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

«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ

«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ
«ХАЛЫҚ» ЖҚ

ХАБАРЛАРЫ

ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
АКАДЕМИИ НАУК РЕСПУБЛИКИ
КАЗАХСТАН»
ЧФ «Халық»

N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF
KAZAKHSTAN
«Halyk» Private Foundation

SERIES

OF GEOLOGY AND TECHNICAL SCIENCES

3 (465)

MAY – JUNE 2024

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.

ЧФ «ХАЛЫҚ»

В 2016 году для развития и улучшения качества жизни казахстанцев был создан частный Благотворительный фонд «Халык». За годы своей деятельности на реализацию благотворительных проектов в областях образования и науки, социальной защиты, культуры, здравоохранения и спорта, Фонд выделил более 45 миллиардов тенге.

Особое внимание Благотворительный фонд «Халык» уделяет образовательным программам, считая это направление одним из ключевых в своей деятельности. Оказывая поддержку отечественному образованию, Фонд вносит свой посильный вклад в развитие качественного образования в Казахстане. Тем самым способствуя росту числа людей, способных менять жизнь в стране к лучшему – профессионалов в различных сферах, потенциальных лидеров и «великих умов». Одной из значимых инициатив фонда «Халык» в образовательной сфере стал проект Ozgeris powered by Halyk Fund – первый в стране бизнес-инкубатор для учащихся 9-11 классов, который помогает развивать необходимые в современном мире предпринимательские навыки. Так, на содействие малому бизнесу школьников было выделено более 200 грантов. Для поддержки талантливых и мотивированных детей Фонд неоднократно выделял гранты на обучение в Международной школе «Мирас» и в Astana IT University, а также помог казахстанским школьникам принять участие в престижном конкурсе «USTEM Robotics» в США. Авторские работы в рамках проекта «Тәлімгер», которому Фонд оказал поддержку, легли в основу учебной программы, учебников и учебно-методических книг по предмету «Основы предпринимательства и бизнеса», преподаваемого в 10-11 классах казахстанских школ и колледжей.

Помимо помощи школьникам, учащимся колледжей и студентам Фонд считает важным внести свой вклад в повышение квалификации педагогов, совершенствование их знаний и навыков, поскольку именно они являются проводниками знаний будущих поколений казахстанцев. При поддержке Фонда «Халык» в южной столице был организован ежегодный городской конкурс педагогов «Almaty Digital Ustaz.

Важной инициативой стал реализуемый проект по обучению основам финансовой грамотности преподавателей из восьми областей Казахстана, что должно оказать существенное влияние на воспитание финансовой грамотности и предпринимательского мышления у нового поколения граждан страны.

Необходимую помощь Фонд «Халык» оказывает и тем, кто особенно остро в ней нуждается. В рамках социальной защиты населения активно проводится работа по поддержке детей, оставшихся без родителей, детей и взрослых из социально уязвимых слоев населения, людей с ограниченными возможностями, а также обеспечению нуждающихся социальным жильем, строительству социально важных объектов, таких как детские сады, детские площадки и физкультурно-оздоровительные комплексы.

В копилку добрых дел Фонда «Халык» можно добавить оказание помощи детскому спорту, куда относится поддержка в развитии детского футбола и карате в нашей стране. Жизненно важную помощь Благотворительный фонд «Халык» оказал нашим соотечественникам во время недавней пандемии COVID-19. Тогда, в разгар тяжелой борьбы с коронавирусной инфекцией Фонд выделил свыше 11 миллиардов тенге на приобретение необходимого медицинского оборудования и дорогостоящих медицинских препаратов, автомобилей скорой медицинской помощи и средств защиты, адресную материальную помощь социально уязвимым слоям населения и денежные выплаты медицинским работникам.

В 2023 году наряду с другими проектами, нацеленными на повышение благосостояния казахстанских граждан Фонд решил уделить особое внимание науке, поскольку она является частью общественной культуры, а уровень ее развития определяет уровень развития государства.

Поддержка Фондом выпуска журналов Национальной Академии наук Республики Казахстан, которые входят в международные фонды Scopus и Wos и в которых публикуются статьи отечественных ученых, докторантов и магистрантов, а также научных сотрудников высших учебных заведений и научно-исследовательских институтов нашей страны является не менее значимым вкладом Фонда в развитие казахстанского общества.

С уважением,
Благотворительный Фонд «Халык»!

«ҚР ҰҒА» РҚБ 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/

«Известия РОО «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/

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/

NEWS of the National Academy of Sciences of the Republic of Kazakhstan
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224–5278
Volume 3. Number 465 (2024), 82–94
https://doi.org/10.32014/2024.2518-170X.411
UDC 556.512; 556.532; 556.542; 546.552; 556.562

© A.S. Madibekov[1], A.M. Karimov[2], L.T. Ismukhanova[1], A.O. Zhadi[1*], K.M. Bolatov[1], 2024

[1] JSC «Institute of geography and water security» MSHE RK, Almaty, Kazakhstan;
[2] LLP «Fesenkov Astrophysical Institute», Almaty, Kazakhstan.
E-mail: askhat.zhadi@mail.ru

MARKAKOL LAKE LEVEL REGIME AS INDICATOR OF CLIMATE CHANGE

Madibekov A.S. — Leading researcher, JSC «Institute of geography and water security» MSHE RK, Almaty, Kazakhstan
E-mail: a.s.madibekov@gmail.com, https://orcid.org/0000-0001-9303-6640;
Karimov A.M. — Researcher, LLP «Fesenkov Astrophysical Institute», Almaty, Kazakhstan
E-mail: karalik0@mail.ru, https://orcid.org/0000-0003-0797-6252;
Ismukhanova L.T. — Senior researcher, JSC «Institute of geography and water security» MSHE RK, Almaty, Kazakhstan
E-mail: ismuhanovalaura@gmail.com, https://orcid.org/0000-0001-6421-8621;
Zhadi A.O. — Junior researcher, JSC «Institute of geography and water security» MSHE RK, Almaty, Kazakhstan
Email: askhat.zhadi@mail.ru, https://orcid.org/0000-0001-7044-3454;
Bolatov K.M. — Researcher, JSC «Institute of geography and water security» MSHE RK, 050010 Almaty, Kazakhstan
E-mail: kaynar.bolatov@gmail.com, https://orcid.org/0000-0002-6349-8569.

