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«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ  
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«ХАЛЫҚ» ЖҚ

# Х А Б А Р Л А Р Ы

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## ИЗВЕСТИЯ

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

## N E W S

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*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. Web of 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.*

*НАНПК сообщает, что научный журнал «Известия НАНПК. 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 НАНПК. 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»!**

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## RESEARCH ON THE CONDITIONS OF WATER FORMATION IN RADIATION-HAZARDOUS SITES OF THE SEMIPALATINSK TEST POINT

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**Abstract.** The article addresses research findings of the relationship between ground and surface waters in radioactively contaminated areas of the former Semipalatinsk Test Site. Research proved that contamination of the Shagan water could have occurred due to the entry of contaminated ground water from the «Balapan» site. It was found that water contamination in the «Atomic Lake» is unrelated to the entry of ground water, as previously suggested. There is no water exchange process at the «Telkem» site between ground and surface waters. Research was conducted using an isotope hydrology technique by analyzing ratios of stable isotopes deuterium and oxygen-18. The isotope hydrology technique applied has demonstrated its efficiency and applicability in solving the task set.

**Keywords:** isotope hydrology, radioactive waters, nuclear test site, tritium, water exchange processes

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## **СЕМЕЙ СЫНАҚ ПОЛИГОНЫНЫҢ РАДИАЦИЯЛЫҚ ҚАУІПТІ АЙМАҚТАРЫНДАҒЫ СУЛАРДЫҢ ҚАЛЫПТАСУ ЖАҒДАЙЫН ЗЕРТТЕУ**

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**Аннотация.** Мақалада бұрынғы Семей полигонының радиациямен ластанған аумақтарындағы жер асты және жер үсті суларының арақатынасын зерттеу нәтижелері берілген. Зерттеу нәтижесінде Шаған өзен суының ластануы Балапан учаскесінен жер асты суларының келуі нәтижесінде пайда болуы дәлелденді. «Атом көлі» суының ластануы бұрын болжанғандай жер асты суларының түсуімен байланысты еместігі анықталды. «Телкем» учаскесінде жер асты сулары мен жер үсті суларының арасында су алмасу процесі жүрмейтіні анықталды. Зерттеу изотоптық гидрология әдісімен дейтерий мен оттегі-18 тұрақты изотоптарының арақатынасын талдау арқылы жүргізілді. Изотоптық гидрологияның қолданбалы әдісі мәселені шешуде өзінің тиімділігін және қолдану мүмкіндігін көрсетті.

**Түйін сөздер:** изотоптық гидрология, радиоактивті су, ядролық полигон, тритий, су алмасу процестері

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## ИССЛЕДОВАНИЕ УСЛОВИЙ ФОРМИРОВАНИЯ ВОД НА РАДИАЦИОННО-ОПАСНЫХ УЧАСТКАХ СЕМИПАЛАТИНСКОГО ИСПЫТАТЕЛЬНОГО ПОЛИГОНА

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**Аннотация.** В статье представлены результаты исследования взаимосвязей между подземными и поверхностными водами на радиационно-загрязненных участках бывшего Семипалатинского испытательного полигона. В результате исследования подтверждено, что загрязнение техногенными радионуклидами вод р. Шаган происходит вследствие поступления подземных вод со стороны площадки «Балапан», где проводились подземные ядерные испытания. Определено, что загрязнение вод «Атомного озера» не связано с поступлением подземных вод, как предполагалось ранее. На площадке «Телькем» отсутствует процесс водообмена между подземными и поверхностными водами. Исследование проводилось с использованием метода изотопной гидрологии путем анализа отношений стабильных изотопов дейтерия и кислорода-18. Примененный метод изотопной гидрологии показал свою эффективность и применимость в решении поставленной задачи.

