PROCEEDINGS OF THE YEREVAN STATE UNIVERSITY
УЧЕНЫЕ ЗАПИСКИ ЕРЕВАНСКОГО ГОСУДАРСТВЕННОГО УНИВЕРСИТЕТА
Geology and Geography **59**(2), 2025 *Геология и география*

Geography

УДК 574.5

ASSESSMENT OF THE POTENTIAL OF CULTURAL ECOSYSTEM SERVICES OF THE HRAZDAN RIVER
(analysis of the suitability of water for swimming)

L. N. POGHOSYAN *, H. H. KOBELYAN **, M. R. DALLAKYAN ***

Scientific Center of Zoology and Hydroecology, NAS RA, Armenia

The Hrazdan River is the largest water vein in the central part of the Republic of Armenia. It flows through the capital Yerevan and more than 60% of the country's population lives in the catchment. Thus, the study of water use opportunities is gaining both scientific and practical importance. Swimming in rivers, as a recreational activity, is one of the most valuable cultural ecosystem services. To assess its potential, a microbiological study of water was carried out in 2023, the coli index and the quantitative composition of saprophytic bacteria were determined at 16 observation points. The results show that there were no violations of the norms set for recreational water use in Solak, Argel, the upper course part of the Bjni tributary and along the course of the Marmarik tributary.

https://doi.org/10.46991/PYSUC.2025.59.2.482

***Keywords*:** Hrazdan River, ecosystem services, recreation, *E. coli*, saprophytic bacteria.

Introduction. The concept of ecosystem services (ES) arose from the need for effective and sustainable management of ecosystems and refers to the benefits people obtain from ecosystems [1]. Therefore, the assessment of ES potential is the basis for sustainable resource use and their conservation [2, 3]. The ES valuation allows to determine the possibilities of having benefited from the involvement of natural capital in the economic systems [4]. Cultural ES are spiritual-cultural, scientific-educational, and recreational resources, formed as a result of ecosystem functioning and processes that contributing to human well-being [4].

Some cultural ES of rivers require direct contact with the water, thus, it is necessary to conduct microbiological studies, since the risks of microbial contamination are leading to health issues [5]. Swimming is the most straightforward way of recreation with intense contact with water. The object of the study is the Hrazdan River, and the safety of swimming in the river from a sanitary and hygienic point of view.

* E-mail: poghosyanliana11@gmail.com
** E-mail: hripsimekobelyan@mail.ru
*** E-mail: dallakyan.marine@gmail.com marine.dallakyan@sczhe.sci.am

The Hrazdan River has domestic, industrial, hydropower, agricultural, and recreational water use potential [6], which is partially utilized. As a result, cultural ES potential is being worn off through several trade-off mechanisms.

Thus, the aim of the study is to assess the appropriateness of the water of the Hrazdan River for swimming from a sanitary and microbiological point of view. The objectives of the work are: 1) to conduct bacteriological research of the Hrazdan River; 2) to assess the water quality of the Hrazdan River according to bacteriological indicators.

Material and Methods. The research was conducted in July 2023, when the river is in a low-water situation and in the most optimal thermal conditions for swimming. Water sampling was carried out from 16 sampling points of the Hrazdan River (Tab. 1).

Table 1

Description of sampling sites

Sampl. site number	Description	Latitude	Longitude	Altitude, *m*	Average water depth, *cm*	Flow velocity, *m/s*
1	Yerkarget tributary, 1 *km* North of Hankavan village	40.646055	44.478522	1994	20	0.7
2	Meghradzor village, middle course of Marmarik tributary	40.601455	44.643859	1768	35	0.9
3	Aghavnadzor village, lower course of Marmarik tributary	40.570991	44.696094	1732	35	0.7
4	Geghamavan village, Hrazdan sources	40.569235	44.895423	1853	15	0.2
5	Tsaghkadzor town, the upper course of Bjni tributary	40.534245	44.700506	1941	7	0.3
6	Solak village, near the sources	40.460802	44.687199	1519	25	0.6
7	Near Bjni mineral water source	40.464827	44.673697	1509	50	0.4
8	1 *km* downstream from Bjni village	40.434764	44.625336	1460	30	0.6
9	0.5 *km* upstream from Argel Hydropower plant	40.389116	44.602873	1389	40	0.6
10	Getamej village	40.282926	44.590127	1225	30	0.5
11	Yerevan, Haghtanak bridge	40.174659	44.500398	941	20	0.4
12	Yerevan, 1.5 *km* downstream from Yerevan Lake reservoir	40.151242	44.460057	881	50	0.4
13	Geghanist village	40.146417	44.436363	871	40	0.5
14	Darbnik village	40.105056	44.379986	836	50	0.3
15	Sis village	40.041033	44.409649	829	200	0.4
16	1 *km* West of Araksavan village	39.99961	44.446996	821	180	0.4