Abstract. The results of the study of fluctuations in the level of Markakol Lake under the influence of climate change are considered. Markakol is one of the high–altitude lakes of Kazakhstan, into which several relatively large rivers flow, including the Urunhaika River, and the Kalzhir River flows from the lake. Lake level Markakol and the flowing river are considered as the main components of the water balance of Markakol Lake. Based on statistical analysis, regression models of levels depending on air temperature are obtained. It has been established that the average monthly values of the level in Markakol Lake, in the period from April to November, have a close correlation with the air temperature at the level of 0.60. The average seasonal level of the summer period of the Kalzhir River (near the village of Chernyaevka) has an inverse correlation with the average monthly temperature in May, at minus 0.65. This is due to the evaporation process, which directly depends on the temperature background of the intermountain depression (graben) in which the lake is located. The obtained regression equations allow us to estimate fluctuations in water levels. The inflow of water into the lake will increase by 0.2 % on average with a projected increase in air temperature at 0.25 °C/decade, and the outflow from the lake will decrease by about 3 %. It will also be necessary to build an evaporation model for the final assessment of changes in the level of Markakol Lake under the influence of changes in air temperature. A more detailed analysis of the components of the water balance indicates a decrease in the water level in the lake by 0.266 %. In the end, in general, the water level in the lake is expected to drop by no more than 0.1 % per decade.

Keywords: climate change, evaporation, lake, temperature, water balance, water level

Acknowledgements. *This research was funded by the grant of the Ministry of Science and Higher Education of the Republic of Kazakhstan individual registration number AR14870595 "Monitoring and evaluation of micro- and macroplastics in the aquatic environment of Markakol lake".*
Data availability statement. *All relevant data are included in the paper or its Supplementary Information.*
Conflict of interest. *The authors declare there is no conflict.*

© **А.С. Мадибеков[1], А.М. Каримов[2], Л.Т. Исмуханова[1], А.Ө. Жәди[1*], К.М. Болатов[1]**

[1]«География және су қауіпсіздігі институты» ҚР ҒЖБМ, Алматы, Қазақстан;
[2]«В.Г. Фесенков атындағы астрофизикалық институт» ЖШС, Алматы, Қазақстан.

E-mail: askhat.zhadi@mail.ru

МАРҚАКӨЛ КӨЛІНІҢ ДЕҢГЕЙЛІК РЕЖИМІ КЛИМАТТЫҢ ӨЗГЕРУІНІҢ КӨРСЕТКІШІ РЕТІНДЕ

Мадибеков А.С. — PhD, қауымдастырылған профессор, Гидрохимия және экологиялық токсикология зертханасының жетекшісі, «География және су қауіпсіздігі институты» АҚ, Алматы, Қазақстан
E-mail: madibekov@mail.ru, https://orcid.org/0000-0001-9303-6640;
Каримов А.М. — Ай және планеталар физикасы зертханасының ғылыми қызметкері, «В.Г. Фесенков атындағы астрофизикалық институт» ЖШС, Алматы, Қазақстан
E-mail: karalik0@mail.ru, https://orcid.org/0000-0003-0797-6252;
Исмуханова Л.Т. — Гидрохимия және экологиялық токсикология зертханасының аға ғылыми қызметкері, «География және су қауіпсіздігі институты» АҚ, Алматы, Қазақстан
E-mail: l--aura@bk.ru, https://orcid.org/0000-0001-6421-8621;
Жәди А.Ө. — Гидрохимия және экологиялық токсикология зертханасының кіші ғылыми қызметкері, «География және су қауіпсіздігі институты» АҚ, Алматы, Қазақстан
E-mail: askhat.zhadi@mail.ru, https://orcid.org/0000-0001-7044-3454;
Болатов К.М. — Гидрохимия және экологиялық токсикология зертханасының ғылыми қызметкері, «География және су қауіпсіздігі институты» АҚ, Алматы, Қазақстан
E-mail: kaynar404@mail.ru, https://orcid.org/0000-0002-6349-8569.

Аннотация. Климаттың өзгеруінің әсерінен Марқакөл көлінің деңгейінің ауытқуын зерттеу нәтижелері қарастырылды. Марқакөл – Қазақстанның биік таулы көлдерінің бірі, оған бірнеше салыстырмалы түрде ірі өзендер, соның ішінде Урунхайка өзені құяды және көлден Қалжыр өзені ағып шығады. Марқакөл көлі мен ағып жатқан өзен деңгейі Марқакөл көлінің су балансының негізгі құрамдас бөлігі ретінде қарастырылады. Статистикалық талдау негізінде ауа температурасына байланысты деңгейлердің регрессиялық модельдері алынды. Марқакөл көліндегі деңгейдің орташа айлық мәндері сәуір мен қараша айлары аралығында ауа температурасымен 0,60 деңгейінде тығыз корреляцияға ие. Қалжыр өзенінің жазғы кезеңінің орташа маусымдық деңгейі (Черняевка ауылының маңында) мамыр айындағы орташа айлық температурамен кері корреляциялық байланысқа ие, минус 0,65 деңгейінде. Бұл булану процесіне байланысты, ол көл орналасқан тау аралық депрессияның (грабен) температуралық фонына тікелей байланысты. Алынған регрессия теңдеулері су деңгейінің ауытқуын бағалауға мүмкіндік береді. Ауа температурасының 0,25 °C/онжылдықта болжамды өсуімен көлге су ағыны орта есеппен 0,2 % артады, көлден ағу шамамен 3 % төмендейді. Сондай-ақ, ауа температурасының өзгеруінің әсерінен Марқакөл көлінің деңгейінің өзгеруін түпкілікті бағалау үшін булану моделін құру қажет болады. Су балансының құрамдас бөліктерін егжей-тегжейлі талдау көлдегі су деңгейінің 0,266 % төмендеуін көрсетеді. Қорытындылай келгенде, жалпы алғанда, онжылдықта 0,1 % аспайтын көлде су деңгейінің төмендеуі күтілуде.

