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HYDROECOLOGICAL INVESTIGATION OF THE HRAZDAN RIVER AND "YEREVANYAN LICH" RESERVOIR, ARMENIA

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Hydroecological state of the Hrazdan River and "Yerevanyan Lich" Reservoir was assessed based on the hydrobacteriological (saprophytic bacteria and *Escherichia coli*) and hydrochemical (five-day biochemical oxygen demand, ammonium and phosphate ions) parameters. Water sampling for hydrobiological and hydrochemical analyses were performed in May and July 2019. The results of the study showed that the Hrazdan River and "Yerevanyan Lich" Reservoir in Yerevan were exposed to significant fecal, organic and nutrient contamination, supposedly induced by urban household activities. The contamination in some cases posed health risks to the aquatic life and hydroecosystem of the Hrazdan River.

Hrazdan River – "Yerevanyan Lich" Reservoir – chemico-bacteriological characteristics – hydroecological status

Ջրաբակտերիոլոգիական (սապրոֆիտ բակտերիաներ և *Escherichia coli*) և ջրաքիմիական (թթվածնի 5 օրյա կենսաքիմիական պահանջ, ամոնիում և ֆոսֆատ իոններ) ցուցանիշների հիման վրա գնահատվել է Հրազդան գետի և «Երևանյան լիճ» ջրամբարի ջրաէկոլոգիական վիճակը: Ջրակենսաբանական և ջրաքիմիական վերլուծությունների համար ջրանմուշառումներն իրականացվել են 2019 թ. մայիս և հուլիս ամիսներին: Հետազոտության արդյունքները ցույց են տվել, որ Երևանում Հրազդան գետը և «Երևանյան լիճ» ջրամբարը ենթարկվել են ֆեկալ, օրգանական և կենսածին նյութերով նշանակալի աղտոտման՝ ենթադրաբար պայմանավորված քաղաքի կենցաղային գործունեությամբ: Աղտոտվածությունը որոշ դեպքերում առաջացրել է առողջական ռիսկեր Հրազդան գետի ջրային օրգանիզմների և հիդրոէկոհամակարգի համար:

Հրազդան գետ – «Երևանյան լիճ» ջրամբար – քիմիկաբակտերիոլոգիական առանձնահատկություններ – ջրաէկոլոգիական վիճակ

Гидроэкологическое состояние реки Раздан и водохранилища "Ереванян лич" оценивалось по гидробактериологическим (сапрофитные бактерии и *Escherichia coli*) и гидрохимическим (пятидневная биохимическая потребность в кислороде, ионы аммония и фосфата) показателям. Отбор проб воды для гидробиологического и гидрохимического анализа были проведены в мае и июле 2019 года. Результаты исследования показали, что река Раздан и водохранилище "Ереванян лич" в Ереване подвергались значительному загрязнению фекалиями, органическими и питательными веществами, предположительно являющимися результатом деятельности городских домохозяйств. Загрязнение в некоторых случаях вызывало риски для здоровья водных организмов и гидроэкосистемы реки Раздан.

Река Раздан – водохранилище "Ереванян лич" – химико-бактериологические характеристики – гидроэкологический статус

Increasing intensity of human activities during the last centuries has led to the significant violation of the existing balance of the nature [20]. As a consequence of rapid urbanization, human activities have caused significant changes in the ecological environment [19]. The increasing pollution of the hydrosphere has become one of serious environmental problems [20]. Due to the huge discharge of municipal wastewater and urban drainage into river basins, the effect is more pronounced in the water quality in urban areas [19]. Besides increasing pollution, human activities have also affected the water flow regime and morphology of rivers, resulting in multiple pressures on freshwater ecosystems and declines in their biodiversity and ecological functioning [16]. The hydroecological state of rivers is changing under anthropogenic activities expressed by the disposal of waste, organic and inorganic substances [24]. The classification of the ecological status of rivers and streams is an important tool for future sustainable management of natural water resources. Consequently, the Water Framework Directive requires the protection and improvement of the ecological status of water systems [22].

The Hrazdan River (Armenia) and "Yerevanyan Lich" Reservoir constructed in the Hrazdan River canyon in the south-west of Yerevan City are economically important water bodies for Armenia, since the waters are used for irrigation, energetic, recreational, industrial and other purposes. Nevertheless, the Hrazdan River flowing through Yerevan City is endangered by anthropogenic pollution due to the insufficient management of the disposal and discharge of waste and wastewater mainly from urban household activities [13, 14, 20]. Urban discharges may enter into the Hrazdan River worsening the hydroecological state of the river ecosystem and "Yerevanyan Lich" Reservoir. Therefore, the investigation of the pollution of the Hrazdan River and "Yerevanyan Lich" Reservoir in the conditions of anthropogenic pressures in Yerevan City is urgently required. The aim of the present study was to investigate the current hydroecological state of the Hrazdan River and"Yerevanyan Lich" Reservoir in Yerevan City.

