The springs of the North-east of the East European Plain: headlands of the river network formation

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Abstract. This study examines the impact of spring water inputs on river water quality in the northeastern sector of the East European Plain, with specific focus on the Chuvash Republic. Ecological assessment of river valleys and springs was conducted through two complementary approaches: visual evaluation of landscape transformation intensity and comprehensive chemical water analysis. River valleys in the study area exhibit significant anthropogenic modification, attributable to extensive settlement coverage (up to 21% of total area) and predominant pastureland use. Spring-adjacent areas demonstrate substantially lower anthropogenic pressure. Chemical analysis reveals single-component point source contamination in spring waters, with affected springs representing less than 5% of sampled locations. In contrast, river water samples display multicomponent contamination in over 70% of cases, with optimal chemical composition observed exclusively in forested watersheds. The findings indicate that water quality degradation in small rivers of the Chuvash Republic primarily results from industrial effluent discharge, agricultural runoff, and proximate livestock operations. No significant correlation emerges between spring water characteristics and river water composition, suggesting limited hydrological connectivity between these systems under current land use condition.

1 Introduction

The Chuvash Republic is located in the northeast of the East European Plain - on the Volga upland. Elevation fluctuations for a given area do not exceed 100-200 meters. However, the positive balance of precipitation and rocks of the Tatar stage of the Permian system contributed to the development of a dense ravine-girder network. The density of erosive fragmentation in the north of the region reaches 1.1 km per square kilometer. The density of the river network reaches 1.4 km per square kilometer. Numerous temporary and permanent watercourses receive mixed nutrition: snowmelt, rainwater, groundwater. Ascending and descending springs are one of the sources of constant nutrition. Springs act as the initial links of the river network of the region.

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From the middle of the 20th century to the present, the issue of the ecological state of the small rivers of the Chuvash Republic has been very acute. The development of the region's territory was carried out along the valleys of the small rivers. Settlements were based at sources of drinking water – springs. Therefore, almost all settlements of the republic are located in river valleys. This led to a high anthropogenic load on the landscapes of the valley type of terrain, pollution of all components of nature, including the terrestrial and underground hydrosphere. A complicating factor is the low ability of small rivers to self-purify [1]. This is due to the low water content of the watercourses. This leads to the fact that the small rivers of the region are chronically polluted. There is an excess of permissible chemical parameters for many components. At the same time, many experts note a sharp decrease in the quality of spring water. The purpose of this study is to identify the degree of influence of spring water on the ecological state of the river network of the Chuvash Republic.

2 Materials and methods

The ecological condition was assessed in a comprehensive way: the degree of anthropogenic transformation of the adjacent landscapes, the analysis of the chemical composition of spring water and river water.

The degree of transformation of adjacent landscapes is determined by the nature (type) of use and the intensity of use. Depending on the economic use of a particular territory, the following types of transformation of natural landscapes are distinguished:

1) agricultural;
2) forestry;
3) residential;
4) industrial;
5) water management.

The agricultural type of transformation includes arable land, pastures, hayfields, orchards and berry fields. The forestry type of landscape transformation includes forest areas where logging has been carried out in the last 50 years. The residential type of transformation is represented by rural and urban settlements. The industrial type of transformation includes the territories of industrial enterprises, mining sites, the road network, and pipelines. The water management type of landscape transformation is all artificial reservoirs: ponds, dams, reservoirs. The most important factors in the transformation of natural geosystems are industry [2] and agriculture [3,4]. Environmental pollution, including groundwater, occurs as a result of construction [5].

In addition to the type of transformation, the most important factor for assessing the ecological state of landscapes is the intensity of transformation. Various scientists identify up to five stages of transformation intensity: unchanged, slightly modified, significantly modified, strongly modified and transformed landscapes. For example, slightly modified landscapes are landscapes where most of the components of nature have been preserved in their natural form. Transformed landscapes are landscapes where most of the components of nature are disrupted. These are the hydrological regime, soil cover, vegetation, and wildlife. We have chosen a four-step scale of the intensity of transformation of landscapes: natural, slightly modified, strongly modified and transformed. The intensity of landscape transformation can be classified most accurately by land. Natural landscapes include specially protected natural territories: nature reserves, natural monuments. Slightly modified – reservoirs, haymaking, pastures, forest. Heavily modified – arable land, rural settlements. Transformed landscapes – industrial facilities and cities.