Түйін сөздер: көл, су деңгейі, климаттың өзгеруі, су балансы, булану, температура

© **А.С. Мадибеков[1], А.М. Каримов[2], Л.Т. Исмуханова[1], А.Ө. Жәди[1*], К.М. Болатов[1]**

[1] АО «Институт географии и водной безопасности», Алматы, Казахстан;
[2] ТОО «Астрофизический институт им. В.И. Фесенкова», Алматы, Казахстан.
E-mail: askhat.zhadi@mail.ru

УРОВЕННЫЙ РЕЖИМ ОЗЕРА МАРКАКОЛЬ КАК ИНДИКАТОР ИЗМЕНЕНИЯ КЛИМАТА

Мадибеков А.С. — PhD, ассоциированный профессор, руководитель Лаборатории гидрохимии и экологической токсикологии, АО «Институт географии и водной безопасности», Алматы, Казахстан
E-mail: madibekov@mail.ru, https://orcid.org/0000-0001-9303-6640;
Каримов А.М. — научный сотрудник Лаборатории физики Луны и планет, ТОО «Астрофизический институт им. В.И. Фесенкова», Алматы, Казахстан
E-mail: karalik0@mail.ru, https://orcid.org/0000-0003-0797-6252;
Исмуханова Л.Т. — старший научный сотрудник Лаборатории гидрохимии и экологической токсикологии, АО «Институт географии и водной безопасности», Алматы, Казахстан
E-mail: l--aura@bk.ru, https://orcid.org/0000-0001-6421-8621;
Жәди А.Ө. — младший научный сотрудник Лаборатории гидрохимии и экологической токсикологии, АО «Институт географии и водной безопасности», Алматы, Казахстан
E-mail: askhat.zhadi@mail.ru, https://orcid.org/0000-0001-7044-3454;
Болатов К.М. — научный сотрудник Лаборатории гидрохимии и экологической токсикологии, АО «Институт географии и водной безопасности», Алматы, Казахстан
E-mail: kaynar404@mail.ru, https://orcid.org/0000-0002-6349-8569.

Аннотация. Рассмотрены результаты исследования колебаний уровня озера Маркаколь под влиянием изменения климата. Маркаколь – одно из высокогорных озер Казахстана, в которое впадает несколько относительно крупных рек, среди которых река Урунхайка, и вытекает из озера река Калжир. Уровень озера Маркаколь и вытекающей реки рассматриваются как основные составляющие водного баланса озера Маркаколь. На основе статистического анализа получены регрессионные модели уровней в зависимости от температуры воздуха. Установлено: среднемесячные значения уровня в озере Маркаколь в период с апреля по ноябрь имеют тесноту корреляции с температурой воздуха на уровне 0,60. Среднесезонный уровень летнего периода реки Калжир (у села Черняевка) имеет обратную корреляционную связь со среднемесячной температурой в мае на уровне минус 0,65. Это связано с процессом испарения, которое напрямую зависит от температурного фона межгорной впадины (грабена), в которой находится озеро. Полученные уравнения регрессии позволяют оценить колебания уровней воды.

При прогнозируемом росте температуры воздуха на уровне 0,25 °С/десятилетие приток воды в озеро в среднем увеличится на 0,2 %, отток из озера примерно снизится на 3 %. Также потребуется построение модели испарения для окончательной оценки изменения уровня озера Маркаколь под влиянием изменения температуры воздуха. Более детальный анализ составляющих водного баланса указывает на падение уровня воды в озере на 0,266 %. В конечном итоге, в целом, ожидается падение уровня воды в озере не более 0,1 % за десятилетие.

Ключевые слова: озеро, уровень воды, изменение климата, водный баланс, испарение, температура

Introduction

As a result of global warming and intense climate change in recent decades, the intermittence of temperature regime in lake ecosystems is observed (Li et al., 2013; Scapozza & Patocchi, 2023; Wrzesiński & Plewa, 2016). In addition, the chemical composition and biological balance are subject to changes, which can lead to eutrophication of the lake (Zhang et al., 2018). Based on the results of forecasting changes in air temperature, this study assesses changes in the components of the water balance which are the leading factors determining the lake level regime when precipitation amounts change against the background of rising temperatures. By the direct analysis of the relationship between air temperature and water level we can see directly proportional relationship between the increases in water level (accompanying warming) due to the melting of glaciers that feed the rivers in the lake's catchment area (Nam et al., 2023; Zhang et al., 2024). However, increase in temperature also has a reverse mechanism of influence through evaporation. In addition, precipitation amounts have tended to decrease over the past 40 years (Guan et al., 2022; Salnikov et al., 2023; Voyevodina et al., 2022). Comparison of the relationship between air temperature and water level and the sum of the water balance components turns out to be more objective in the second case. And that is more fully reflecting the existing picture. In addition, it is required to take into account the existing outflow from the lake, which is inversely related to temperature. Based on multiple statistical relationships, prognostic equation for the water level in the lake was obtained based on the water balance components, taking into account temperature changes.

Materials and research methods

Markakol Lake is tectonic and is the second largest lake in Ertis River basin, located in Southern Altai between the Kurchum and Azutau ridges in the deepest part of the graben at the altitude of 1449 m, its area is 449 km^2 (Figure 1). The length of the lake is 38 km, the width is 19 km, the surface area is 455 km^2, the average depth is 14 m and the greatest is 24 m. The large number of tributaries inflowing the lake (Musakulkyzy & Madibekov, 2016; Volokitina et al., 2021).

The following rivers inflowing Markakol Lake: Zhirelka, Elovka, Matabay, Tikhushka, Topolevka, Urunkhaika. Kalzhyr River flows out of the lake and inflows Ertis River. As a result of climate change (increase in temperature and precipitation) the lake ecosystem will be subjected to fluctuations in the level and to the influence of nutrients, which will lead to eutrophication of the reservoir and river ecosystem, which determine the lake water balance (Madibekov et al., 2024; Madibekov et al., 2018). To analyze the current state of the ecosystem, the following data was used: water levels of Markakol Lake and Kalzhyr rivers, air temperature and humidity according to observations data of Markakol weather station and calculated evaporation values.

