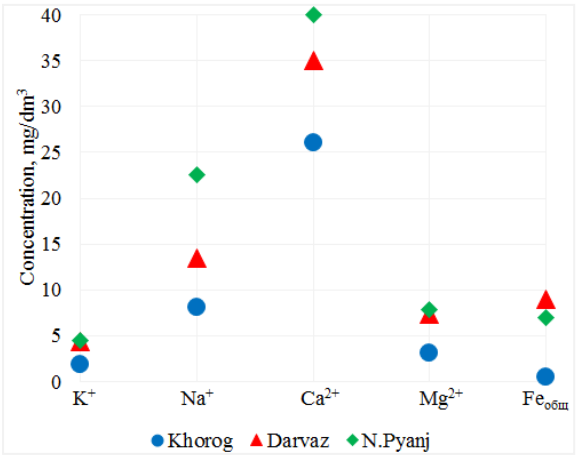


Figure 2 – Concentration of water composition cations on the upstream (Khorog), middle (Darvaz) and downstream (Nijniy Pyanj) of the Pyanj river

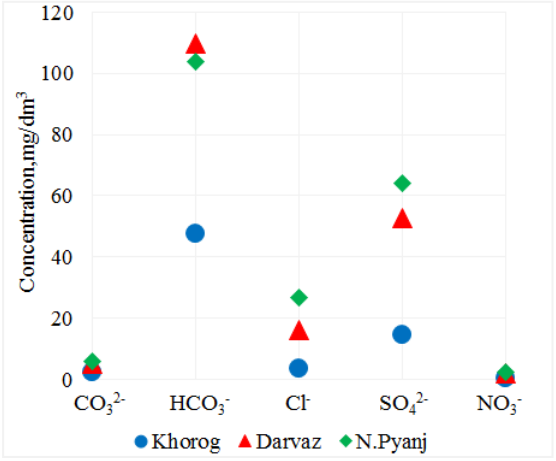


Figure 3 – Concentration of water composition anions on the upstream (Khorog), middle (Darvaz) and downstream (Nijniy Pyanj) of the Pyanj river

To assess water quality for irrigation purposes $Na^+$ or alkaline hazard expressed by the coefficient of sodium adsorption (SAC), is widely used. If the water used for irrigation has a high $Na^+$ and low $Ca^{2+}$ contents the ion-exchange sites can be saturated by $Na^+$ that destroys the soil structure due to the dispersion of clay particles. Such soils reduce plant growth

The sodium adsorption coefficient for the test waters is expressed as follows [22]:

$$SAC = Na^+ / ((Ca^{2+} + Mg^{2+}) / 2)^{1/2}$$

The concentration of cations at the Pyanj river upstream is insignificant and increases downstream. A particularly noticeable increase of the $Na^+$ and $Ca^{2+}$ cations is observed (figure 2). According to Table at the Darvaz and the Nijniy Pyanj hydrological stations, the water of the Pyanj river is slightly alkaline. Therefore, it can be assumed that leaching of coastal ground sediments occurs downstream of the river and water is enriched by $Na^+$ and $Ca^{2+}$ cations.

Thus, the calculated SAC values for water samples at the three water sampling points of Khorog, Darvaz, and Nijniy Pyanj correspond to 0.88; 1.07; 1.71 respectively. The obtained SAC values for all water samples from the Pyanj River indicate their good qualities for irrigation of agricultural land.

The $NO_3^-$ content in upstream water samples corresponds to 0.3 mg/dm$^3$ and increases to 2.2 mg/dm$^3$ in the Pyanj river downstream. Relatively low concentration of the $NO_3^-$ anion along the Pyanj riverbed indicate that there are no stationary sources of anthropogenic pollution from agricultural and municipal wastewater.

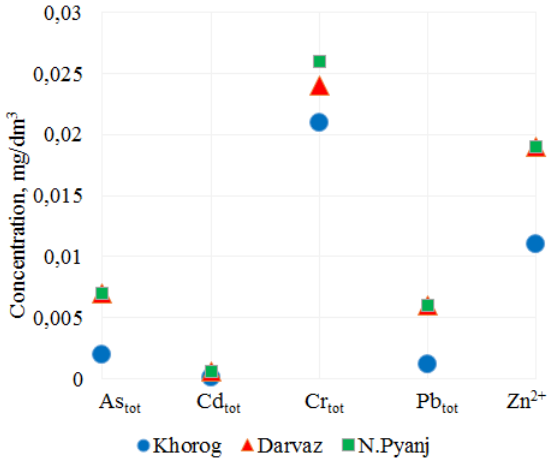


Figure 4 – Concentration of heavy metals on the water composition at the upstream (Khorog), middle reaches (Darvaz) and downstream (Nijniy Pyanj) of the Pyanj river

The content of heavy metals in the composition of the Pyanj river water in the formation zone, the middle course and the Nijniy Pyanj river show that the concentration of heavy metals along the entire channel of the Pyanj River is significantly lower the MPC (figure 4).