Materials and methods. We investigated the Hrazdan River originated from Lake Sevan in the eastern part of Armenia and "Yerevanyan Lich" Reservoir situated in the south-west of Yerevan City. The Hrazdan River is the longest (141 km) tributary of the transboundary Araks River in the territory of Armenia [13, 14].

For assessing the current hydroecological state of the Hrazdan River and "Yerevanyan Lich" Reservoir, hydrobacteriological (saprophytic bacteria (SB) and *Escherichia coli* (*E. coli*)) and –chemical (five-day biochemical oxygen demand (BOD_5), ammonium and phosphate ions) investigations were carried out. Water samples for microbial and chemical analyses were collected from the river and reservoir sites described in tab. 1. The sampling was performed in May and July 2019. The water samples for BOD_5 and nutrient measurements were taken with cleaned polythene bottles and for bacteriological analysis – with sterile sample containers. The collected samples were kept in a cool box in low temperature conditions during the transportation to the laboratory and were analysed immediately after reaching the laboratory.

Table 1. Coordinates of river and reservoir investigated sites

Sampling site number	N/Lat	E/Long	River site location
1	40°16'51.1"	44°35'21.1"	Hrazdan River site located in Getamej Village, upstream of Yerevan City
2	40°09'31.6"	44°29'33.5"	Hrazdan River site located in Yerevan City, upstream of "Yerevanyan Lich" Reservoir
3	40°09'34.2"	44°28'23.2"	"Yerevanyan Lich" Reservoir site located near the dam
4	40°08'57.0"	44°27'50.7"	Hrazdan River site located in Yerevan City, downstream of "Yerevanyan Lich" Reservoir

Under laboratory conditions, the quantitative analysis of SB and *E. coli* was implemented by the standard methods accepted in hydrobiology. SB were grown on nutrient agar, *E. coli* – on Endo agar using the membrane filtration method. Bacterial culture media were incubated at 20°C (SB) and 37°C (SB and *E. coli*) for 24-48 hours and the colonies grown on the media were counted [6-8]. The experiments were performed under sterile conditions. Based on the quantitative parameters of SB, organic contamination degree in the investigated water bodies was assessed using a surface water quality assessment scale accepted in the CIS (Commonwealth of Independent States) and EU (European Union) countries [9].

BOD_5 values were determined according to the standard methods accepted in hydrochemistry [25, 26]. Initial dissolved oxygen (DO) and residual DO after five days incubation at 20°C were measured by the electrochemical probe method using a water oximeter (HI98193) [27]. The concentration of ammonium (Nessler method) and phosphate (ascorbic acid method) ions was determined by a multi-parameter photometer (HI83200) [18].

Results and Discussion. For the quantitative investigation of organic matter in water, the easy and cost-effective chemical and biochemical methods have been developed that give an opportunity to assess organic matter content in water by the determination of oxygen content consumed during the oxidation of organic matter [1]. BOD_5 values were used to assess organic matter content in the water of the Hrazdan River and "Yerevanyan Lich" Reservoir. The results of the BOD_5 study showed that organic matter content in all the investigated sites were conditioned by natural and anthropogenic factors, since it exceeded the background level for the river waters of the Hrazdan River basin [3]. Increased organic matter content was registered in the investigated sites located in Yerevan City (Nos. 2–4 with the exception of No. 3 in July) which can be explained by the impact of urban household discharges. It is necessary to mention that the July concentration of organic matter in the Hrazdan River site located upstream of "Yerevanyan Lich" Reservoir (No. 2) even exceeded the ecological norm for the river ecosystem health and biodiversity conservation (fig. 1) [3].

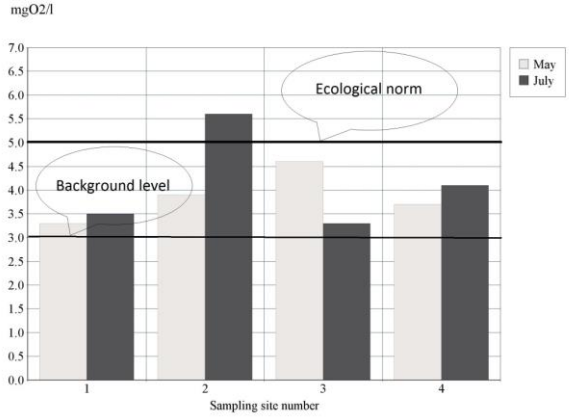

Fig. 1. BOD_5 values in the water of the Hrazdan River and "Yerevanyan Lich" Reservoir.