**Ключевые слова:** изотопная гидрология, радиоактивные воды, ядерный полигон, тритий, процессы водообмена

### Introduction

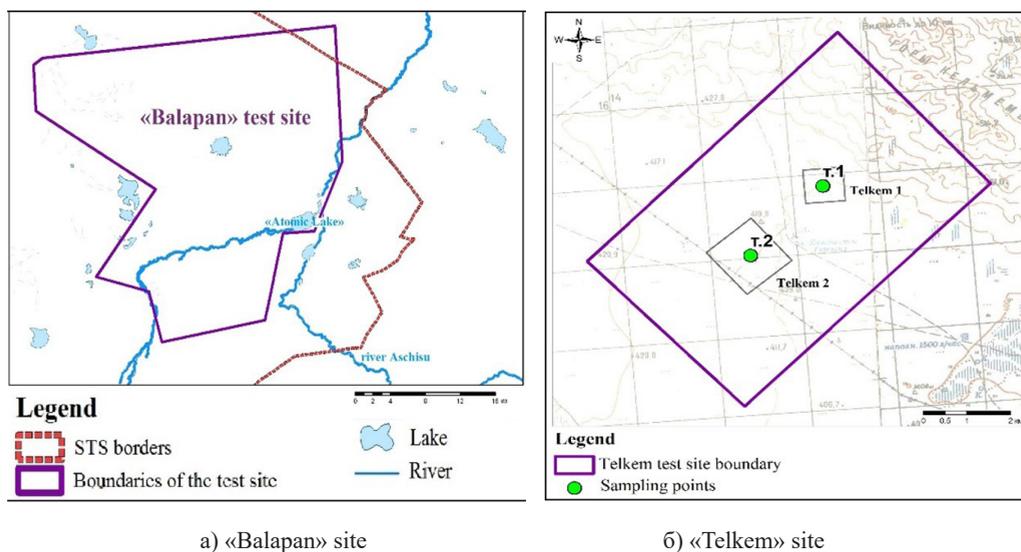
Currently, an isotope hydrology technique is one of direct techniques to obtain information on the origin and the condition in which different water types are formed. The technique is underlaid by research into the ratio of stable isotopes oxygen and hydrogen in water studied. Numerous papers written in many regions worldwide show that the task to investigate water origin is solvable by means of this technique

(Joussaume et al., 1984; Delavau et al., 2017; Marx et al., 2021; Montanari et al., 2012; Dubinchuk et al., 1989; Bugai et al., 2010).

Within the former Semipalatinsk Nuclear Test Site (further on STS), there are a number of water bodies that are characterized by the elevated content of man-made radionuclides and differ in a complicated formation mechanism (Subbotin et al., 2013; Larionova et al., 2017; Aidarkhanova et al., 2018; Gorbunova et al., 2012; Aidarkhanov et al., 2012; Subbotin et al., 2020). The main of these are common at the «Balapan» and «Telkem», which have surface waters from the Shagan riv. and an artificial water reservoir «Atomic Lake» as well as a number of underground aquifers with ground and fracture waters.

The «Balapan» site (Fig 1), a 780 km<sup>2</sup> area, located in the southeastern STS part, was used for underground nuclear explosions in boreholes. A total of 105 nuclear tests up to 150 kt were conducted here including the first excavation explosion in the former USSR with soil ejection as part of the experiment to make an artificial reservoir (Logachyov et al., 2001; Lukashenko et al., 2009). As a result, a crater of about 100 m deep and 400 m diameter was formed at the junction of the Shagan and Aschysu rivers, which was subsequently filled up with water and named as the «Atomic Lake» (Akhmetov et al., 1994; Ptitskaya et al., 2003).

Two underground nuclear explosions with soil ejection were conducted at the «Telkem» testing site: a single explosion Telkem-1 and a multiple one (consisting of three linearly arranged charges) – Telkem-2 (Myasnikov et al., 1970; Lukashenko et al., 2011). As a result of excavation explosions, craters named as Telkem-1 and Telkem-2 were formed and filled up with flood water afterwards.



Earlier research undertaken at the «Balapan» site allowed the definition of the level and pattern of the distribution of man-made radionuclides in water of the «Atomic

Lake» and the Shagan riv. as well as in ground waters. Data on the depth distribution of man-made tritium and strontium in water were obtained for the «Atomic Lake». Minima were registered at 10 m deep, maxima — at a depth of 60 to 80 m (Aktayev et al., 2017; Aktayev et al., 2021). In surface waters of the Shagan riv., 5 km away from the «Atomic Lake» downstream, sections of abnormally high tritium values reaching up to 350,000 Bq/l are localized. Tritium values in ground and fracture waters were 35,000 and 450,000 Bq/l, respectively (Aktayev et al., 2021). Strontium and tritium with the activity concentrations of up to 150 and 50 Bq/l were revealed in water of craters at the «Telkem» site (Lukashenko et al., 2014).