Water sampling for bacteriological studies was carried out in sterile containers using standard microbiological methods [7, 8]. *Escherichia coli* bacteria are indicators of fresh fecal contamination of aquatic ecosystems [5]. To calculate the coli-index, 10 *mL* and then 1 *mL* of water was filtered from each sample in 3 replicates. Filtration was carried out using membrane filters using a vacuum pump. Then, the membrane filters were transferred to a petri dish filled with pre-prepared Endo nutrient medium and incubated for 24 *h* in a thermostat at a temperature of +37°C [9]. Coli-index was calculated by recalculation of the number of colonies to a volume of 1000 *mL* [7]. Based on the coli-index, the suitability of river water for recreational purposes was assessed according to European Union (EU) and United States of America (USA) standards [10, 11] and the Order of the Minister of Health of the Republic of Armenia (RA) No. 09 N of April 5, 2018 [12] (Tab. 2).

Table 2

Maximum thresholds for the suitability of river water for recreational use according to E. coli bacteria (CFU/100 mL) based on RA, EU and USA standards

Norms set for	Maximum allowed quantity
RA	500
EU	250
USA	126

Water quality classes were determined considering a number of current EU directives and approaches [9] (Tab. 3).

Table 3

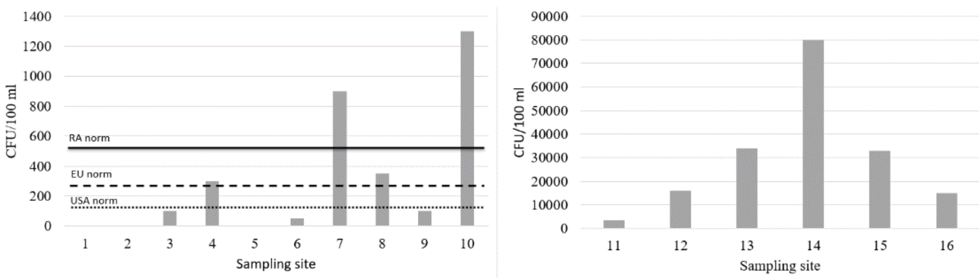
EU water quality classes by mean E. coli count (CFU/100 mL)

Class I Poorly polluted	Class II Slightly polluted	Class III Moderately polluted	Class IV Strongly polluted	Class V Extremely polluted
≤ 100	101–1000	1001–10 000	10001–100 000	>100 000

The numbers of saprophytic bacteria growing at 22°C and 37°C in water samples were determined [13] by inoculation of the saprophytic bacteria on dry nutrient agar. The number of saprophytic bacteria growing at 22°C was determined after 24 *h* of incubation in the thermostat, and the number of saprophytic bacteria growing at 37°C was determined after 48 *h* of incubation. Unlike allochthonous bacteria growing at 37°C, saprophytic bacteria growing at 22°C are autochthonous and participate in the process of water self-purification [14]. Therefore, the state of the river's self-purification process was assessed using the ratio of these groups of microorganisms. Based on the quantitative indicators of saprophytic bacteria, the ecological and sanitary state of surface waters was also assessed using the Romanenko et al. [15] scale.

Results and Discussion. The results of microbiological studies revealed significant spatial differences in river pollution, which also affects the potential for providing cultural ES. The spatial patterns of fecal pollution are determined by the population distribution, river fragmentation, reservoirs and water intake points, as well as the spatial distribution of source water fluxes into the river. The main regularity is in the increase in pollution from the upper to the lower course of the river, which was also confirmed by other hydrobiological studies [16].

