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Original article

Biogenic Elements in the Waters of the Eastern Gulf of Finland According to the Results of Studies 2020–2022

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Abstract

The paper studies the dynamics of biogenic elements (mineral (phosphate) and total phosphorus and ammonium) content based on the results of annual monitoring surveys of water in the eastern Gulf of Finland conducted in 2020–2022. Information on the horizontal and vertical distribution of the indicators was analysed, so samples were taken in the surface, bottom and middle (at deep-water stations) layers of water. The content of elements was determined by the spectrophotometric method. The results are compared and analysed by median values. During the study period, phosphate phosphorus concentrations in the absolute majority of cases did not exceed the maximum permissible concentration (0.15 mg/dm^3), total phosphorus concentrations on average corresponded to the mesotrophic status, although there were cases of its concentration increase to values characteristic of the eutrophic status of a water body. Namely, in 2020, the concentrations amounted up to 0.091 mg P/dm^3 in the bottom and surface water layers in June (mainly at the coastal stations) and in September (mainly in the bottom layer at the central offshore stations). In summer 2021, the concentrations reached 0.147 mg P/dm^3 (surface layer) and 0.171 mg P/dm^3 (bottom layer) at the coastal stations and 0.163 mg P/dm^3 at the central station. Ammonia nitrogen concentrations were mainly within the MPC (0.5 mg/dm^3). In June 2021, local areas along the southern and northern shores of the Gulf of Finland with relatively high levels of ammonia nitrogen (up to 0.285 mg/dm^3) in surface and bottom water layers were identified. In general, despite the high anthropogenic load, concentrations of mineral phosphorus and ammonium in the waters of the Gulf of Finland were within the MPC, with exceedances recorded rarely, usually in Neva Bay, Koporye Bay and near the coast of the Kurortny district. Elevated concentrations of total phosphorus at the central stations can apparently be explained by transport of the substance from the western part of the Gulf and diffusion from bottom sediments. On average, higher concentrations of total phosphorus were found in bottom water layers than in surface water layers. In general, concentrations of biogenic elements correspond to the mesotrophic status of the water body.

Key words: mineral phosphorus, total phosphorus, ammonium ions, Gulf of Finland, biogenic elements, trophic state

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Биогенные элементы в водах восточной части Финского залива по результатам исследований 2020–2022 годов

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Аннотация

Изучена динамика содержания биогенных элементов (минерального (фосфатного) и общего фосфора и аммония) по результатам ежегодных мониторинговых исследований воды восточной части Финского залива, проводившихся в 2020–2022 гг. Анализировалась информация о распределении показателей по горизонтали и по вертикали, поэтому пробы отбирали в поверхностном, придонном, а на глубоководных станциях и в серединном слоях воды. Содержание элементов определяли спектрофотометрическим методом. Сопоставляются и анализируются результаты по среднемедианным значениям. В период исследований концентрация фосфатного фосфора в абсолютном большинстве случаев не превышала ПДК (0.15 мг/дм^3), концентрации общего фосфора в среднем соответствовали мезотрофному статусу, хотя наблюдались случаи повышения его концентрации до значений, характерных для эвтрофного статуса водоема: в 2020 г. в придонном и поверхностном слоях воды (в июне в основном на прибрежных станциях (0.091 мг Р/дм^3) и в сентябре преимущественно в придонном слое на центральных станциях, удаленных от берега), в 2021 г. летом концентрации достигали 0.147 мг Р/дм^3 (поверхностный слой) и 0.171 мг Р/дм^3 (придонный слой) на прибрежных станциях, 0.163 мг Р/дм^3 на центральной станции. Концентрации аммонийного азота в основном находились в пределах ПДК (0.5 мг/дм^3). В июне 2021 г. выделялись локальные области вдоль южного и северного берега Финского залива с относительно высоким содержанием аммонийного азота (до 0.285 мг/дм^3) в поверхностном и придонном слоях воды. В целом, несмотря на высокую антропогенную нагрузку, концентрации минерального фосфора и аммония в водах Финского залива находились в пределах ПДК, превышения фиксировались редко, обычно в Невской Губе, Копорской Губе, у побережья Курортного района. Повышенные концентрации общего фосфора на центральных станциях, по-видимому, можно объяснить переносом вещества из западной части залива и диффузией из донных отложений. В среднем в придонных слоях воды обнаруживается более высокое содержание общего фосфора, чем в поверхностных. В целом концентрации биогенных элементов соответствуют мезотрофному статусу водоема.

