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THE BALANCE OF INORGANIC NITROGEN IN THE BASINS OF SMALL RIVERS (ON THE EXAMPLE OF THE WATERSHED NORTHERN DVINA)

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Abstract

In article features of nitrogen circulation transformation as a result of influence of anthropogenous factor on the example of the small river basin of the river Northern Dvina are considered. Relevance of research is confirmed by a number of negative processes common to the present stage of humanity development over its expense caused by excess of nitrogen inflow to the biosphere. The method of balance which allows to objectively estimate a contribution of economic activity and extent of transformation of nitrogen circulation is the cornerstone of anthropogenous nitrogen component allocation.

The structure analysis of received inorganic nitrogen balance part showed that 80 - 97% of the nitrogen amount arriving on reservoirs are the share of atmospheric precipitation. Even in the low-developed territories, with insignificant anthropogenous influence, the transformation of biogeochemical nitrogen circulation which is expressed in accumulation of this component is noted. The circulating air streams are the main distributors of nitrogen influencing its natural cycle. Thus, cross-border transfer of the polluting substances represents one of priority and relevant environmental problems of the present.

Keywords: nitrogen balance, watershed, nitrogen cycle, anthropogenic factor.

1. Introduction

The intensive activity of the person involves violating the balance existing in environment; in recent years that becomes the reason of the environmental problems connected with environmental pollution. Geochemical cycles of many elements are exposed to anthropogenous influence which leads to natural geochemical landscapes change, especially in zones of industrial and agricultural production, to changes in ecological systems, to violation of the main biosphere property – self-control [1, 2].

In modern conditions biogeochemical nitrogen circulation in natural cycle makes significant amount of nitrogen, to this anthropogenous factor is added as a result it leads to change of the natural caused concentration of nitrogen within a geographical sphere [3, 4]. Studying ways of nitrogen compounds migration, assessment of anthropogenous component amount and definition of components contribution of landscape to total balance of inorganic nitrogen represents the relevant direction of modern geochemistry. The purpose of this work is to calculate components balance of ammonium and nitrogen nitrate, to assess contribution of anthropogenous factor to nitrogen circulation in basins of the small rivers – inflows of Northern Dvina.

2. Methods

Hydrological and hydrochemical information on 2 posts located in the territory of catchment basins is the basis for work. We are Lezha and Elva samples (inflows of the second and third about r. Northern Dvina), and also materials of supervision on meteorological stations Vologda and Ust-Vym during 2000 - 2007.

The method of balance which allows to estimate objectively the contribution of economic activity and extent of nitrogen circulation transformation is the cornerstone of nitrogen anthropogenous component allocation. The balance equation of inorganic nitrogen within a catchment area represents a difference between receipt and account parts.

The receipt part is made by the following components:

$$V_{inflow} = V_{atm.} + V_{nitrofix.} + V_{fert} + V_{anim.comp.} + V_{inorg.nit.},$$

where V_{atm}- amount of the inorganic nitrogen which arrived on the area of a reservoir with an atmospheric precipitation; $V_{nitrofix..}$- amount of the inorganic nitrogen formed in the territory as a result of nitrogen fixation by microorganisms; V_{fert} - the mass of the inorganic nitrogen which arrived on the territory of the farmland with mineral fertilizers; $V_{anim.comp.}$.and $V_{inorg.nit.}$ – the mass of the inorganic nitrogen formed on livestock complexes and territories of settlements.

The account part includes:

$$C_{acc} = C_{agr} + C_{soil} + C_{woods} + C_{swamp} + C_{agr.crop.} + C_{live\ stock},$$

where C_{agr}, C_{soil}, $C_{live\ stock}$, .$C_{woods.}$, $C_{swamp..}$- amount of the inorganic nitrogen which is taken out by superficial and underground drain from territories of the farmland, settlements, livestock complexes, forest and boggy territories; $C_{agr.crop}$ - exertion of inorganic nitrogen with an agricultural harvest.

The amount of the inorganic nitrogen (ammonium and nitrate form) which is dropping out on the territory along with atmospheric precipitation shows on the basis of left sediment about monthly amounts and concentration of inorganic nitrogen. The amount of inorganic nitrogen formed in the territory as a result of nitrogen fixation by microorganisms was established for subbands of northern and southern taiga according to the coefficients offered by B. N. Moiseyev and I.O. Alyabina (2007) [5]. The amount of the inorganic nitrogen formed in settlements and livestock complexes was defined on the basis of data on population and information on livestock. For determination of size of inorganic nitrogen runoff from the farmland data on their areas, types of soils, the structure of sown areas, harvest and amount of mineral fertilizers were used (in terms of nitrogen). The areas of agricultural holdings within the considered pools were established as a result of topographic maps digitization and satellite shots. Information on the structure of sown areas (the territory occupied with different cultures), harvest, amount of the introduced mineral fertilizers (in terms of nitrogen) was received according to actual data of land use.