It's known that SB in water react quickly to water environmental changes and their amount indicates the organic contamination load of the water [21]. Accordingly, the organic contamination of the water of the Hrazdan River and "Yerevanyan Lich" Reservoir was also investigated by the quantitative values of SB grown at 20°C. The quantitative parameters of SB in the investigated river and reservoir sites reflected

almost the same organic contamination pattern as BOD_5: the amount of saprophytes increased noticeably in the investigated river and reservoir sites located in Yerevan City (Nos. 2–4 with the exception of No. 3 in July), indicating the significant contribution of urban household discharges to the formation of organic matter content in the investigated water bodies (Table 2). According to the count of SB grown at 20°C, the water quality in the investigated river site No. 1 was assessed as "sufficiently clean", in the investigated river site No. 2 – as "sufficiently clean"-"very dirty", in the investigated reservoir site No. 3 – as "clean"-"sufficiently clean" and in the investigated river site No. 4 – as "sufficiently clean"-"lightly polluted" [9].

The sanitary status of the Hrazdan River and "Yerevanyan Lich" Reservoir was investigated according to *E. coli* and SB grown at 37°C. *E. coli* is always present in the digestive tracts of animals and humans and is found in their waste. Therefore, its presence in a water body indicates the fecal contamination of the aquatic ecosystem [12]. SB grown at 37°C may also indicate the sanitary status of water, since they can enter water systems from the bodies of humans and warm-blooded animals. The results of the study of *E. coli* and SB grown at 37°C showed the significant worsening of the sanitary status of the investigated water bodies in Yerevan City (sampling site Nos. 2–4), indicating water contamination with urban sewage (tab. 2).

Table 2. SB and *E. coli* count in the water of the Hrazdan River and "Yerevanyan Lich" Reservoir

Sampling site number	Saprophytic bacteria (CFU/ml)				*E. coli* (CFU/l)	
	May		July		May	July
	20°C	37°C	20°C	37°C		
1	1520	210	2720	480	3000	0
2	3000	1640	35200	24000	3000	9000
3	3000	1050	840	470	6000	1000
4	2560	2300	4880	4200	8000	10000

CFU – colony-forming unit

The concentration of ammonium ion is used to indicate environmental pollution mainly from agricultural and household activities [15]. The results of the study showed that ammonium concentration in the investigated river and reservoir sites was mostly conditioned by anthropogenic factors, exceeding the background level for the rivers of the Hrazdan River basin by 4.2–55.8 times. If ammonium concentration in the Hrazdan River site located in Getamej Village (No. 1) and in "Yerevanyan Lich" Reservoir (sampling site No. 3) ranged within safe levels for the ecosystem health, so its content in the Hrazdan River sites located in Yerevan City (Nos. 2 and 4) sometimes exceeded the ecological norm for the river ecosystem health and biodiversity conservation, indicating about the high impact of urban household discharges on the river ecosystem (fig. 2) [3]. It's known that increased nutrient concentration affects all the trophic levels of an ecological pyramid. The reduction of upper trophic levels leads to changes in lower trophic levels, dominant species, to the succession of communities and to the reconstruction of food webs [5, 15]. All of this allows concluding that ammonium contamination in some cases posed health risks to the aquatic life and hydroecosystem of the river sites located in Yerevan City (Nos. 2 and 4).

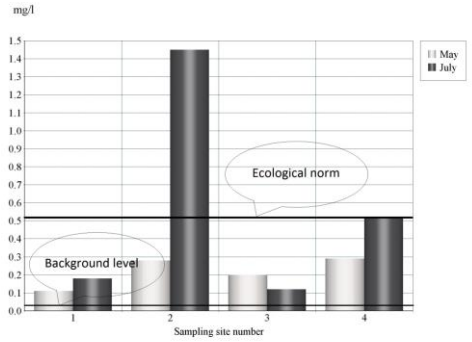

Fig. 2. Ammonium ion concentration in the water of the Hrazdan River and "Yerevanyan Lich" Reservoir.