Thus, earlier research made it possible to reliably determine radioactive contamination of ground and surface waters. However, conditions in which water bodies themselves were formed and their possible relationships were not studied.

The analysis of available data showed that contamination of STS water bodies with radionuclides can be due to the mutual influence of surface and ground waters. For example, ground waters developed within nuclear test locations may contribute to ground water contamination. In turn, surface waters may affect ground water contamination with radionuclides owing to water exchange processes. In this regard, in order to study water exchange processes, the following work was performed in areas of interest:

- Definition of the influence of ground waters at the «Balapan» site on the «Atomic Lake».

- Assessment of relationships between ground waters of the «Balapan» site and those of the Shagan riv.

- Assessment of the entry of surface waters from the «Telkem» site into ground waters of the adjacent area.

### **Materials and methods**

Waters of the Shagan riv. and the «Atomic Lake» as well as ground and fracture waters were research objects at the «Balapan» site. At the «Telkem» site, research into surface waters of the Telkem-1 and Telkem-2 craters as well as into ground waters of the adjacent area was conducted.

*Sampling.* Water from the «Atomic Lake», the Telkem-1 and Telkem-2 craters was sampled at different depths at centers of water bodies. In the Shagan riverbed, water was sampled from various contaminated sections of the river at a distance of 2.6 km, 2.8 km, 5.1 km, 5.2 km, 5.3 km, 14 km, 28 km, 50 km and 110 km downstream from the «Atomic Lake». Ground waters were sampled from monitoring boreholes located in adjacent areas of the «Balapan» and «Telkem» sites.

*Laboratory analysis.* Ratios of stable isotopes  $^2\text{H}/^1\text{H}$  and  $^{18}\text{O}/^{16}\text{O}$  were measured with a highly sensitive laser spectrometer LGR 912-0008 in the branch «Institute of radiation Safety and Ecology» RSE NNC RK. The international standard «VSMOW-2» (Vienna Standard Mean Ocean Water) was used as a calibration standard. The accuracy of  $^2\text{H}$  and  $^{18}\text{O}$  determination was  $\pm 0.5\text{‰}$  and  $0.1\text{‰}$ , respectively.

Office studies and interpretation of findings were carried out according to conventional rules of isotope hydrology. For the analysis of different types of water, all measurements were plotted as the  $\delta^{18}\text{O}-\delta^2\text{H}$  ratio. This diagram reflects a regular distribution of deuterium and oxygen in precipitation – as sources that form all types

of water and is called a Global meteoric water line (further on GMWL) (Craig 1961; Dansgaard 1964; Rozanski et al., 1993; Vasilchuk et al., 2010; Toktaganov et al., 2018).

### Results and discussion

*Definition of the influence of ground waters at the «Balapan» site on the «Atomic Lake».* Recharge zones were assumed to exist at the bottom as one of possible contamination mechanisms at the «Atomic Lake» water body. Contaminated ground waters entered from cavities of «warfare» boreholes located in the territory of the «Balapan» site through these zones (Subbotin et al., 2011). To clarify this assumption, the analysis of the isotopic composition of all types of water was carried out including ground and fracture waters that are common in potential sections of the contaminated water entry.

All results obtained for isotopic values of ground waters and the «Atomic Lake» were plotted on the diagram of the  $\delta^{18}\text{O} \div \delta^2\text{H}$  ratio (GMWL). Results are presented in the figure (Fig 2).