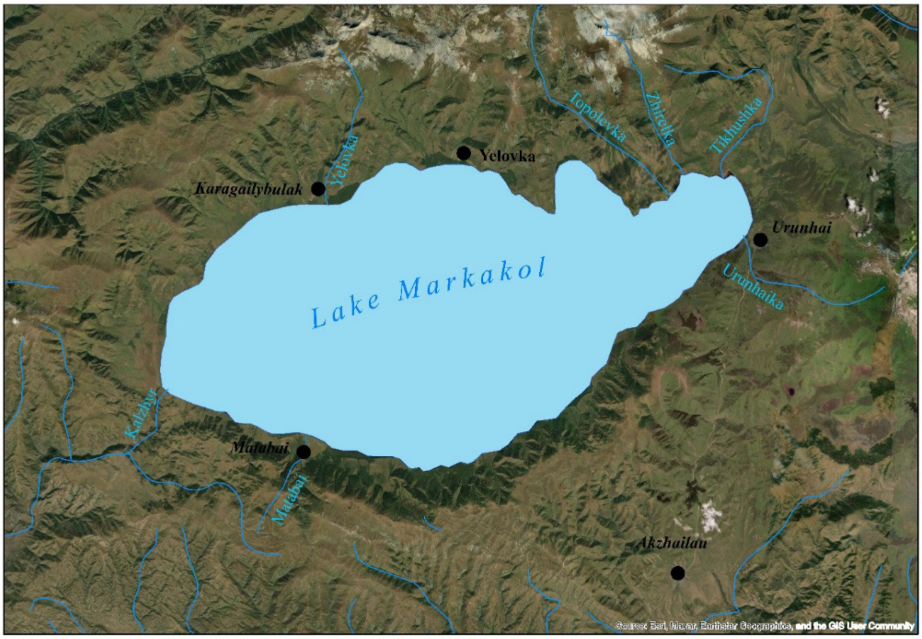

Figure 1. Rivers net in the area of Markakol Lake

Results.

The studies of this work are based on the study of the climatic features of Markakol Lake ecosystem. The obtained results described by climatic characteristics are taken as initial conditions, which are subject to changes that determine the expected fluctuations of the ecosystem under the global warming influence. According to expert estimates (Masson-Delmotte et al., 2022; Dvorak et al., 2021), in the period 2020–2040 the average air temperature on the planet will increase by 0.5 °C. By including this magnitude of changes in the climate system into the calculations, it is possible to approximately estimate the conditions under which the natural environment will continue to exist.

As a result of the analysis, the correlation coefficients between air temperature and water levels were obtained. Average monthly water level values of Markakol Lake in the period from April to November have a close correlation with air temperature at the level of 0.60. The average seasonal level of the summer period of Kalzhyr River (near the village of Chernyayevka) has an inverse correlation with the average monthly temperature in May at the level of minus 0.65. These correlation coefficients characterize a linear trend, which does not always describe the existing relationship between values that are indirectly related to each other. The relationship between quantities could be approximated by curves that have more complex equations described by power, exponential and logarithmic functions. When choosing nonlinear approximating functions, the closeness of the correlation relationship can be higher compared to linear equations. The nonlinearity of the correlation relationship can be caused by strong relief dissection, remoteness of meteorological stations, inertia of processes forming the water balance and by a number of other factors.

The temperature background characterizing these correlations determines the melting of glaciers, which in turn feed the rivers flowing into the lake. For the Markakol Lake, the period of formation of the main flow is from April to November inclusive. In April in average observed the temperature transition through 0 °C, which is not reflected in the average monthly data. The influence of temperatures to the water level in November is not entirely explainable. Average temperature in November in 1983–2022 was -8.2 °C (Appendix Table 3). By excluding November temperatures from the calculations, there is a drop in the temperature-level correlation by 6 %. Probably, there is an inertial mechanism for the release of groundwater feeding the Markakol Lake. Part of the underground flow from the heated layers of the earth continues to contribute to Markakol Lake level although the average monthly air temperatures in November are negative. Or it could be that the entire catchment area of the Markakol Lake functions with a certain degree of inertia. At the same time, the hydrological observation station in the village of Urunkhaika is located in the coastal zone of Markakol Lake.

In summer, the average level of Kalzhyr River (flowing from the lake) is in inverse correlation with May average monthly air temperatures at the level of 0.65–0.69 (Table 1). The negative nature of the correlation is probably due to the fact that by increase of air temperature increases also the evaporation, which reduces the lake level. As the lake level decreases, the outflow from it decreases. The maximum level in Kalzhyr River is observed in May-June. At the beginning of summer, the high level of the lake becomes the initiating factor for increased outflow of water from it. Thus, there is a dynamic factor of the lake water pressure to the Kalzhyr River flow volumes. The hydrological measuring station on the Kalzhyr River is located in the village of Chernyayevka at the distance of more than 65 kilometers south of the Markakol Lake coastline. Along the entire course of the river there is inflow to the Kalzhyr River, which reduces the statistical relationship between temperature and outflow level.

Some characteristics, correlations and regression equations linking air temperature with the levels of Markakol Lake and Kalzhyr river are presented in Table 1.

Table 1. Characteristics of statistical relationships between air temperature (t °C) and water levels (h m) in the Markakol Lake (t, h April-November) and Kalzhyr river (t May, h^* June-August).

Observation period	Correlation coefficient		Trend type (degree)	Regression equation
	Linear r	Trend r^*		
Markakol Lake (1983-2022)	0,6066	0,6127	Polynomial (2)	$h_{IV\text{-}XI} = 0{,}0254t^2_{IV\text{-}XI} + 0{,}9684t_{IV\text{-}XI} + 149{,}53$
Kalzhyr River (1983-2005)	-0,6544	-0,6958	Polynomial (4)	$h^*_{VI\text{-}VIII} = 0{,}0489t^4_V - 1{,}1216t^3_V + 9{,}8557t^2_V - 44{,}361t_V + 124{,}12$

As can be seen from Table 1, by using a power-law trend, there is an increase in the closeness of the connection with increasing degree of the polynomial trend, which makes it possible to use the obtained regression equations with higher reliability for the natural processes modeling.