In natural water, the concentration of phosphate is usually very low ranging between 0.001 mgP/l and 0.009 mgP/l, however it can significantly increase due to anthropogenic impact [2]. The investigation showed that mineral phosphorus content in the investigated river sites was formed under high anthropogenic influence. Phosphate concentration in the investigated river sites mostly exceeded the ecological norm for the rivers of the Hrazdan River basin, indicating unfavorable environmental conditions for the growth of aquatic organisms [3]. The highest phosphate concentration was registered in the Hrazdan River site located in Yerevan City, upstream of "Yerevanyan Lich" Reservoir (No. 2) which can be explained by the high impact of urban household discharges. The lowest phosphate levels in "Yerevanyan Lich" Reservoir water and the Hrazdan River site No. 4 in July could have not surely indicated about favorable environmental conditions in the aquatic ecosystems, since it may have been conditioned by phytoplankton activity in the reservoir (fig. 3). It's known that algae need to absorb nitrate and phosphate to grow [17]. According to the previous studies, planktonic algae in "Yerevanyan Lich" Reservoir reached massive growth during warm periods, which allows to conclude that decreased phosphate concentration in "Yerevanyan Lich" Reservoir water and the Hrazdan River site located downstream of "Yerevanyan Lich" Reservoir (No. 4) may have been conditioned by the algal depletion of the nutrient [4, 10, 11, 14, 23].

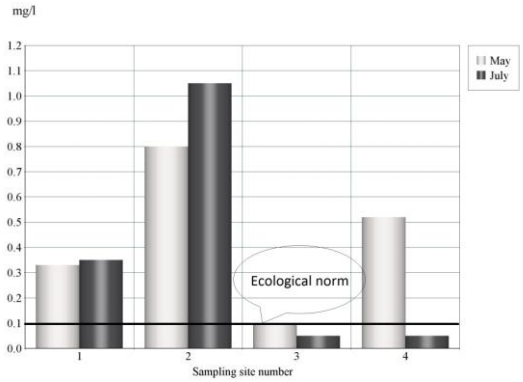

Fig. 3. Phosphate ion concentration in the water of the Hrazdan River and "Yerevanyan Lich" Reservoir.

In general, it can be concluded that the Hrazdan River and "Yerevanyan Lich" Reservoir in Yerevan City were affected by irregular discharges, supposedly from urban household activities that resulted in the significant fecal, organic and nutrient (ammonium and phosphate) contamination of the water bodies which in some cases posed health risks to the aquatic life and hydroecosystem of the Hrazdan River.