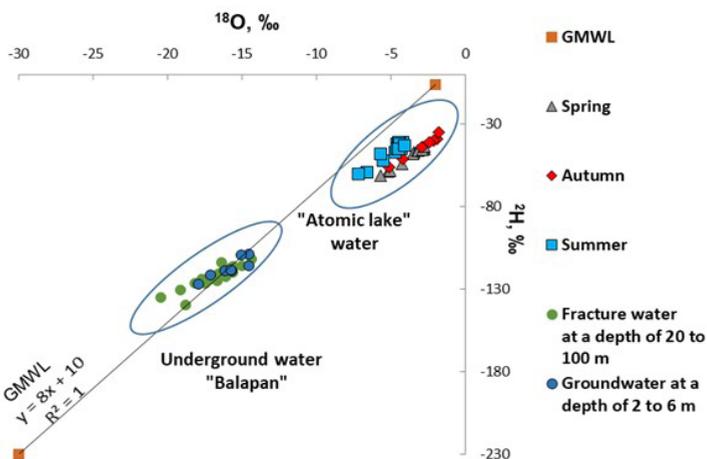


Fig 2. The ratio of stable isotopes of ground waters and water of the «Atomic Lake»

According to the analysis, the isotopic composition of the «Atomic Lake» is essentially different from that of ground waters at the «Balapan» site. The content of stable isotopes of ground waters varies from -14.5 to -20.5 ‰ for  $^{18}\text{O}$  and -109.0 to -139.5 ‰ for  $^2\text{H}$ , which is regarded as «light». The content of stable isotopes in water of the «Atomic Lake» over the entire observation period varied from -1.9 to -7.2 ‰ for  $^{18}\text{O}$  and -35.0 to -61.2 ‰ for  $^2\text{H}$ , which is regarded as relatively «heavy».

According to the comparative analysis, there is no water exchange between ground waters of the «Balapan» site and waters of the «Atomic Lake». This suggests that contamination of «Atomic Lake» waters with radionuclides is attributed to other processes related to leaching of radionuclides from contaminated soil in the dump rather than to the entry of ground waters from locations of nuclear tests at the «Balapan» site according to (Aktayev et al., 2021).

*Assessment of the relationship between ground waters of the «Balapan» site and the*

*Shagan riv.* Environmental compartments were previously revealed to have the elevated content of man-made radionuclides in the vicinity of the Shagan riv. in soil, bottom sediments and plants as well as their contamination mechanisms identified (Timonova al., 2020). Underflow waters flowing out of the «Atomic lake» and passing through radioactively contaminated soils in the dump were found to be a contamination source of surface waters of the Shagan riv. in the riverbed section of «2 km» (Aktayev et al., 2021). At the same time, downstream in the «5 km» area, the contamination source was linked to the entry of fracture waters from the «Balapan» site (Genova al., 2010; Yesimbekov al., 2013). To refine the relationship between ground and surface waters, the analysis of the isotopic composition of waters at the «Balapan» site and the Shagan riv. was carried out. The results are presented in the figure (Fig 3).

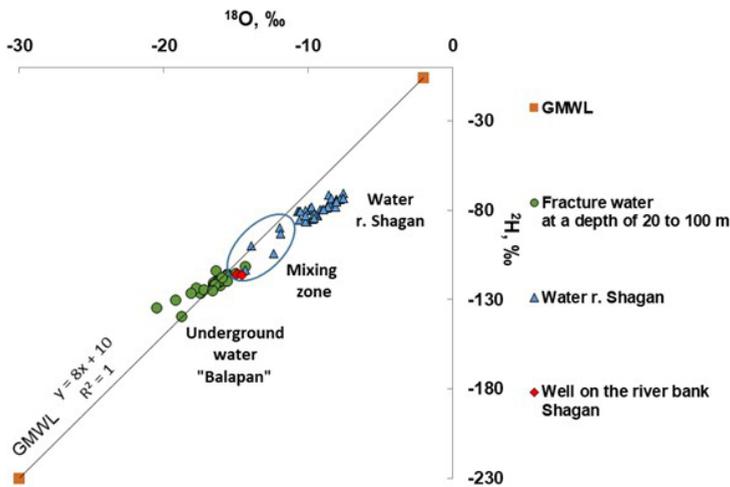


Fig 3. Ratios of stable isotopes for ground waters and the Shagan riv. waters

The content of stable isotopes in surface waters of the Shagan riv. varies widely - from -7.5 to -14.4 ‰ for  $^{18}\text{O}$  and -70.3 to -113.6 ‰ for  $^2\text{H}$ . The content of stable isotopes in ground waters varied from -14.4 to -20.5 ‰ for  $^{18}\text{O}$  and -111.7 to -139.5 ‰ for  $^2\text{H}$ . The data analysis showed that waters of the Shagan riv. are in the zone, which exhibits mixing of ground and surface waters. This is evidenced by identical values of stable isotopes in ground and surface waters sampled from the «5.0 km» area.