Increase in temperature can have a dual meaning. On the one hand, increase in air temperature increases evaporation (Buis, 2022). At the same time (Zhu et al., 2022; Kumar et al., 2022; Li et al., 2013; Serikbay et al., 2023), increase in the thermal background leads to increase in the melting of glaciers that feed the rivers inflowing Markakol Lake. This factor works in relation to the Markakol Lake, where there is a direct connection between rising temperatures and rising water levels. In Kalzhyr River which flowing out of the lake, there is a decrease in level as the temperature rises. Most likely this happens because decrease in the level of Markakol Lake itself leads to decrease in outflow through the Kalzhyr River. By prognosis of the lake level depending on temperature changes it becomes necessary to analyze the elements of the water balance of both - Markakol Lake itself and the water balance of the rivers feeding this reservoir. It is also important to analyze the water regime of the Kalzhyr River taking into account climate change (temperature rise and changes in precipitation).

The main elements of the lake's water balance are inflow and outflow of rivers feeding the lake (level), amount of precipitation and evaporation from the water surface. Since evaporation from the water surface can be considered as the maximum accepted by unlimited moisture reserves, it can be considered as evaporability. Secondary (implicit) elements of the water balance can be considered: groundwater outflows, dew formation and economic activity (anthropogenic factor). Industrial economic activity is prohibited in the territory of the Markakol Lake Nature Reserve, as it belongs to Specially Protected Natural Areas. Outside this reserve, water intake from the rivers that feed the lake is possible (Biological substantiation..., 2021). Illegal fishing activity, in isolated cases, primarily affects the biological component of the entire ecosystem of the lake (Wang et al., 2023). Chemical pollution of the lake is determined by such substances as: Zinc (Zn), Copper (Cu), Polychlorinated biphenyls (PCBs) (Madibekov et al., 2024).

This study, covering the period 1983-2022, considers such elements of the water balance as the amount of precipitation and evaporation from the surface of the lake, according to the data of meteorological station "Markakol Reserve" 48°48.402'N, 85°50.778'E; 1500 m above sea level. Evaporability was determined by the formula of N.N. Ivanov (Khromov and **M**amontova, 1974):

$$\mathbf{E}_m = 0{,}0018 \times (25 + t)^2 \times (100 - f) \quad (1)$$

where, $\mathbf{E}_m$ – evaporability in mm. t – air temperature **°C.** f – relative humidity in percent. Next, a multiple regression equation was obtained for the Markakol Lake:

$$h_{\text{VI-X}} = -\,0{,}0565\mathbf{E}_{m\text{IV-IX}} + 0{,}0713R_{\text{IV-IX}} + 165{,}691 \quad (2)$$

where, $h_{\text{VI-X}}$ – average water level in meters (June-October). $\mathbf{E}_{m\text{IV-IX}}$ – evaporability in millimeters (April-September), is the sum of the water layers evaporating from the lake water surface. $R_{\text{IV-IX}}$ – amount of precipitation in millimeters (April-September). Overall multiple correlation coefficient r_m = 0,7139. The amount of precipitation taken during the period April-September determines the runoff of the liquid part of precipitation.

The volume of meltwater was not estimated in this study due to the lack of data, although this value is the most important component of the runoff feeding Markakol Lake. This fact probably significantly reduces the closeness of the multiple correlations. The time series of precipitation amounts for the period April-September is presented in Figure 2.

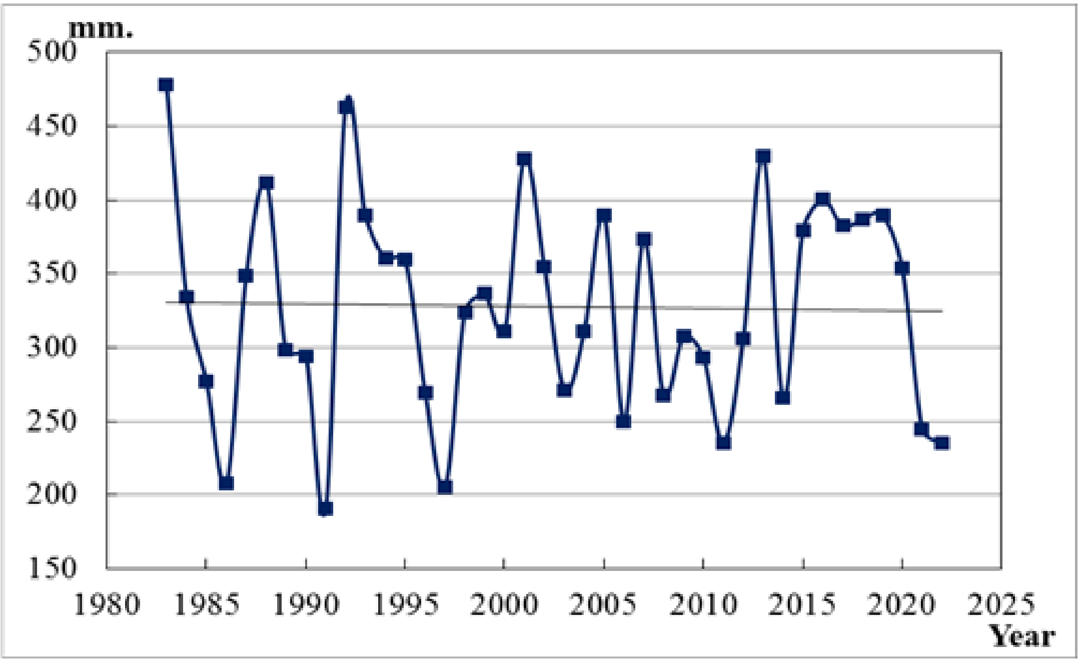

Figure 2. Annual precipitation amounts for the period April-September, weather station "Markakol Nature Reserve"

As can be seen from Figure 2, over the forty-year period there is a slight downward trend in precipitation amounts in April-September. The rate of decline is approximately 2 % over 40 years, or -0.5 %/decade.

The evaporability value calculated using formula 1 is provided in Table 2 for the warm period (April-September), at the boundaries of which a temperature transition through 0 °C is observed. Positive temperatures determine the state of evaporation from the ice-free water surface, the appearance of which also indicates an increase in the energy of the solar radiation ranges responsible for evaporation (Buis, 2022; Nyssanbayeva et al., 2019). Maximum evaporation from the surface of the lake occurs in the summer months against the background of high air temperatures and warming of the water surface.