For superficial drain the following ratio of inorganic nitrogen forms was accepted: N (NO_3) - 19,2%, N (NH_4) - 80%. Contains in an underground drain nitrogen of nitrate 96,6%, ammonium - 3,3% [6].

The size of runoff of inorganic nitrogen various forms with a vegetable mass of crops was determined by dependence:

$$B_y = \sum_{j=1}^{n} C_{ij} * U_j * F_j \text{, kg/year,}$$

where C_{ij} - contents of *i*-from inorganic nitrogen in *j*-crop, kg/c; U_j - fertility of *j-crop*, c; F_j - area of *j*-crop, ga; *n* – crop quantity.

In the conditions of the studied territories subsolic and cespitose and subsolic soils, widespread in areas of lowlands - various options of marsh and boggy soils, were researched. The main cultures which are grown up here are grain, potatoes and vegetables. Makes indicators of nitrogen runoff on soil with a grain yield 2,94, potatoes - 0,5, vegetables – 0,29 kg/c of the main production [6].

Runoff of various forms of inorganic nitrogen from the territory of rural settlements is caused by superficial drain from territories of settlements, as well as filtration of pollution from cesspit. For an assessment of inorganic nitrogen runoff the superficial drain from territories of rural settlements information on building area, population, amount of precipitation and concentration of the polluting substances in a superficial drain was used.

The nitrogen runoff assessment by drain from livestock complexes was carried out on the basis of information on the number of different animal types, a manure exit from 1 animal and the content of nitrogen in it, as well as amount of the nitrogen detained by the soil.

For an assessment of inorganic nitrogen runoff from forest territories and bogs we used information on the indicators characteristic of the biomes of central and southern taiga and bogs calculated by B. N. Moiseyev and I.O. Alyabina (2007). Thus, authors specify that the following ratios of account parts of nitrogen are common to woods of northern taiga (Elva river basin): it is washed away from soils and about 65% of the nitrogen which dropped out with an atmospheric precipitation for a subband of the southern taiga (Lezha river basin) this value makes 30%. For bogs runoff makes about 70% of the nitrogen which dropped out with an atmospheric precipitation [5].

When calculating accumulation of nitrogen in forest wood vegetation, nitrogen consumption indicators by various tree types, as well as structure of forest phitocenosis were used. These, according to V. N. Bashkin, A.S. Kurbatova and D. S. Savin (2004) work according to pollutant amount in ecosystems: 1 hectare of wood consisting of coniferous trees consumes about 22 kg of nitrogen a year, the soft-leaved trees – 88 kg/hectare a year.

The difference between the inorganic nitrogen formed on a reservoir (and also arrived with an atmospheric precipitation), and washed away and taken out from this territory, is the amount of inorganic nitrogen which is deposited within the pool. This size testifies to nitrogen balance features in the water-collecting territory. So, if the specified indicator is positive, then it is possible to talk about nitrogen accumulation process. If it has negative value, then it testifies to nitrogen reserve exhaustion within the studied pool.

3. Results

The considered river basins are located in the territories which are relating to various landscape subbands, differing with degree of familiarity, development of agricultural industry (table 1) and characterized by lack of industrial facilities.

Table 1. Distribution areas in studied river basins.

№	River-post	Area watershed (km^2) landscape subzone	Forested, %	Waterlogge, %	Plowing, %	
1	Lezha - Zimnajk	1627	South taiga	78	5	15
2	Elva - Meshura	2689	Northern taiga	87	11	1,2

Components of ammonium and nitrate nitrogen balance during 2000 - 2007 are presented in table 2.

Table 2. Average long-term value of the ammonium and nitrate nitrogen balance components in the studied basins for the 2000 - 2007, kg/km^2.

Sources	Ammonium nitrogen		Nitrate nitrogen	
	Elva - Meshura	Lezha - Zimnajk	Elva - Meshura	Lezha - Zimnajk
Receipt				
Depositions with precipitation	690,19	166,53	198,65	2342,6
Received on farmland with fertilizers	18,22	101,19	4,55	25,3
Formed in the cattle-breeding complexes	1,49	121,42	3,29	269,52
Formed in settlements	0,03	0,4	-	-
Flow				
Removal from the forest areas	392,25	36,47	112,9	513,03
Runoff from wetlands	54,88	5,79	15,8	81,42
Removal of surface runoff from agricultural land	0,91	5,06	0,23	1,26
Removal of the underground runoff from agricultural land	0,08	0,42	2,2	12,22
Removal from the territories of livestock farms	1,49	121,42	3,29	269,52
Removal from the runoff from residential areas	0,31	6,4	0,002	0,06
Stoke cesspool of rural settlements	0,03	0,4	-	-
Other indicators				
The loss to the agricultural harvest	-	-	0,011	180,6
Indicators of river flow-Deposition in forest and marsh vegetation	67,92	55,41	8,33	94,59