The values of *E. coli* bacteria in the studied sampling points ranged from 0.3 to 80 000 CFU/100 *mL* (see Figure), where the highest values were recorded in the area of the village of Darbnik. Such worsening of the water quality is the result of the untreated wastewater discharge mainly from Yerevan, downstream of the Aeration water treatment station [17]. After the collapse of the USSR, due to inability to treat sewage of millionaire City Yerevan in the Aeration Station, such high pollution is of a permanent nature [13]. Low values or absence of *E. coli* bacteria was recorded in the upper course part of the Hrazdan River (Yerkarget, Meghradzor, Aghavnadzor stations and Bjni tributary), or in the places, where sources inflow into the river (e.g. Solak station). In these sampling stations no violation of international and local norms for *E. coli* bacteria were recorded. Thus, famous recreation area of Marmarik tributary is safe for bathing activities. The release of limnic waters from the Marmarik reservoir during the summer also contribute to the state of water contamination in Marmarik stations [18]. In remaining sampling stations, the local norm was exceeded by 2–60 times, the European norm – by 1.2–320 times, and the US norm – by 2.3–634 times.



Average number of *E. coli* bacteria recorded in the Hrazdan River sampling sites in 2023 and established norms [6, 12, 15].

The first category of water quality was recorded only for six sampling sites in the Hrazdan River (Tab. 4), while in the six sampling sites distributed in the lower course part water quality corresponded to fourth category. The greatest variability in water quality is observed in the middle course part of the river, where both first and third category waters are recorded. Such differences are due in part to the geomorphological features of the river valley in the middle course part, which is mostly gorge. Limited possibilities for the development of the settlement system enhances self-purification of the river.

Spatial changes in the quantitative indicators of saprophytic bacteria mainly repeat the patterns of *E. coli* distribution, which confirms that the existing pollution is multicomponent and permanent. In the Hrazdan River, the number of saprophytic bacteria growing at a temperature of 22°C changed within the range of 500–26200 CFU/*mL*, and the number of mesophilic saprophytic bacteria (37°C) fluctuated within the range of 100–29200 CFU/*mL*. The minimum value was recorded in Solak station, and the maximum value – in the Darbnik village observation point (Tab. 5).

Table 4

Assessment of water quality at Hrazdan River sampling sites from a recreational perspective, according to the average number of E. coli bacteria on the EU pollution assessment scale

Sampling site	EU scale classes
1	Poorly polluted
2	Poorly polluted
3	Poorly polluted
4	Slightly polluted
5	Poorly polluted
6	Poorly polluted
7	Slightly polluted
8	Slightly polluted
9	Poorly polluted
10	Moderately polluted
11	Strongly polluted
12	Strongly polluted
13	Strongly polluted
14	Strongly polluted
15	Strongly polluted
16	Strongly polluted

The number of saprophytic bacteria in the Marmarik tributary fluctuated within the range of 1180–11480 CFU/*mL*. Relatively high values were recorded at the samplint site of the Yerkarget tributary (11480 CFU/*mL*), then decreased at the sampling site of the Meghradzor village (1180 CFU/*mL*), and increased again in the sampling station of the Aghavnadzor village (CFU/*mL*) (Tab. 5).

Table 5

Annual average number of E. coli and saprophytic bacteria recorded in the sampling points of the Hrazdan River

Sampling site number	Saprophytic bacteria count (22°C) CFU/*mL*	Saprophytic bacteria count (37°C) CFU/*mL*
1	11480	10000
2	1180	650
3	4640	3000
4	3000	2640
5	2900	2800
6	500	100
7	2400	1900
8	5400	4160
9	1600	800
10	4000	2000
11	1110	810
12	7160	5160
13	8820	7720
14	26200	29200
15	20400	21400
16	22200	20200

The number of saprophytic bacteria growing at 37°C exceeded the number of bacteria growing at 22°C in the Darbnik village, which indicate significant pollution in that part and lack of self-purification potential.

The ecological and sanitary assessment of the Hrazdan River shows that in the upper and middle course parts the water is classified as "pure" to "sufficiently pure" and in the lower reaches, starting from the City of Yerevan, it is classified as "polluted".