Table 2. Amount of evaporation (evaporability) from the surface of Markakol Lake during the warm period, mm.

Year	April	May	June	July	August	September	October
1983	33,94	42,23	88,85	94,07	89,10	61,73	39,24
1984	20,41	62,61	68,56	83,36	112,65	73,07	35,64
1985	27,90	58,35	74,58	97,73	88,25	79,46	29,53
1986	28,17	65,92	75,39	118,14	86,47	84,93	36,85
1987	21,04	95,65	75,13	108,40	112,23	70,27	14,94
1988	22,90	48,27	93,75	82,12	75,31	79,25	32,45
1989	29,22	73,57	90,95	111,17	135,26	74,19	37,01
1990	34,11	83,19	134,43	82,34	86,89	89,68	47,22

1991	31,79	83,07	104,30	104,98	86,09	93,79	45,53
1992	26,08	65,40	81,21	101,59	61,41	54,43	51,63
1993	23,11	52,76	80,60	82,96	82,39	70,68	44,78
1994	24,02	58,71	119,90	111,98	92,23	67,50	42,12
1995	39,02	50,56	102,39	104,73	82,67	98,32	46,32
1996	25,16	80,80	105,98	111,14	125,06	68,21	37,95
1997	73,58	74,71	121,85	125,19	120,73	132,42	100,83
1998	24,62	69,73	118,10	105,34	145,04	97,40	50,20
1999	32,59	97,65	97,62	108,41	123,93	63,69	53,79
2000	62,12	61,46	84,61	117,35	123,73	118,42	-
2001	25,30	79,79	111,91	90,46	100,90	70,99	44,82
2002	29,74	69,58	87,70	92,57	112,82	108,99	52,81
2003	22,40	77,62	111,38	71,00	103,98	94,63	55,78
2004	35,34	96,20	124,22	96,56	99,56	88,36	57,40
2005	33,20	73,08	89,62	99,48	90,79	100,32	68,08
2006	37,41	86,26	108,79	98,34	115,17	108,30	44,37
2007	67,63	65,22	85,27	74,38	101,36	99,53	45,23
2008	40,69	100,70	128,62	140,70	134,80	68,12	45,27
2009	43,08	76,53	73,42	107,75	102,94	68,58	51,19
2010	26,54	53,98	100,42	94,09	114,88	103,74	60,12
2011	36,63	85,15	84,75	119,54	110,84	127,77	63,26
2012	58,87	85,79	94,09	96,00	102,97	92,27	36,93
2013	34,46	63,04	74,15	70,17	64,86	87,21	50,39
2014	46,47	90,79	97,66	97,69	116,65	94,58	22,86
2015	25,10	74,21	98,78	108,82	132,39	61,34	48,12
2016	37,87	74,08	77,53	74,35	106,33	79,79	18,35
2017	37,28	87,08	97,47	111,56	109,56	72,90	41,83
2018	39,48	52,85	125,13	108,63	95,66	71,18	47,12
2019	36,81	65,47	88,84	100,15	112,07	71,30	52,44
2020	60,31	110,96	101,85	83,74	93,20	69,82	39,14
2021	32,43	96,44	96,07	111,91	105,18	92,48	41,39
2022	45,04	109,07	114,77	105,78	115,39	111,45	51,06
Note: «-» – no data							

Equation 2 includes evaporation and the amount of precipitation; the calculation of the first term includes temperature and relative humidity, which is also a function of temperature. By increasing the average of a series of available temperatures by the projected change of 0.25 **°C/decade, we obtained modified value of evaporation taking into account expected warming**. The amount of precipitation for the period April-September, by years, is shown in Figure 2. The magnitude of changes in precipitation amounts, as already noted, is taken at the level of -0.5 %/decade. By adding this value to the average for the decade, we change the average amount of precipitation for the decade. Taking into account the changes made, an average decrease in level in the Markakol Lake was obtained (according to equation 2), which averages 0.48 %/decade, against the background of increase in evaporation of 0.625 %/decade. The decrease in Kalzhyr River level will be about 3 %/decade. Thus, in general, there will be decrease in water levels, decrease in precipitation amounts and increase in evaporation.

Discussion

Initially, the statistical relationship between air temperature and water level (Markakol Lake) was considered for the period April-November. Monthly average pairs of values were compared over forty years of research from 1983-2022. The result of these comparisons is presented in Figure 3.

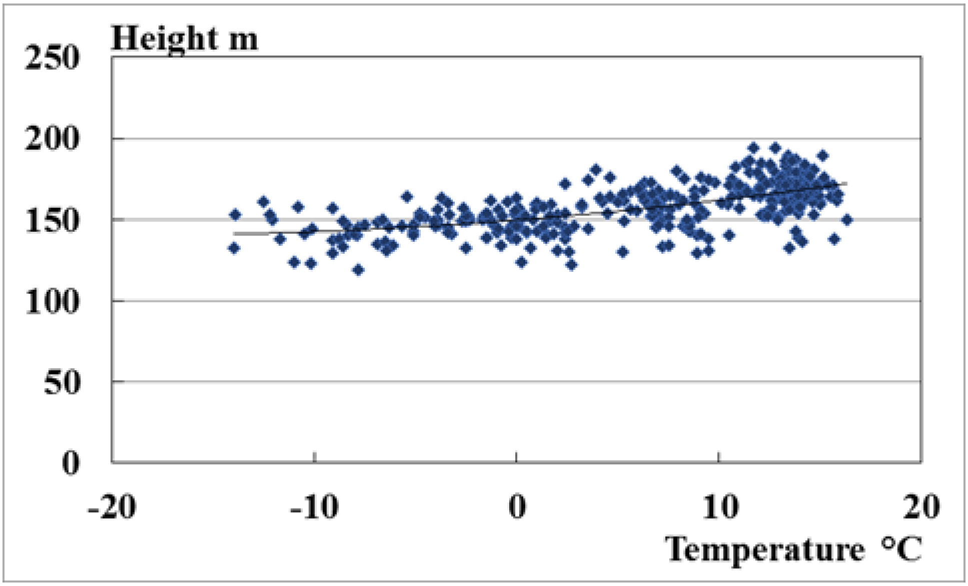

Figure 3. Distribution of average monthly pair values air temperature-water level (Markakol Lake) for the period April-November, 1983-2022. Trend equation and the closeness of the correlation are shown in Table 1

Increasing the temperature by average ten-day value of 0.25 °C, the average level in the Markakol Lake was recalculated using the trend equation, it turned out to be 0.2 % higher compared to the average initial value.