Ключевые слова: фосфор минеральный, фосфор общий, ионы аммония, Финский залив, биогенные элементы, трофность

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Introduction

The Baltic Sea belongs to the Atlantic Ocean basin. The sea is deeply incised into the land, it has a long coastline and complex coastal contours [1)].

Within the Baltic Sea, several relatively isolated zones can be distinguished, including the Gulf of Finland. The area of the Gulf of Finland is 29.5 thousand km^2; the average depth is 38 m, the maximum one is 115 m. The rivers Neva, Luga, Narva, and Sestra flow into the Gulf. The part of the Gulf between the mouth of the Neva River and Kotlin Island is called Neva Bay; a fairway for the passage of ships was dug along its bottom [1)]. The coast of the Gulf of Finland is characterized by a high concentration of anthropogenic objects: settlements, ports, agricultural complexes, as well as nature reserves and historical monuments. A nuclear power plant is located in the town of Sosnovy Bor, and the second most important city in Russia, Saint Petersburg, was founded at the mouth of the Neva River.

Thus, the Gulf of Finland is of great importance for the functioning of the economy of the North-West region of Russia and experiences high anthropogenic load. This determines the need for careful monitoring of its ecological state. The Leningrad Region Committee on Natural Resources publishes collections containing information on the state of the atmospheric air and water of water bodies in the region regularly, including information on the state of the waters of the Gulf of Finland [2), 3), 4), 5)]. The hydrochemical characteristics of the Gulf are studied in [1–5].

The parameters under control include concentrations of total phosphorus, mineral phosphorus and ammonium nitrogen. Phosphorus and nitrogen are among the elements necessary for the development of living organisms as can be seen, for example, from the formula of organic matter according to Redfield $(CH_2O)_{106}(NH_3)_{16}H_3PO_4$ and the C:N:P ratio as 106:16:1 [6]. In natural conditions, it is the lack of phosphorus that often limits the development of hydrobionts. At the same time, when phosphorus enters water bodies, uncontrolled growth of plant

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1) Zonn, I.S., Kostyanoy, A.G., Semenov, A.V. and Zhiltsov, S.S., 2015. [*The Baltic Sea: Encyclopedia*]. Moscow: Mezhdunarodnye Otnosheniya, 570 p. (in Russian).

2) Natural Resources Committee of Leningrad Region, 2018. [*State of Environment in Leningrad Region*]. Saint Peterburg, 372 p. (in Russian).

3) Natural Resources Committee of Leningrad Region, 2019. [*State of Environment in Leningrad Region in 2018*]. Saint Peterburg, 448 p. (in Russian).

4) Natural Resources Committee of Leningrad Region, 2022. [*State of Environment in Leningrad Region*]. Saint Peterburg, 528 p. (in Russian).

5) Natural Resources Committee of Leningrad Region, 2023. [*State of Environment in Leningrad Region in 2022*]. Saint Peterburg: Papirus, 320 p. (in Russian).

biomass begins, eutrophication of the water body occurs with the change of its trophic status and the number of phytoplankton and bacteria increases. According to trophicity criteria [7], oligotrophic water bodies are characterized by phosphate concentrations (for phosphorus) from 0 to 0.012 mg P/dm^3, mesotrophic ones – from 0.012 to 0.024 mg P/dm^3 and eutrophic water bodies – from 0.024 to 0.096 mg P/dm^3. Higher values correspond to hypereutrophic waters.

The content of phosphorus compounds is subject to significant seasonal fluctuations since it depends on the ratio of the intensity of photosynthesis and biochemical oxidation of organic matter. Minimum concentrations of phosphates in surface fresh waters are usually observed in spring and summer, maximum ones – in autumn and winter. Maximum concentrations in sea waters are more typical for spring and autumn and minimum ones – for summer and winter [6)].

Ammonium ions are absorbed by plants turning into glutamic acid, on the basis of which α–amino acids are synthesized and then proteins, nucleic acids and other nitrogen-containing substances [6]. They are necessary for the development of aquatic organisms. At the same time, the NH_4^+ excess has a negative impact, thus causing fish intoxication [7)] [8]. Increased concentration of ammonium ions can be used as an indicator reflecting the deterioration of the sanitary condition of a water body and the pollution of surface and ground waters. Significant amounts of phosphorus and nitrogen compounds enter water bodies with wastewater from agricultural enterprises [7)], including livestock complexes [8, 9], domestic wastewater from populated areas and a result of the activities of some industrial enterprises.