In the atmospheric precipitation which is dropping out in the territory of the river Lezha reservoir, the nitrate form of nitrogen which share makes 87-97% that is connected with large volumes of industrial emissions of NO_x in the territory of the city of Vologda which is in close proximity to the studied pool prevails. On a site of the river Elva basin the opposite picture is observed: the share of ammonium form of nitrogen makes 67-87% of all inorganic nitrogen losses while respectively 13-33% are the share of nitrate form that is caused by absence of the large industrial enterprises in this territory. The main production here is the share of logging and the woodworking industry which is characterized by plentiful ammonia emissions in air (at hot pressing, pasting and drying of interline interval vapors of formaldehyde, phenol, ammonia are emitted) that is one of the high concentration reasons of ammonium form of nitrogen in rainfall. The analysis of nitrogen content in the river Elva drain of ammonium form showed 80-95% of the general inorganic nitrogen revealed prevalence in water of the river. In river Lezha drain the nitrate nitrogen is prevailing making 51-77% of annual values of total inorganic nitrogen.

Runoff of ammonium nitrogen with a superficial drain from agricultural holdings exceeds the size of the specified ingredient underground drain by 12 times. Runoff of nitrate nitrogen from agricultural holdings an underground drain exceeds the similar indicator of a superficial drain approximately by 9-10 times. It is connected with the fact that in underground waters there are no consumers of nitrates (phytoplankton and denitrifying bacteria).

The studied basin territories with various intensity are used for farming (tab. 1), respectively the contribution of this branch to intake of inorganic nitrogen differs.

The grown cultures in the territory of agricultural holdings of the pools investigated by us are presented by grain, potatoes and vegetables. And, a ratio of the areas on which they are grown, and respectively indicators of harvest are various. So, in the territory of the river Lezha basin the prevailing crop is grain (60% of harvest), then - potatoes (30%) and vegetables (10%). Within the basin of the river Elva more than 80% of a harvest is the share of potatoes, 20% for vegetables, grain is absent. Thus, in view of crops structure, various intensity of nitrogen consumption by crops and the individual content of nitrogen in different types of plants we determined losses of nitrogen with harvest. The vegetation consumes nitrogen mainly in the form of nitrates therefore at assessment of inorganic nitrogen losses with an agricultural harvest we were limited to the specified form. The size of the nitrate nitrogen withdrawn with a vegetable mass of harvest is directly proportional to volumes of crops harvested (tab. 2).

The inorganic nitrogen nitrate form lost with vegetable mass of harvest in the studied region makes from 0,01 (the basin of river Elva) up to 19% (the basin of river Lezha) from the general inorganic nitrogen which is run off from the studied territories. The amount of the polluting substances which came to water objects from objects of animal husbandry is defined by their power and look. Generally the studied territories are engaged in cultivation of cattle, pigs, sheep and goats. And on two sites the animal husbandry different degree is developed that predetermines its various share in inorganic nitrogen drain formation. The contribution of ammonium and nitrate nitrogen drain from objects of animal husbandry represents a considerable balance component of these forms of nitrogen on a site of the river Lezha basin - the r. Zimnajk, 69% of the ammonium nitrogen which is washed away from the territory, and 31% of the washed-away nitrate nitrogen are the share of this component. For the basin of the river of Elva the Meshura animal husbandry contribution to balance of inorganic nitrogen is insignificant (0,3 - 2,4%).

The timberland occupies the prevailing part of basins territories (tab. 1). The contribution of ammonium and nitrate nitrogen drain from the timberland represents the main component of these forms of nitrogen balance. In the studied territories runoff of a nitrate form of inorganic nitrogen from the timberland makes: for a site of the r. Lezha - Zimnajk it is 58%, for river of Elva - Meshura - 84% of the general taken-out nitrogen nitrate; and for an ammonium form: 21% for river Lezha - Zimnajk, and 87% for river of Elva - Meshura. The contribution of boggy sites to total runoff of inorganic nitrogen from the territory of basins is second-large 3-12% of inorganic nitrogen runoff of an ammonium form, and 9-12% for a nitrate form fall to their share. As the timberland occupies the prevailing part of basins territories, they not only are the main suppliers of the inorganic nitrogen which is taken out by a superficial and underground drain, but also the main consumers of nitrogen, and, therefore, the main stores. As a result of the carried-out calculations it was determined that the forest vegetation presented in the studied territories generally coniferous (fir-tree, pine) and soft-leaved (birch, linden, aspen) trees, plays a huge role in formation of overall nitrogen balance. As the basin of the river Elva-Meshura is highly covered with woods, respectively the specific indicators of nitrogen deposition in forest vegetation are maximum here. Having calculated specific indicators of chemical elements consumption, including inorganic nitrogen, various trees received that the basin of the river Elva - Meshura annual accumulation of nitrogen in biomass of vegetation averages 2976 kg/sq.km. For comparison, in the basin of the river Lezha - Zimnajk this indicator is equal to 2812 kg/sq.km. The marsh vegetation deposits 60-130 kg/sq.km.