According to the regression equation obtained for the Kalzhyr River (Table 1), the average air temperature in May determines the summer level of water flowing from the lake. With an increase in average air temperature in May by 0.25 °C/decade, the decrease in outflow partially (by 3 %/decade) compensates the decrease in losses due to water inflow. Loss of moisture from the surface of the lake will occur due to increased evaporation as the temperature rises.

Taking into account all the elements of the lake's water balance available for analysis, a multiple correlation equation was obtained in which the water level at Markakol Lake *h* (April-September) is considered depending on the amount of precipitation *R* (April-September), evaporation *Em* (April-September) and water level in Kalzhyr River *h** (April-September) flowing out of the lake:

$$h_{\text{IV-IX}} = 0{,}1289R_{\text{IV-IX}} + 0{,}2109E_{m\ \text{IV-IX}} + 0{,}1656h^{*}_{\text{IV-IX}} + 129{,}972 \quad (3)$$

The multiple correlation coefficient r_m for this equation is 0.6509. Equation 3 was obtained from relatively continuous data series characterizing the time period 1995–2005. Further, taking into account the existing trend of changes in precipitation amounts -0.5 %, the average precipitation amounts were reduced by this amount. By calculating evaporation (according to equation 1) and water level in Kalzhyr River (Table 1), average temperatures were included in the calculations, taking into account a projected increase of 0.25 °C/decade. Increase in evaporation of 0.625 %/decade is also critical element of the water balance, reducing the water level in the lake. To compare the average level at Markakol Lake mouth and recalculated level taking into account climate change, there was obtained expected level decrease (minus 0.266 %). In total, decrease in outflow through the Kalzhyr River by 3%/10 years, decrease in precipitation during periods of positive temperatures and increase in evaporation will ensure decrease in the lake water level by 0.66 %, compared to the lake level calculated using the temperature-level model. This can be considered as more multifactorial forecast by analyzing more components of the water balance. Despite the general trend of rising water levels of Markakol Lake, with increasing temperatures there are more reasons to consider decrease in lake level as the most likely scenario. This is indicated by more comprehensive analysis of the water balance components: amount of precipitation, evaporation and decrease in the level of melt water. Decrease in Kalzhyr River level, which is a tributary of the Ertis River, looks clearer.

Conclusion

All possible fluctuations in the components of the lake's water balance are based on global warming value of 0.25 °C/decade. In the analysis, this value was added to the average characteristic without progressive increase over time, just as in the case of precipitation trends.

In addition to adding temperature to the average calculated characteristics, we also analyzed for forty years (1983–2022) the own trends in precipitation amounts for the period April-September and average monthly pairs of air temperature-water level values at Markakol Lake for the period April-November. Increase in the trend of the lake water level taking into account climate warming will be compensated by decrease in precipitation amounts in the April-September period and by increase in evaporation in the same season.

The increase in evaporation is estimated at 0.625 %/decade. Warming will not only lead to increase in air temperature, but also the surface water temperature experiencing increase will contribute to increase in the supply of moisture from the lake surface to the atmosphere.

Precipitation amounts for the April-September period had a general decreasing trend of -0.5 % per decade. This trend value was included in the calculations when analyzing the water balance of Markakol Lake. During the analyzed period 1983–2022 in the season of positive temperatures, precipitation amounts decreased by 2 %. This decline is the predominant factor determining lake levels in the near future.

Taking into account the expected climate change (Dvorak et al. 2021), decrease in precipitation against the background of increased evaporation and decrease in outflow from the lake, the water level in the lake is expected to decrease by minus 0.266 %.

The level of the Kalzhyr River is influenced by the dynamic factor: the high-water level in the lake determines the high-water flow from it. Thus, decrease in the lake water level will lead to the shallowing of the Kalzhyr River by 3 %. This will reduce the flow into Ertis River.

REFERENCES

Biological substantination for the program: *"*Determination of fish productivity of fishery reservoirs and/or their areas, development of biological substantination for the maximum permissible limit of fish and other aquatic animals, the regime and regulation of fishing in fishery reservoirs of international and republican significance and water bodies of the protected areas of Yertis basin, as well as assessment of the state of fish resources in reserve water bodies of local importance*"* Section: Reservoir of the Markakol State Nature Reserve (Markakol Lake). — Ust-Kamenogorsk: NPC RH LLP, — 2021. — 49 p. State registration number 0121PK00639. (in Russ.).

Buis A. (2022). Steamy relationships: how atmospheric water vapor amplifies Earth's greenhouse effect. https://climate.nasa.gov/explore/ask-nasa-climate/3143/steamy-relationships-how-atmospheric-water-vapor-amplifies-earths-greenhouse-effect/#:~:text=It%20works%20like%20this%3A%20As,concentration%20of%-20water%20vapor%20increases. (accessed 8 February 2022)

Dauletkhan G.J., Zhumalipov A.R. (2019). Meteorological aspects of the influence of air pollution on Lake Markakol// Young Scientist. — 45. — Pp. 391–395. (in Kaz.).

Doganovskiy A.M. (2007). The level regime determines the integral indicator of climatic and environmental changes// Society. Environment. Development. (Terra Humana). — 1. — Pp. 103–110. (in Russ.).

Dvorak M., Armour K., Frierson Dargan M.W., Proistosescu C., Baker M., Smith Ch. (2021). When will the world be committed to 1.5 and 2.0°C of global warming?// Research Square. — Pp. 1–27. — DOI: 10.21203/rs.3.rs-969513/v1

Guan X., Langhamer L., Schneider Ch. (2022). Lagrangian analysis of moisture sources of precipitation in the Tianshan Mountains, Central Asia// Earth and Space Science. — 9(7). — DOI: 10.1029/2022EA002318

Khromov C.P., Mamontova L.I. (1974). Meteorological Dictionary// L.: Gidrometeoizdat. — 569 p. (in Russ.).