The aim of this study is to investigate the dynamics of the content of mineral (phosphate) and total phosphorus and ammonium in the waters of the Gulf of Finland according to the results of monitoring studies 2020–2022.

Materials and methods of study

The content of various forms of phosphorus and ammonium ions in the waters of the eastern Gulf of Finland is monitored as part of the studies conducted annually by the Saint Petersburg Branch of VNIRO (GosNIORKH named after L.S. Berg). As a rule, two cruises are carried out under these studies: in spring and early summer, as well as in late summer and early autumn. More specific dates depend on weather conditions. During the cruises, samples are taken at stations distributed throughout the water area from several layers of water: surface, bottom and also middle layers of water at deep-water stations. This is done in order to describe the distribution of indicators not only horizontally, but also vertically. The number of sampling points can vary from cruise to cruise.

As a rule, the content of total phosphorus, mineral (phosphate) phosphorus and ammonium ions is determined in water samples by the spectrophotometric

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6) Available at: https://wwtec.ru/index.php?id=213 [Accessed: 28 May 2024].

7) Available at: https://wwtec.ru/index.php?id=212#8.2 [Accessed: 28 May 2024].

method in accordance with regulatory documents [8), 9)]

Results and discussion

2020

In 2020, two cruises were carried out as part of the monitoring studies: in June and September. The cruises were carried out according to the VNIRO state assignment No. 076-00005-20-02. Samples were collected at 15 stations during the cruises (Fig. 1, *b*).

a

b

F i g . 1 . Gulf of Finland (the rectangular on the map shows the study area in the eastern part of the Gulf) (*a*) and an enlarged image of the selected area with a sampling station grid (*b*) [3, 10]. Google Maps image (available at: https://www.google.ru/maps)

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8) Guideline РД 52.24.387-2019; Guideline РД 52.24.382-2019; Guideline РД 52.24.486-2009.

9) Ministry of Agriculture of Russia, 2016. On the Approval of Water Quality Standards for Water Bodies of Commercial Fishing Importance, Including Standards for Maximum Permissible Concentrations of Harmful Substances in the Waters of Water Bodies of Commercial Fishing Importance: Order of the Ministry of Agriculture of Russia dated December 13, 2016, No. 552. Moscow: Ministry of Agriculture of Russia (in Russian).

Table 1 shows results of determination of total and mineral phosphorus content. According to the obtained results, the concentrations of mineral phosphorus in the studied areas of the Gulf of Finland in June and September differed slightly. In September, compared to June, the concentration of mineral phosphorus at many points decreased,

T a b l e 1 . Results of determination of phosphorus (in terms of phosphorus) in water samples in 2020

Station	Water layer	Mineral phosphorus, mg P/dm^3		Total phosphorus, mg P/dm^3	
		June	September	June	September
1	S	0.001	0.005	0.006	0.013
	M	0	0.005	0	0.018
	B	0.003	0.008	0.013	0.042
2	S	0	0.002	0.005	0.011
	B	0.004	0.008	0.011	0.044
3	S	0	0.004	0.008	0.021
	M	0.008	0.002	0.015	0.020
	B	0.010	0.009	0.037	0.021
3k	S	0.005	0.004	0.005	0.012
	B	0.006	0.005	0.018	0.016
4	S	0.003	0.002	0.023	0.007
	B	0.005	0.004	0.040	0.019
6k	S	0.008	0.004	0.028	0.014
	B	0.015	0.006	0.076	0.009
6L	S	0.007	0.006	0.014	0.023
	B	0.005	0.004	0.023	0.013