Conclusion. The numbers of saprophytic and *E. coli* bacteria were increased from the upper course to lower course part of the river. According to the ecological-sanitary assessment, the pollution level in the upper course part of the river is low, and in the lower course part it is high. Water quality fluctuates in a wider extent in the middle course part of the river, which is the consequence of morphological features of the river valley and very limited anthropogenic impact. The number of saprophytic bacteria growing at a temperature of 37°C exceeds the number of saprophytic bacteria growing at 22°C in the lower course part, which indicates the low self-purification potential of the river. According to sanitary-microbiological indicators, the bathing in the Hrazdan River is safe only in the upper course part and some areas of the middle course.

The research was conducted within the framework of the RA Higher Education and Science Committee's 22RL-023 "Mapping of ecosystem services availability at Armenian rivers and floodplains" project.

Received 04.04.2025
Reviewed 05.06.2025
Accepted 15.08.2025

REFERENCES

1. *Ecosystems and Human Well-Being: Synthesis. Millennium Ecosystem Assessment*. Washington DC, World Resources Institute, Island Press (2005).
2. Grunewald K., Bastian O. *Ökosystemdienstleistungen. Konzept, Methoden und Fallbeispiele*. Berlin, Heidelberg, Springer Spektrum (2013), 332.
3. Ruskule A., Vinogradovs I., Villoslada M. *The Introduction to the Ecosystem Service Framework and its Application in Integrated Planning*. Latvia (2018), 31.
4. Haines-Young R., Potschin M.B. *Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure* (2018).
5. Augustyn Ł., Babula A., et al. Microbiological Indicators of the Quality of River Water, Used for Drinking Water Supply. *Pol. J. Environ. Stud.* **25** (2016), 511–519. https://doi.org/10.15244/pjoes/60899
6. Asatryan V., Dallakyan M. The Changes of Ecological Status of the Hrazdan River under the Impact of Aghbyurak Dam. *Proc. of the Intern. Scientific Conf. "Regularities of Formation and Impact of Marine and Atmospheric Hazardous Phenomena and Disasters on the Coastal Zone of the Russian Federation under the Conditions of Global Climatic and Industrial Challenges*. Russia, Rostov-on-Don (2019).
7. Labinskaya A.S. *Microbiology with Techniques of Microbiological Research.* Moscow (1978), 392 (in Russian).
8. Leonova I.B. *Fundamentals of Microbiology*. Laboratory Practicum. Moscow (2012), 80–85 (in Russian).

9. Malnik, V.V., Timoshkin, O.A., et al. Anthropogenic Changes of Hydrochemical and Sanitary-Microbiological Indicators of Water Quality in Tributaries of South Baikal. *Water Resources* **46** (2019), 533–543. https://doi.org/10.31857/S0321-0596465533-543
10. Kavka G.G., Kasimir G.D., Farnleitner A.H. Microbiological Water Quality of the River Danube (km 2581–km 15). Longitudinal Variation of Pollution as Determined by Standard Parameters. *Proc. of the 36th Intern. Conf. of IAD*. Vienna, Austrian Committee Danube Research/IAD (2006), 415–421.
11. *Recreational Water Quality Criteria*. Washington DC, USA. US Environ. Protection Agency, Office of Water 820F-12-058 (2012), 63.
12. Ministry of Health of the Republic of Armenia, Order No. 09 of April 5, 2018 on Approving Sanitary Rules and Norms No. 2.1.5.001-18 "Hygienic Requirements for the Quality of Surface Water Resources in Places of Water Use for Recreational Purposes". https://www.arlis.am/DocumentView.aspx?docid=121555
13. Kobelyan H.H., Ghukasyan E.Kh., Khosrovyan A.M. Assessment of the Current Ecological State of the Hrazdan River. *Armenian Biological Journal* **1** (2021).
14. Parshukov A.N., Sidorova N.A. Bacterial Self Purification of Water Bodies Intended for Fish Farming. *Biologia* **8** (2010), 14–17 (in Russian).
15. Romanenko V.D., Oksyiuk O.P., et al. *Ecological Assessment of the Impact of Hydraulic Engineering Construction on Water Bodies.* Kiev (1990), 218–221 (in Russian).
16. Yepremyan H., Asatryan V., Dallakyan M. Structural Changes of River Ecosystem's Biological Quality Elements under Conditions of Mineral Water Flux. *Electron. J. Natur. Sci.* **38** (2022), 20–25. https://doi.org/10.55841/1728-791X-2022.1.38-20
17. Stepanyan L., Ghukasyan E. Nutrient Enrichment and its Effect on the Phytoplankton Community of Hrazdan River in the Yerevan District, Republic of Armenia. *Ecosystem Transformation* **4** (2021), 3–12. https://doi.org/10.23859/estr-210329
18. Barseghyan N.E., Vardanyan T.V., et al. Species Structure and Spatial Distribution of Fish in the Marmarik River. *Biological Journal of Armenia* **74** (2022), 44–51. https://doi.org/10.54503/0366-5119-2022.74.3-44
19. Tepanosyan G., Harutyunyan N., et al. Potentially Toxic Elements Contents and the Associated Potential Ecological Risk in the Bottom Sediments of Hrazdan River under the Impact of Yerevan City (Armenia). *Environ. Sci. Pollut. Res.* **29** (2022), 36985–37003. https://doi.org/10.1007/s11356-022-18526-2
20. Kondakova G.V. *Bioindication: Microbiological Indicators.* Yaroslavl, Yaroslavl State University (2007), 135 (in Russian).