Kumar R., Manzoor S., Vishwakarma D.K., Al-Ansari N., Kushwaha N.L., Elbeltagi A., Sushanth K., Prasad V., Kuriqi A. (2022). Assessment of climate change impact on snowmelt runoff in Himalayan Region// Sustainability. — 14(3). — 1150. DOI: 10.3390/su14031150

Li B., Yaning Ch., Chen Zh., Li W., Zhang B. (2013). Variations of temperature and precipitation of snowmelt period and its effect on runoff in the mountainous areas of Northwest China. *Journal of Geographical Sciences*// —23(1). — DOI: 10.1007/s11442-013-0990-1

Li Y., Liu Y., Zhao L., Zou R., Wang C., Guo H. (2013). Survey on threshold detection methods of regime shift in shallow lake ecosystem// Acta Ecologica Sinica. — 33(11). — 3280-3290. — DOI: 10.5846/stxb201203140340

Madibekov A., Ismukhanova, L., Zhadi, A., Sultanbekova, B., Zhumatayev, S., Karimov, A., Fokin, S. (2024). Assessment of the physical and chemical condition of Markakol lake with consideration of eutrofication processes. *Central Asian Journal of Water Research.* (in press).

Madibekov A., Nysanbaeva A., Kurmanova M. (2018). Role of the chemical composition of an atmospheric precipitation in pollution of a surface water// *News of the Academy of Sciences of the Republic of Kazakhstan*, series of geology and technical sciences. — 2018. — 431(5). — Pp. 120–127. — DOI: 1032014/2018.2518-170X.17

Masson-Delmotte V., Zhai, P., Pörtner, H.O., Roberts, D., Skea, J., Shukla, P.R. (2022). Global Warming of 1.5 C: IPCC special report on impacts of global warming of 1.5 C above pre-industrial levels in context of strengthening response to climate change, sustainable development, and efforts to eradicate poverty// Cambridge University Press. — DOI: 10.1017/9781009157940

Musakulkyzy A., Madibekov A. (2016). Modern level regime of lake Markakol// Materials international scientific-practical conference devoted to the summing-up of the "Water for Life" decade declared by the United Nations Almaty, Kazakhtan. September 22-24. — 1. — Pp. 360–365.

Nam S., Lim H., Choi B., Li Q., Moon H., Tae Choi H. (2023). Responses of stream water temperature to water levels in forested catchments of South Korea// Forests. — 14(10) — 2085. — DOI: 10.3390/f14102085

Nyssanbayeva A., Cherednichenko A, V., Abayev N., Madibekov A. (2019). Bioclimatic conditions of the winter months in Western Kazakhstan and their dynamics in relation to climate change// International Journal of Biometeorology. — 2019. — 63(5). — Pp. 659–669. — DOI: 1007/s00484-018-1513-7

Salnikov V., Talanov Ye., Polyakova S., Assylbekova A., Kauazov A., Bultekov N., Musralinova G., Kissebayev D., Beldeubayev Ye. (2023). An assessment of the present trends in temperature and precipitation extremes in Kazakhstan// Climate. — 11(2). —33. — DOI: 10.3390/cli11020033

Scapozza C., Patocchi N. (2023). Lake Maggiore: geomorphological genesis, lake-level evolution, and present and future ecosystems importance// Journal of Limnology. — 81(s2). — DOI: 10.4081/jlimnol.2022.2146

Serikbay N., Tillakarim T., Rodrigo-Illari J., Rodrigo-Clavero M.E., Duskayev K. (2023). Evaluation of reservoir inflows using semi-distributed hydrological modeling techniques: Application to the Esil and Moildy Rivers' catchments in Kazakhstan// Water. — 15. — 2967. — DOI: 10.3390/w15162967

Volokitina A., Kalachev A., Korets M, Sofronova T. (2021). Fire behavior prediction in larch forests of the Kazakhstan Altai// Symmetry. — 13(4). — DOI: 578 10.3390/sym13040578

Voyevodina V., Turulina G., Polyakova S. (2022). Circulation features of precipitation formation in winter in the north and south of Kazakhstan in the conditions of climate warming// Hydrometeorology and ecology. — 104(1). — Pp. 31–39. — DOI: 10.54668/2789-6323-2022-104-1-31-39

Wang J., Zhou H., Kwok Fai Tso G., Hsun Ch.P., Tua Ch., Zheng T. (2023). Integrated safety assessment of water–energy–food systems based on improved substance element extensions// — *Journal of Water and Climate Change*. — 14 (12). — Pp. 4617–4634. — DOI: 10.2166/wcc.2023.343

Wrzesiński D., Plewa K. (2016). Stability of the water levels regime on the lakes in Poland// Badania Fizjograficzne nad Polską Zachodnią Seria A — Geografia Fizyczna. — A67. — Pp. 305–316. — DOI: 10.14746/bfg.2016.7.22

Zhang T., Mamatkov D., Ermenbaev B., Shang Sh., Gao Y., Huang L., Zhang R., Chen F., Yu Sh., Yin Z., Yuan Yu. (2019). Tree ring record of annual runoff for Issyk Lake, — Central Asia// *Journal of Water and Climate Change*. — 2019. — 10 (3). — Pp. 610–623. — DOI: 10.2166/wcc.2018.232

Zhang Z., Cong Zh., Gao B., Li G., Wang X. (2024) The water level change and its attribution of the Qinghai Lake from 1960 to 2020// — *Journal of Hydrology: Regional Studies*. — 52. — 101688. — DOI: 10.1016/j.ejrh.2024.101688

Zhu G., Wang L, Liu Yu, Bhat M.A., Qiu D., Zhao K., Sang L., Lin X., Ye L. (2022) Snow-melt water: An important water source for Picea crassifolia in Qilian Mountains// — *Journal of Hydrology*. — 613. — 128441. — DOI: 10.1016/j.jhydrol.2022.128441.

CONTENT

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 work described 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 originality detection service Cross Check 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 onh 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 сайте:
www:nauka-nanrk.kz
ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)
http://geolog-technical.kz/en/archive/

Подписано в печать 15.06.2024.
Формат 60x88 1/8. Бумага офсетная. Печать - ризограф.
15,0 п.л. Тираж 300. Заказ 3.

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