Continued Table 1

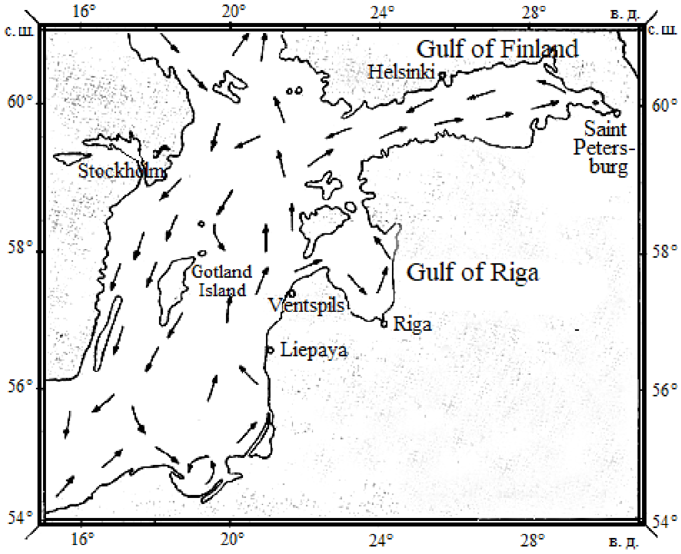
Station	Water layer	Mineral phosphorus, mg P/dm^3		Total phosphorus, mg P/dm^3	
		June	September	June	September
18L	S	0.009	0.005	0.044	0.016
	B	0.007	0.004	0.010	0.016
19	S	0.001	0.003	0.033	0.013
	B	0	0.005	0.003	0.015
20	S	0.002	0.003	0.007	0.011
	B	0.006	0.002	0.013	0.013
21	S	0.001	0.004	0.005	0.010
	B	0.005	0.004	0.028	0.014
22	S	0.004	0.002	0.012	0.018
	B	0.002	0.005	0.036	0.009
24	S	0.003	0.006	0.019	0.037
	B	0.012	0007	0.091	0.007
26	S	0.009	0.004	0.073	0.017
	B	0.006	0.003	0.013	0.017
A	S	0.005	0.005	0.027	0.013
	M	0.002	0.002	0.021	0.021
	B	0.006	0.005	0.072	0.039
Median value		0.005	0.004	0.018	0.016

Note: S – surface water layer (0–0.3 m); M – middle layer (equidistant from the surface and bottom); B – bottom layer; mg P/dm^3 – concentration of mineral and total phosphorus expressed as phosphorus. Maximum permissible concentration (MPC) of mineral phosphorus – 0.15 mg/L. MPC of total phosphorus is absent.

which corresponds to the expectations and can be explained by the increased consumption of mineral phosphorus by photosynthetic organisms in the summer. The exceptions were deep-water stations and stations *1*, *2* and *4* located far from the shore.

Total phosphorus concentrations were naturally higher and varied from 0 (i.e. below the detection limit), which corresponds to the oligotrophic status of the water body, to 0.091 mg P/dm^3, which corresponds to its eutrophic status. Total phosphorus concentration levels characterising the eutrophic status of the water body were also noted at central stations far from anthropogenic sources (stations *2–4*). However, such concentrations are more typical for the stations where water quality can be affected by man-made, domestic and agricultural wastewater (stations *19*, *21*, *24*, *26*, *A*, *6k*, *18L*). It should be noted that in September, high values of total phosphorus concentration were observed mainly in the bottom layers of water, including at station *2*, where its maximum value (0.044 mg P/dm^3) was recorded. This can be stipulated by the sedimentation of suspended organic matter and its destruction, transfer of phosphorus compounds from the western part of the Gulf and their entry from bottom sediments.

The current regime in the Gulf of Finland is determined by the water exchange of the Gulf of Finland and the Gulf of Riga with the main part of the Baltic Sea. The currents are significantly influenced by the runoff of water from the land. There is a more or less stable constant current directed to the west and explained by the runoff of the Neva River (Fig. 2). In addition, temporary wind currents arise under the influence of winds [10].



F i g . 2 . Diagram of main constant currents in the Gulf of Finland. The arrows show current directions

[10] https://studwood.net/1660488/tehnika/navigatsionno_gidrograficheskiy_gidrometeorologicheskiy_ocherki_baltiyskogo_morya_chast [Accessed: 8 May 2023].

According to literature data, phosphorus accumulation occurs actively in the deep-water western part of the Gulf where the biogenic regime is determined by the internal load on the water body, when additional phosphorus compounds are supplied from bottom sediments under conditions of oxygen deficiency [11]. Permanent currents transport the released phosphorus compounds from the western Gulf of Finland to the eastern one.

A decrease in the concentration of dissolved oxygen in the water and the development of hypoxic zones are less typical for the eastern Gulf of Finland due to its shallower waters. However, such phenomena are observed precisely in the area of deep-water station *4* (according to [11], oxygen concentration can vary from 5 to 2 mg/dm^3).

