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Background Nitrogen Concentrations in the Unmonitored and Partially Monitored Rivers of the Gulf of Finland Basin

E. V. Stepanova and G. T. Frumin

Russian State Hydrometeorological University, Malookhtinskii pr. 98, St. Petersburg, 195196 Russia
e-mail: gfrumin@mail.ru

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Abstract—The unit area background discharges of total nitrogen from the catchment areas of some unmonitored and partially monitored rivers of the Gulf of Finland basin and background concentrations of total nitrogen in waters of these rivers were estimated.

Keywords: eutrophication, nutrients, background concentrations, unit area discharges, Gulf of Finland

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Assessment of the state of the marine environment of the Baltic Sea over the last few decades by experts of the Helsinki Commission for the Protection of the Marine Environment of the Baltic Sea (HELCOM) has resulted in the conclusion that the major negative changes in the sea are associated with eutrophication process [1–3]. The Gulf of Finland is considered to be one of the most eutrophic regions of the Baltic Sea, not only because of a high nutrient load but also because of a relatively small volume of seawater. The water of the Gulf of Finland is shallow, with the average depth of 35 m.

The causes and relative significance of the natural and anthropogenic components in eutrophication of the Baltic Sea are very difficult to elucidate and remain open to debate. The reason lies in the specific physical and geographical features of the sea, owing to which natural processes and factors have emerged as possible essential contributors to eutrophication in many of its manifestations.

The sources of nutrient enrichment of Baltic Sea may be of natural or anthropogenic origin. The natural load is mainly due to chemicals carried by surface water runoff from natural landscapes (forests, wetlands, grasslands of natural origin, etc.) during rainfall or snowmelt events. The sources of anthropogenic component are industrial, municipal, and agricultural wastewater discharges, as well as contaminants dissolved and suspended in the runoff from agricultural and arable lands, pastures, and fertilized and abandoned areas. According to the HELCOM estimates [4], 30 to 40% of the nitrogen input to the Baltic Sea aquatic area is accounted for by agriculture today. In the Baltic Sea catchment area on the whole, diffuse sources are the most powerful contributors (71%) to the total nitrogen load [3].

The Gulf of Finland catchment area is shared between Russia (67%), Finland (26%), and Estonia (7%), with <0.1% belonging to Latvia. The largest river in this catchment area and in the entire Baltic Sea catchment area is Neva.

The Russian part of the Gulf of Finland catchment area includes St. Petersburg, almost entirely Leningrad oblast and Novgorod oblast, the eastern part of Pskov oblast, and the north-western parts of Tver oblast and Vologda oblast, as well as the western part of Arkhangelsk oblast and south of Karelia. In general, the landscape in this area consists of lowlands, with abundant wetlands. Forests cover more than 55% of the territory; lakes and bogs occupy 17% and 13%, respectively. This area has a population density of 30 people km^{-2}; the total population is 8 mln, among them ca. 80% in St. Petersburg and Leningrad oblast; the proportion of urban areas is 2%, and that of agricultural land, 12% [4–6].

During the Baltic Sea study period, the nutrient balance was repeatedly evaluated and consistently updated. According to [7], the main item (>60%) of the revenue in the nutrient balance is the riverine runoff, which situation is typical of seas located in the humid