REFERENCES

1. *Բեհմանեշ Ա.* Բաբոլռուդ գետի (Իրան) էկոլոգիական բնութագիրը: Ատենախոսություն, Երևան, 119 էջ, 2014:
2. *Գրիգորյան Կ.Ա.* ՀՀ Շիրակի մարզի Ամասիայի տարածաշրջանի շրջակա միջավայրի և Արփի լճի վրա մարդածին գործոնի ազդեցության գնահատականը: Ատենախոսություն, Երևան, 115 էջ, 2014:
3. ՀՀ կառավարության 2011 թվականի հունվարի 27-ի N 75-Ն որոշում: Հասանելի է https://www.e-gov.am/u_files/file/decrees/kar/2011/02/11_0075.pdf հասցեով:
4. *Ստեփանյան Լ.* Երևանյան լճի ֆիտոպլանկտոնային համակեցության և ջրաքիմիական ցուցանիշների սեզոնային դինամիկայի ուսումնասիրությունները: Գիտություն և տեխնիկա, *11*, էջ 13-16, 2005:
5. *Վարագյան Ա.Լ.* Ողջի գետի ջրահավաք ավազանի գետային էկոհամակարգերի կենսածին տարրերի աղտոտման ուսումնասիրություն: Հայաստանի ճարտարագիտական ակադեմիայի լրաբեր, *15*, 4, էջ 664-667, 2018:
6. *Гулая Н.К.* Формирование микробиологического режима водохранилищ Верхнего Иртыша (Бухтарминское, Усть-Каменогорское). Алма-Ата, "Наука", 163 с., 1975.
7. *Лабинская А.С.* Микробиология с техникой микробиологических исследований. М., "Медицина", 394 с., 1978.
8. Методические указания по санитарно-микробиологическому анализу воды поверхностных водоемов. Мин-во здравоохранения СССР, Москва, 36 с., 1981.
9. *Романенко В.Д., Оксиюк О.П., Жукинский В.Н., Стольберг Ф.В., Лаврик В.И.* Экологическая оценка воздействия гидротехнического строительства на водные обьекты. Киев, "Наукова Думка", 256 с., 1990.
10. *Степанян Л.Г., Гамбарян Л.Р., Оганесян Р.О.* Динамика развития фитопланктонного сообщества Ереванского озера. Известия аграрной науки, *9*, 4, с. 65-67, 2011.
11. *Степанян Л.Г., Гамбарян Л.Р., Оганесян Р.О., Микаелян А.Л.* Исследование фитопланктонного сообщества Ереванского водохранилища в период "цветения" 2003 и 2005 г. Биолог. журн. Армении, *58*, 1-2, с. 158-160, 2006.
12. *Gevorgyan G.A.* Assessment of the sanitary-bacteriological state of the Arpa and Yeghegis Rivers, Armenia. Biological Journal of Armenia, *69*, 3, pp. 47-51, 2017.
13. *Gevorgyan G.A., Gabrielyan B.K.* Assessment of the ecologo-sanitary state of the Hrazdan River and "Yerevanyan Lich" Reservoir by bacteriological parameters. Electronic Journal of Natural Sciences, *26*, 1, pp. 20-23, 2016.
14. *Gevorgyan G.A., Mamyan A.S., Hambaryan L.R., Stepanyan L.G.* Investigation of bacterio- and phytoplankton communities in "Yerevanyan lich" reservoir and the Hrazdan river in Yerevan city, Armenia. Proceedings of the III International Scientific-Practical Conference "Problems of Biodiversity Conservation and Use of Biological Resources" (Minsk, Belarus, 7–9 October). Part 2, pp. 89-93, 2015.
15. *Ghazaryan K.A., Minasyan S.H., Grigoryan K.V., Gevorgyan G.A.* Chemico-ecological evaluation of the quality of Lake Arpi waters according to nutrient elements. International Journal of Arts and Sciences, *5*, 4, pp. 265-268, 2012.
16. *Grizzetti B., Pistocchi A., Liquete C., Udias A., Bouraoui F., van de Bund W.* Human pressures and ecological status of European rivers. Scientific Reports, *7*, 205, pp. 1-11, 2017.
17. *Hesni M.A., Hedayati S.A., Qadermarzi A., Pouladi M., Zangiabadi S., Naqshbandi N.* Comparison ability of algae and nanoparticles on nitrate and phosphate removal from aquaculture wastewater. Environmental Health Engineering and Management Journal, *6*, 3, pp. 171-177, 2019.

18. Instruction manual. Available at: http://hannainst.com/downloads/dl/file/id/1168/man83200_18_04_12.pdf
19. *Liyanage Ch.P., Yamada K.* Impact of population growth on the water quality of natural water bodies. Sustainability, *7*, pp. 1-14, 2017.
20. *Petrosyan V., Pirumyan G., Perikhanyan Y.* Determination of heavy metal background concentration in bottom sediment and risk assessment of sediment pollution by heavy metals in the Hrazdan River (Armenia). Applied Water Science, *9*, 4, pp. 1-9, 2019.
21. *Rheinheimer G.* Regional and seasonal distribution of saprophytic and coliform bacteria. In book: Microbial ecology of a brackish water environment, vol. 25. Berlin, Springer, pp. 121-137, 1977.
22. *Spanhoff B., Dimmer R., Friese H., Harnapp S., Herbst F., Jenemann K., Mickel A., Rohde S., Schonherr M., Ziegler K., Kuhn K., Muller U.* Ecological status of rivers and streams in Saxony (Germany) according to the Water Framework Directive and prospects of improvement. Water, *4*, 4, pp. 887-904, 2012.
23. *Stepanyan L.G., Hambaryan L.R.* Investigations of algal bloom in "Yerevanyan Lich" Reservoir. Proceedings of the Yerevan State University, *51*, 3, pp. 198-202, 2017.
24. *Vaghela K.B., Shukla D.P., Mishra A.Y., Jain N.K.* Impact of pollution on aquatic fauna of river ecosystem: A review. International Journal of Current Advanced Research, *6*, 10, pp. 6518-6524, 2017.
25. Water quality – Determination of biochemical oxygen demand after n days (BOD_n) – Part 1: Dilution and seeding method with allylthiourea addition. Norm ISO 5815-1:2003. Geneva, International Organization for Standardization Publ., 15 pp., 2003.
26. Water quality – Determination of biochemical oxygen demand after n days (BOD_n) – Part 2: Method for undiluted samples. Norm ISO 5815-2:2003. Geneva, International Organization for Standardization Publ., 13 pp., 2003.
27. Water quality – Determination of dissolved oxygen – Electrochemical probe method. Norm ISO 5814:2012. Geneva, International Organization for Standardization Publ., 14 pp., 2012.

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