It is known that various forms of inorganic nitrogen (ammonium and nitrate) in the course of biogeochemical circulation periodically pass each other therefore the total balance of nitrogen we calculated for the sum of two main forms of nitrogen. Results of calculations show that in this region balance of nitrogen is positive, i.e. the receipt component exceeds account, and it is possible to speak about nitrogen accumulation process. The formed excess of nitrogen is deposited within pools. The average size of inorganic nitrogen accumulation in territories of rivers Elva and Lezha reservoirs makes 460 and 1837 kg/sq.km respectively (fig. 1).

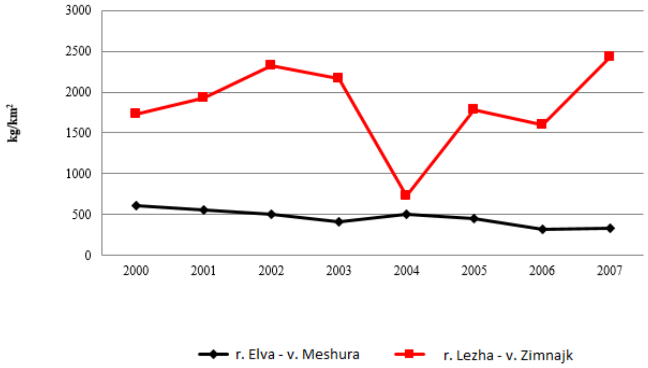

Fig. 1. Dynamics of inorganic nitrogen accumulation indicators in the territory of the studied watersheds.

The receipt part structure analysis of inorganic nitrogen balance showed that the most significant components are atmospheric precipitation to which share 80 - 97% fall. Even in the low-developed territories, with insignificant anthropogenous influence, the transformation of biogeochemical nitrogen circulation which is expressed in accumulation of this component is fixed. This circumstance demonstrates that the circulating air streams are the chief distributors of nitrogen influencing its natural cycle. Thus, cross-border transfer of the polluting substances represents one of priority environmental problems of the present.

4. Summary

The received results confirm excess of nitrogen runoff to the biosphere over its expense that breaks natural circulation of this element and leads to its accumulation in natural geosystems. The most significant contribution to process of the natural nitrogen course transformation is made by atmospheric precipitation which causes cross-border transfer of the polluting substances.

5. Conclusion

The quantitative assessment of anthropogenous load of catchment basins which is carried out in the work presented violation of biogeochemical cycle of nitrogen, showed that the nitrogen of anthropogenous origin which is dropping out with atmospheric precipitation actively joins in biological cycles, increasing efficiency of ecosystems, and also collects in soil cover.

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References

1. Khairullina D.N., Fedorova V.A. (2014) Sodium Balance Structure within the Elementary Geosystems (by the Example of Basin of the Elva River in the Komi Republic) // Advances in Environmental Biology, 8(4) March 2014, Pp.: 1015-1520.

2. Camargo J.A., Alonso A. (2006) Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: A global assessment // Environment International. Volume 32, Issue 6, August 2006, pp. 831 – 849.
3. Roebeling P.C., Rocha J., Nunes J.P., Fidelis T., Alves H., Fonseca S. (2014) Using the Soil and Water Assessment Tool to Estimate Dissolved Inorganic Nitrogen Water Pollution Abatement Cost Functions in Central Portugal // Journal of Environmental Quality. 43, 1, 168-176. Pp. 1537-2537.
4. Kudeyarov V. N. About an intensification of nitrogen involvement in its biogeochemical cycle//Circulation and balance of nitrogen in system the soil – fertilizer – plant – water: Sb. Art. - M., 1979. – Page 280 - 284.
5. Moiseyev B. N., Alyabina I.O. An assessment and mapping of carbon and nitric components balances in the main biomes of Russia // Pub. Ran.ser. geogr. 2007, No. 5. - Page 1-12.
6. Method of biogenous substances runoff calculation and assessment of perspective condition of the small rivers pollution. – appr. By Ministry of Natural Resources and Environmental Protection of Republic of Belarus 19.11.1999 N 331.

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