On average, the level of total phosphorus (based on the median values) indicates a mesotrophic status, which is why the MPC for mesotrophic water bodies was used in Table 1 [9)]. As follows from the data in Table 1, the mineral phosphorus MPC was not exceeded either in June or in September.

2021

In 2021, sampling was carried out in May and June, as well as in August and September, according to the standard sampling scheme from the stations showed in Fig. 1, *a*.

This year, not only phosphate (mineral) phosphorus and total phosphorus were determined, but also ammonium nitrogen.

Table 2 shows the results of water sample analysis.

In spring and early summer 2021, mineral phosphorus concentrations were very low (lower than in June of the previous year). This can have been stipulated by the clear sunny weather during that period and, as a result, the intensive development of biota, which consumed mineral phosphorus rapidly. On the contrary, the values of total phosphorus concentration were on average higher than in the same period last year, and at the same time the median values in May and June were at the eutrophic level. At stations *3к* (surface), *4* (middle), *20* (bottom), they exceeded 0.096 mg P/dm^3 – the upper limit of the eutrophic level. Station *3k* is located in Koporye Bay, station *20* – near the coast of the Kurortny district (the town of Zelenogorsk). It is logical to assume that increased concentrations of total phosphorus are explained by anthropogenic influence. On the contrary, station *4* is located far from the coast, though a significant content of total phosphorus was observed in the area of this station earlier, which gives reason to assume the influx of phosphorus from bottom sediments and with water masses coming from the western part of the Gulf, as was already noted above [10].

In May and June 2021, the mineral phosphorus MPC was exceeded at station *4* in the middle layer of waters and at station *20* in the bottom layer.

Unusually high levels of ammonium nitrogen were recorded at a number of stations (*6k*, *6L*, *18L*) located along the southern coast of the Gulf within Koporye Bay and neighboring Luga Bay, as well as at stations *19* and *20* located near the northern coast of the Gulf within the boundaries of the Kurortny district of Saint Petersburg. It is noteworthy that high content of NH_4^+ was characteristic of both surface and bottom layers of water. Areas of ammonium nitrogen increased concentrations in Koporye and Luga Bays can be associated with the influx of biogen-rich river waters, and near the northern coast – with the anthropogenic load of the Kurortny district.

T a b l e 2 . Results of determination of phosphorus and ammonium nitrogen in water samples in 2021

Station	Water layer	Mineral phosphorus, mg P/dm^3		Total phosphorus, mg P/dm^3		Ammonium, mg/dm^3	
		May – June	August – September	May – June	August – September	May – June	August – September
1	S	N/D	N/D	0.004	N/D	<0.03	N/D
	M	N/D	N/D	0.009	N/D	0.06	N/D
	B	0.005	N/D	0.017	N/D	0.09	N/D
2	S	0.004	0.003	0.029	0.003	< 0.03	< 0.03
	M	0.004	0	0.095	0.0055	< 0.03	< 0.03
	B	0.005	0.003	0.037	0.005	< 0.03	< 0.03
3	S	0	0.003	0.042	0.003	< 0.03	< 0.03
	M	0.005	0.004	0.005	0.0065	< 0.03	< 0.03
	B	0.002	0.003	0.032	0.006	< 0.03	< 0.03
3k	S	0	0.003	0.147	0.005	< 0.03	< 0.03
	B	0.002	0.004	0.039	0.005	< 0.03	< 0.03
4	S	0.003	0.002	0.017	0.036	< 0.03	< 0.03
	M	0.006	0.002	0.163	0.039	< 0.03	< 0.03
	B	0.009	0.002	0.034	0.006	< 0.03	< 0.03
6k	S	0.001	0.001	0.042	0.027	0.130	< 0.03
	B	0.005	0.002	0.024	0.004	0.285	< 0.03
6L	S	0.002	0.004	0.002	0.013	0.055	< 0.03
	B	0.003	0.002	0.021	0.008	0.075	< 0.03