Լ. Ն. ՊՈՂՈՍՅԱՆ, Հ. Հ. ԿՈԲԵԼՅԱՆ, Մ. Ռ. ԴԱԼԼԱՔՅԱՆ

ՀՐԱԶԴԱՆ ԳԵՏԻ ՄՇԱԿՈՒԹԱՅԻՆ ԷԿՈՀԱՄԱԿԱՐԳԱՅԻՆ ԾԱՌԱՅՈՒԹՅՈՒՆՆԵՐԻ ՆԵՐՈՒԺԻ ԳՆԱՀԱՏՈՒՄ
(լողալու համար ջրի պիտանիության վերլուծություն)

Ամփոփում

Հրազդան գետը Հայաստանի Հանրապետության կենտրոնական մասի ամենամեծ ջրային ուղին է: Գետը հոսում է մայրաքաղաք Երևանով, և նրա ջրհավաք ավազանում ապրում է ՀՀ բնակչության ավելի քան 60%-ը: Այսպիսով, ջրօգտագործման հնարավորությունների բազմազանության ուսումնասիրությունը մեծ գիտական և գործնական նշանակություն ունի: Լողը որպես հանգստի տեսակ մշակութային էկոհամակարգի ամենակարևոր ծառայություններից մեկն է: Դրա ներուժը գնահատելու համար 2023 թվականին իրականացվել է ջրի մանրէաբանական ուսումնասիրություն: 16 դիտարկման կետերում որոշվել են կոլիի ինդեքսը և սապրոֆիտ բակտերիաների քանակական կազմը: Հանգստի նպատակով օգտագործվող ջրերի համար սահմանված նորմերը չեն գերազանցել միայն Սոլակ և Արգել դիտարկման կետերում, ինչպես նաև Մարմարիկ վտակում և Ծաղկաձոր քաղաքով հոսող Բջնի գետի վերին հոսանքներում:

Л. Н. ПОГОСЯН, Р. О. КОБЕЛЯН, М. Р. ДАЛЛАКЯН

ОЦЕНКА ПОТЕНЦИАЛА КУЛЬТУРНЫХ ЭКОСИСТЕМНЫХ УСЛУГ РЕКИ РАЗДАН

(анализ на примере соответствия воды для плавания)

Резюме

Река Раздан является крупнейшей водной артерией в центральной части Республики Армения. Река протекает через столицу г. Ереван, а на водосборном бассейне проживает более 60% населения РА. Таким образом, изучение многообразия возможностей водопользования имеет большое научное и практическое значение. Купание в реках как вид рекреации является одной из важнейших культурных экосистемных услуг. С целью оценки его потенциала в 2023 г. было проведено микробиологическое исследование воды. На 16 пунктах наблюдения определялись коли-индекс и количественный состав сапрофитных бактерий. Нормы, установленные для вод, используемых в рекреационных целях, не были превышены только в пунктах наблюдения Солак и Аргел, а также в притоке Мармарик и в верховьях р. Бжни, протекающей через г. Цахкадзор.