**Conclusion.** Summary of the results of chemical analyzes established that the transboundary Pyanj river is not affected by stationary sources of anthropogenic pollution. The nature of the formation of the chemical composition of water is due to the geological properties of the formation zone and the processes of leaching of rocks. In terms of quality, the Pyanj river water throughout the river channel meets all the requirements for drinking water. According to the values of the sodium adsorption coefficient (SAC), the water flow of the Pyanj river is quite suitable for irrigation of agricultural land. The content of heavy metals in the composition of water is significantly lower than the MPC.

**И. Ш. Норматов[1], В. В. Гончарук[2], Н. А. Амиргалиев[3], А. С. Мадибеков[3], А. И. Норматов[4]**

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## ПЯНДЖ ТРАНСШЕКАРАЛЫҚ ӨЗЕНІНІҢ ЖОҒАРҒЫ, ОРТА ЖӘНЕ ТӨМЕНГІ АҒЫСЫНЫҢ ГИДРОХИМИЯСЫ ЖӘНЕ СУАРУ ҮШІН ПАЙДАЛАНУ КРИТЕРИЙЛЕРІ

**Аннотация.** Жұмыс Пяндж трансшекаралық өзенінің қалыптасу аймағынан бастап, өзен арнасы бойымен Амудария трансшекаралық өзенінің басқа саласы – Вахш өзеніне қосылғанға дейінгі суының сапасын кешенді зерттеуге арналған. Пяндж өзенінің суы қалыптасу аймағында өте жұмсақ класқа (шекті мәні 1.5 ммоль/дм$^3$), ал орташа және төменгі ағысындағы суы – жұмсақ класқа (шекті мәні 1.5-3.0 ммоль/дм$^3$) сәйкес келеді. Пяндж өзенінің жоғарғы, орта ағысы мен төменгі ағысынан алынған су сынамаларында сілтілік жер металдары сілтіліктен асып түседі ($Ca^{2+} + Mg^{2+} > Na^+ + K^+$) және әлсіз гидрокарбонат қышқылы күшті қышқылдардан асып түседі ($HCO_3^- > SO_4^{2-} + Cl^-$), жалпы қабылданған Handa жіктемесіне сәйкес оларға уақытша кермек тән. Суару үшін Пяндж өзенінің суын қолдану критерийлерін бағалау үшін сәйкесінше 0,88; 1,07; 1,71 болатын Пяндж өзенінің жоғарғы (Хорог), орта (Дарваз) және төменгі (төменгі Пяндж) су сынамалары үшін натрийдің адсорбция коэффициенті (САС) есептелді. Пяндж өзенінің барлық су үлгілері үшін SAC мәні (жоғарғы, орта және төменгі ағыстардан) ауылшаруашылық жерлерін суару үшін олардың жақсы қасиеттерін көрсетеді. Пяндж өзеніндегі ауыр металдардың концентрациясы шекті рұқсат етілген концентрациядан (ШРК) әлдеқайда төмен.

**Түйін сөздер:** ауылшаруашылығы, жерасты суы, катион ерігіштігі, адсорбциялық, ирригация

**И. Ш. Норматов[1], В. В. Гончарук[2], Н. А. Амиргалиев[3], А. С. Мадибеков[3], А. И. Норматов[4]**

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## ГИДРОХИМИЯ ТРАНСГРАНИЧНОЙ РЕКИ ПЯНДЖ В ВЕРХНЕМ, СРЕДНЕМ И НИЖНЕМ ТЕЧЕНИИ И КРИТЕРИЙ ЕЕ ИСПОЛЬЗОВАНИЯ ДЛЯ ОРОШЕНИЯ

**Аннотация.** Изучено качество воды трансграничной реки Пяндж в зоне формирования и вдоль русла до слияния с другим притоком трансграничной реки Амударьи – рекой Вахш. Качество воды в верхнем течении реки соответствует очень мягкому классу (> 1,5 ммоль/дм3), а в среднем и нижнем течении – мягкому классу (1,5-3,0 ммоль/дм3). В верхнем, среднем и нижнем течении реки Пяндж концентрация щелочноземельных

металлов превышает концентрацию щелочных металлов (Ca2+ + Mg2+> Na+ + K+) при HCO3- > SO42- + Cl – и по классификации Ханда они характеризуются временной жесткостью. Для оценки критерия применимости воды реки Пяндж для орошения был рассчитан коэффициент адсорбции натрия (CAC) для проб воды верхнего (Хорог), среднего (Дарваз) и нижнего (Нижний Пяндж) течения реки Пяндж, которые были равны 0,88; 1,07; 1,71 соответственно. Значения SAC для всех проб воды (из верхнего, среднего и нижнего течения) реки Пяндж указывают на их хорошие качества для орошения сельскохозяйственных угодий. Концентрация тяжелых металлов в реке Пяндж значительно ниже предельно допустимой концентрации (ПДК).

**Ключевые слова:** сельское хозяйство, подземные воды, растворимость катионов, адсорбция, ирригация.

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

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

Редакторы *М. С. Ахметова, Д. С. Аленов, А. Ахметова*
Верстка *Д. А. Абдрахимовой*

Подписано в печать 01.02.2021.
Формат 70x881/8. Бумага офсетная. Печать – ризограф.
12,75 п.л. Тираж 300. Заказ 1.

*Национальная академия наук РК*
*050010, Алматы, ул. Шевченко 28, т. 272-13-19, 272-13-18*