Continued Table 2

Station	Water layer	Mineral phosphorus, mg P/dm³		Total phosphorus, mg P/dm³		Ammonium, mg/dm³	
		May – June	August – September	May – June	August – September	May – June	August – September
18L	S	0.0008	0.0040	0.0008	0.012	0.150	< 0.03
	B	0.0010	0.0030	0.0016	0.0055	0.055	< 0.03
19	S	0.0030	0.0065	0.0060	0.008	0.155	< 0.03
	B	0.0030	0.0060	0.0050	0.006	0.055	< 0.03
20	S	0.0030	0.0040	0.0260	0.005	0.075	< 0.03
	B	0.0030	0.0035	0.1710	0.006	0.170	< 0.03
21	S	0.0020	0.0150	0.0360	0.015	< 0.03	< 0.03
	B	0.0020	0.0065	0.0080	0.0065	< 0.03	< 0.03
22	S	0.0016	0.0080	0.0080	0.029	< 0.03	< 0.03
	B	0.0030	0.0120	0.0240	0.016	< 0.03	< 0.03
24	S	0.0020	0.0040	0.0500	0.013	< 0.03	< 0.03
	B	0.0020	0.0040	0.0440	0.004	< 0.03	< 0.03
26	S	0.0030	0.0050	0.0090	0.005	< 0.03	< 0.03
	B	0.0010	0.0050	0.0630	0.010	< 0.03	< 0.03
A	S	0.0004	0.0020	0.0120	0.021	< 0.03	< 0.03
	M	0.0030	0.0016	0.0030	0.009	0.030	< 0.03
	B	0.0065	0.0030	0.0680	0.031	0.070	< 0.03
Median value		0.0020	0.0040	0.0290	0.008	< 0.03	< 0.03

Note: N/D – not determined. See designations to Table 1. MPC of ammonium – 0.5 mg/L.

Moreover, high content of NH_4^+ was recorded at station *4* in the upper water layer. Thus, it is possible to assume the formation of local areas (“spots”) with a relatively high content of ammonium nitrogen, which correlate partially with areas with an increased level of total phosphorus. Despite the recorded high level of ammonium concentrations, all values of this indicator were below the MPC.

At the end of August and in September of the same year, the concentrations of mineral phosphorus changed insignificantly compared to June. The concentrations of total phosphorus decreased significantly and ranged from 0.003 to 0.039 mg P/dm^3. Values corresponding to hypereutrophic status were completely absent; values exceeding the upper limit of the mesotrophic level were recorded only at stations *4* (surface and middle), *22* (surface) and *A* (bottom). Ammonium nitrogen concentrations were either below the detection limit or negligible.

2022

In 2022, samples were taken in June and September from the stations shown in Fig. 1, *a*.

As in 2021, phosphate (mineral) phosphorus, total phosphorus and ammonium nitrogen were determined.

Table 3 shows the results of water sample analysis.

Table 3. Results of determination of phosphorus and ammonium nitrogen in water samples in 2022

Station	Water layer	Mineral phosphorus, mg P/dm^3		Total phosphorus, mg P/dm^3		Ammonium, mg/dm^3	
		May – June	August – September	May – June	August – September	May – June	August – September
1	S	0.0008	0.0008	0.007	0.0008	< 0.03	< 0.03
	M	0.0040	0.0040	0.001	0.0200	< 0.03	< 0.03
	B	0.0070	0.0070	0.002	0.0390	< 0.03	< 0.03
2	S	0.0004	0.0004	0.027	0.0020	< 0.03	< 0.03
	M	0.0003	0.0003	0.008	0.0004	< 0.03	< 0.03
	B	0.0003	0.0003	0.041	0.0003	< 0.03	< 0.03