Thus, the radioactive contamination of the Shagan riv. waters due to the entry of ground waters from the «Balapan» site into the riverbed has proved true.

*Assessment of the entry of surface waters from the «Telkem» site into ground waters of the adjacent area.* According to available data, craters near the «Telkem» site are drainless. However, in order to control the variation in the level of radioactive waters and their subsequent entry into ground waters of the adjacent area, monitoring observations are carried out (Lukashenko al., 2016). In this regard, the isotopic composition was analyzed to assess the relationship between surface and ground waters. The results are depicted in the figure (Fig 4).

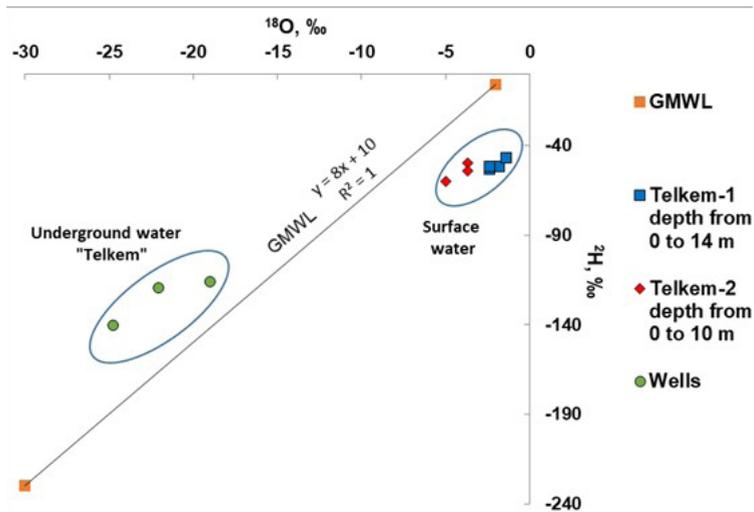


Fig 4. Ratio of stable isotopes for surface and ground waters of the «Telkem» site

The analysis of findings showed that the content of stable isotopes in water bodies of «Telkem-1» and Telkem-2 is essentially different from the one in ground waters varying from  $-1.4$  to  $-5.1$  ‰ for  $^{18}\text{O}$  and  $-47.2$  to  $-60.2$  ‰ for  $^2\text{H}$ . The content of stable isotopes in ground waters of the adjacent area varied from  $-19.0$  to  $-24.8$  ‰ for  $^{18}\text{O}$  and  $-115.9$  to  $-140.4$  ‰ for  $^2\text{H}$ .

Based upon outputs it was found that there is no water exchange between ground and surface waters at the «Telkem» site, hence, no migration of radionuclides to ground waters is expected.

### Conclusion

A technique to research into the origin and conditions of how waters are formed demonstrated its efficiency under conditions of the former Semipalatinsk Test Site and was helpful to establish the cause of contamination at objects of interest objectively.

The water body «Atomic Lake» was found not to be recharged by the entry of any ground waters from the «Balapan» site. The radioactive contamination of the «Atomic Lake» waters is solely related to the leaching of radionuclides from soils in the dump of the explosion crater.

A surface and ground water exchange section was discovered in the Shagan riverbed at a distance of 5.2 km from the «Atomic Lake». The hypothesis for the contamination of surface waters of the Shagan riv. with radionuclides due to the entry of contaminated ground waters from the «Balapan» testing site proved true.

There is no water exchange between surface and ground waters at the «Telkem» site. Findings showed that these craters can be regarded as drainless water bodies, which are only recharged by precipitation. Consequently, man-made radionuclides are not expected to migrate from surface waters to ground waters.

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