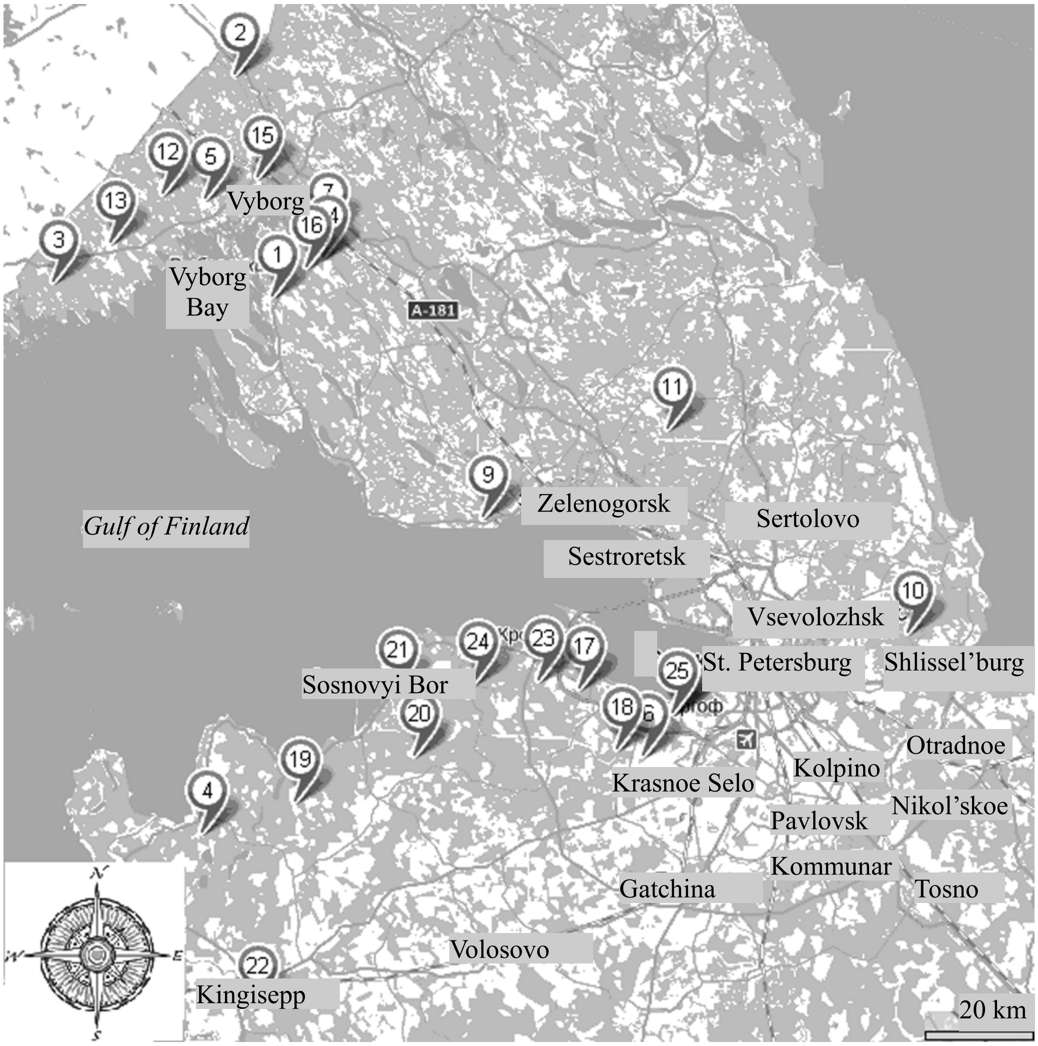
Unit area background discharges and background concentrations of total nitrogen for selected rivers of the Gulf of Finland basin

Run no.	River	S, km^2	R_{AA}, m^3 s^{-1}	$M(TN)^{BCKGD}$, (N kg) km^{-2} year^{-1}	$Q(TN)^{BCKGD}$, t year^{-1}	$R_t(TN)$	$C_{AA}(TN)^{BCKGD}$, μg dm^{-3}
1	Gorokhovka (Aleksandrovka)	731	7.9	225	164	0.50	323
2	Chernaya (Gladyshevka)	668	7.2	233	156	0.57	392
3	Ser'ga (Urpala-joki)	94.5	1.02	224	21	0.61	399
4	Khabolovka (Khobalovka)	330	3.53	251	83	0.55	411
5	Polevaya (Terva-joki)	160	1.74	220	35	0.67	428
6	Strelka	155	2.45	250	39	0.85	430
7	Cherkasovka (Ilya-joki)	116	1.25	212	25	0.69	438
8	Vila-Joki (Velikaya)	161	1.7	221	36	0.66	444
9	Privetnaya (Inon-joki)	70	0.8	235	16	0.74	470
10	Kamenka	134	1.5	240	32	0.75	510
11	Sestra	399	4.3	233	93	0.77	529
12	Chulkovka (Kisi-joki)	72	0.78	220	16	0.83	540
13	Peschanka (Santa-joki)	200	2.1	223	45	0.81	551
14	Drema (Korpelan-joki)	45.7	0.5	222	10	0.87	552
15	Seleznevka (Yukspan-joki)	623	5.6	199	124	0.79	555
16	Matrosovka (Sommen-joki)	55.2	0.6	223	12	0.93	590
17	Karasta	55.8	0.62	243	14	0.83	595
18	Shingarka	121	1.3	248	30	0.84	615
19	Sista (Teplushka)	672	7.2	250	168	0.91	674
20	Voronka	286	2.08	247	71	0.70	759
21	Kovashi	612	4.45	246	151	0.73	786
22	Luga	13200	102	284	3749	0.81	945
23	Chernaya Rechka (Sapa-oja)	96.2	0.7	254	24	0.87	947
24	Lebyazh'ya	101	0.74	243	25	0.93	997
25	Dudergofka	120	0.69	247	30	0.74	1021
26	Kikenka (Kekenka)	68	0.29	245	17	0.88	1638