Continued Table 3

Station	Water layer	Mineral phosphorus, mg P/dm^3		Total phosphorus, mg P/dm^3		Ammonium, mg/dm^3	
		May – June	August – September	May – June	August – September	May – June	August – September
3	S	0.0007	0.0007	0.0170	0.0007	< 0.03	< 0.03
	M	0.0040	0.0040	0.0013	0.0670	< 0.03	< 0.03
	B	0.0030	0.0030	0.0120	0.0030	< 0.03	< 0.03
3k	S	0.0016	0	0.0016	0.0020	< 0.03	< 0.03
	B	0.0010	0.0020	0.0030	0.0024	< 0.03	< 0.03
4	S	0.0013	0	0.0060	0.0003	< 0.03	< 0.03
	M	0.0013	0.0030	0.0740	0.0030	< 0.03	< 0.03
	B	0.0070	0.0070	0.1140	0.0240	< 0.03	< 0.03
6k	S	0.0010	0.0008	0.0080	0.0008	< 0.03	< 0.03
	B	0.0050	0.0040	0.0010	0.0120	< 0.03	< 0.03
6L	S	0.0080	0.0030	0.0010	0.0100	< 0.03	< 0.03
	B	0.0013	0.0040	0.0160	0.0040	< 0.03	< 0.03
18L	S	0.0016	0.0040	0.0120	0.0200	< 0.03	< 0.03
	B	0.0016	0.0030	0.0390	0.0065	< 0.03	< 0.03
19	S	0.0020	0.0030	0.0020	0.0060	< 0.03	< 0.03
	B	0.0020	0.0040	0.0050	0.0130	< 0.03	< 0.03
20	S	0.0013	0.0003	0.0016	0.0130	< 0.03	< 0.03
	B	0.0010	0.0040	0.0160	0.0290	< 0.03	< 0.03
21	S	0.0013	0.0010	0.0070	0.0310	< 0.03	< 0.03
	B	0.0013	0.0080	0.0016	0.0340	< 0.03	< 0.03

Ended Table 3

Station	Water layer	Mineral phosphorus, mg P/dm^3		Total phosphorus, mg P/dm^3		Ammonium, mg/dm^3	
		May – June	August – September	May – June	August – September	May – June	August – September
22	S	0.0013	0.0030	0.0013	0.0030	< 0.03	<0.03
	B	0.0003	0.0050	0.0013	0.0090	< 0.03	< 0.03
24	S	0.0013	0.0010	0.0013	0.0120	< 0.03	< 0.03
	B	0.0010	0.00070	0.0220	0.0120	0.04	< 0.03
26	S	0.0013	0.0016	0.0100	0.0040	0.06	< 0.03
	B	0.0140	0.0016	0.0410	0.0050	< 0.03	< 0.03
A	S	0.0008	0.0008	0.0016	0.0008	< 0.03	< 0.03
	M	0.0013	0.0016	0.0100	0.0070	< 0.03	< 0.03
	B	0.0030	0.0340	0.0590	0.0430	< 0.03	< 0.03
Median value		0.0010	0.0030	0.007	0.0070	< 0.03	< 0.03

Note: N/D – not determined. See designations to Table 1. MPC of ammonium – 0.5 mg/L.

In June 2022, mineral phosphorus concentrations were at traditionally low levels. Ammonium nitrogen concentrations were also insignificant. The total phosphorus content varied from 0.001 to 0.074 mg P/dm^3. It exceeded 0.024 mg P/dm^3 at stations *2* (bottom), *4* (middle), *18L* (bottom), *26* (bottom) and *A* (bottom). A similar picture was observed in September, only the content of total phosphorus was from 0.002 to 0.067 mg P/dm^3 and the overflow of the mesotrophic state was recorded at stations *1* (bottom), *3* (middle), *20* (bottom), *21* (bottom) and *A* (bottom). As in September 2020, total phosphorus was accumulated in the bottom layer. In general, the content of biogenic elements in the Gulf water this year was lower than in 2020 and 2021, and the median values of total phosphorus concentrations in both seasons were even at the oligotrophic level.

Conclusion

A comparison of the 2020–2022 measurement results makes it possible to draw a number of conclusions.

Despite high anthropogenic load, the concentrations of mineral phosphorus and ammonium in the waters of the Gulf of Finland are within the MPC limits, and exceedances have been recorded quite rarely.

Over the period under discussion (three years for phosphorus, two years for ammonium), the concentrations of the studied biogenic elements fluctuated within relatively narrow ranges of values showing no obvious trends toward increase or decrease. Significant concentrations of total phosphorus are usually observed in such areas as Neva Bay, Koporye Bay, the area near the coast of the Kurortny district, that is, in the areas with the greatest anthropogenic impact. Once in 2021, an elevated, compared to normal, level of NH_4^+ was recorded in Koporye and Luga Bays, as well as near the coast of the Kurortny district. Stations *4* (deep-water) and *A* (remote from the coast) deserve special attention as there, elevated concentrations of total phosphorus have been periodically recorded. Apparently, this can be explained both by the transport of the substance from the western part of the Gulf and diffusion from bottom sediments.

On average, higher concentrations of total phosphorus were found in bottom water layers than in surface water layers.

Generally, concentrations of biogenic elements correspond to the mesotrophic status of the water body.

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