zone and having a hindered water exchange with the ocean. This clearly necessitates the quantitative assessment of not only the sources of nutrients in the basin but also of the differentiated natural (background) and anthropogenic components at the nutrient riverine runoff outlets.

Previously, we proposed and tested techniques for assessing the background component of the nutrient runoff for the monitored rivers of the Baltic Sea drainage basin, for which there exist hydrochemical and hydrological observation data series [8–11]. However, estimation of background concentrations of nutrients in unmonitored or partially monitored rivers requires development of special techniques.

In [12], we determined the unit area background discharges of total (unfiltered) phosphorus from



Selected rivers of the Gulf of Finland basin (numbered as in the table).

catchment areas and background concentrations of total phosphorus (*TP*) in the waters of more than fifty unmonitored and partially monitored rivers in the Baltic Sea drainage basin.

The aim of this study was to estimate the unit area background discharges from the catchment areas and background concentrations of total nitrogen (*TN)* in the waters of selected rivers of the Gulf of Finland basin.

In estimating the unit area background discharges of total nitrogen from the catchment areas of the rivers considered, we reasoned as follows. According to [13], the status of an oligotrophic water body poor in dissolved nutrients is characterized by $TN : TP = 35$. On the other hand, the oligotrophic status is due to input of not very large amounts of nitrogen and phosphorus to a water body, which can be interpreted as background levels. In this case, $TN : TP = 35$ can be regarded in the first approximation as corresponding to the ratio of the respective unit area background discharges from the catchment area, i.e.:

$$M(TN)^{\mathrm{BCKGD}} = 35M(TP)^{\mathrm{BCKGD}}. \quad (1)$$

The background components of the total nitrogen discharge from the catchment areas of the rivers considered $Q(TN)^{\mathrm{BCKGD}}$, t year^{-1}, without taking into account its retention by the catchment areas and drainage network, were determined using the equation:

$$Q(TN)^{\mathrm{BCKGD}} = \frac{M(TN)^{\mathrm{BCKGD}}}{1000} S, \quad (2)$$

where S is the catchment area size, km^2.

Further, the average annual background concentrations of total nitrogen [$C_{\mathrm{AA}}(TN)^{\mathrm{BCKGD}}$, μg dm^{-3}] were calculated, with retention of nutrients by their catchment area and drainage network taken into account:

$$C_{AA}(TN)^{BCKGD} = \frac{R_t(TN)Q(TN)^{BCKGD}}{0.0315R_{AA}}, \quad (3)$$

where R_{AA} is the long-term average annual water consumption, m^3 s^{-1}, and $R_t(TN)$ is the total nitrogen runoff coefficients.

The coefficients of total nitrogen runoff from the catchment areas were calculated on the basis of the empirical relationships proposed in [14–15].

The calculated results are presented in the table.

As expected, the calculated background concentrations of total nitrogen show an overall increasing trend from Gulf of Finland north-east to south-east (see figure).

The unit area background discharges of total nitrogen, calculated by us, are consistent with the official estimates of nutrient inputs to the Baltic Sea from the catchment areas of the HELCOM participating countries, specifically, with the average unit area background discharge of total nitrogen in the Gulf of Finland of ca. 270 (N kg) km^{-2} year^{-1} according to [4, 16].

Thus, the approach we proposed allows estimating a priori the background concentrations of total nitrogen in rivers in a way such that time-consuming collection and processing of large data arrays characterizing their catchment areas can be avoided.

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