The analysis of the chemical composition of spring and river water involved the determination of the main chemical components: hydrogen index, total hardness, total mineralization, ammonium, iron ions, nitrates and nitrites, sulfates, chlorides, sodium. Subsequently, the data obtained were compared with acceptable parameters [6]. An important point was the parallel sampling of spring water and water samples in the rivers that feed the studied springs [7].

3 Results

As part of the study, in 2024-2025, expeditions were carried out to municipalities of the Chuvash Republic in order to study the ecological state of small rivers and springs that feed these rivers.

The vast majority of the river valleys in which the research was carried out were developed long ago and intensively used in agriculture. Unformed river valleys are extremely rare. They are represented by protected areas. In other cases, the key areas were related to settlements, pastures, and hayfields. Traditionally, in the Chuvash Republic, mountainous areas are occupied by arable land. Valleys of small rivers are allocated for pastures due to the complexity of cultivation and the demand for land. In some cases, industrial facilities are located in river valleys: highways, transmission lines, and pipelines. A dense network of paved roads has a particularly strong impact on the environment.

The factors highlighted above have led to the fact that the valleys of small rivers in the region are experiencing maximum anthropogenic stress, exceeding the load of more stable flat, sloping, terraced landscapes. Such a load leads to a deterioration in the water quality of the entire hydrographic system of the region.

The assessment of the ecological state of spring water and river water was carried out in 2 stages:

1) visual assessment of the level of anthropogenic influence by analyzing the ecological state of the landscapes of the nature reserve zone and river valleys;

2) laboratory – by conducting chemical analysis of water from selected samples.

A visual analysis of the ecological state of the river valleys has shown that most of the studied objects are in poor condition. This condition is explained by the fact that 55% of all river valleys studied are used as pastures or hay fields. 33% of river valleys are occupied by rural settlements (with an acceptable 8%). The identified reasons led to a high anthropogenic pressure. The valleys of the small rivers of the region belong to the slightly modified and strongly modified types of landscape transformation. In rare cases, there are natural landscapes associated with the Prisursky and Zavolzhsky forest areas. From the facts outlined above, it can be argued that spring and river water in the region is potentially susceptible to pollution from both economic and industrial facilities and agricultural production.

The ecological condition of the territory adjacent to the springs can be assessed as satisfactory. Most of the investigated springs are protected by a fence. This prevents access by pets, cars, and other sources of pollution. The natural landscapes adjacent to the springs are not disturbed. There are often springs characterized by a cultural landscape that is more stable than a natural meadow. From this it can be concluded that the ecological condition of the river valley landscapes is characterized as poor. The ecological condition of the spring landscapes is good.

As part of the water quality assessment, water samples were taken. Samples for chemical analysis were taken at a time from the springs and rivers they feed. Sampling was carried out in dry weather. At least two days have passed since the last precipitation. The chemical analysis included the determination of chlorides, sulfates, iron, ammonium, nitrites, nitrates, total hardness, and hydrogen index.

In total, at least 70 springs in different municipalities were surveyed. According to most parameters, the water quality of the springs was at the required level. These are the hydrogen index, the total hardness, and nitrites. For other indicators, a point excess of acceptable values was detected. There are cases when in settlements out of 4-5 surveyed springs, only a few were contaminated. Such cases indicate local decreases in water quality of anthropogenic origin. These may include the application of mineral and organic fertilizers on agricultural land, the impact of farm buildings, and the presence of construction and household debris [8]. So, in the extreme northwest of the region (Yadrinsky district), spring water was discovered, in which there is an excess of sulfates and chlorides. Springs with an excess of ammonium content are evenly distributed throughout the region. These springs are most closely located to outbuildings and farms. Similar springs were found in Kanashsky, Batyrevsky, Marposadsky districts. Outdated equipment can also affect water quality: pipes through which a spring flows, a drainage chamber. One similar case was found in the region: in the Marposadsky district.

As part of the study of the dependence of water quality in the river on spring water, 23 samples were taken from the local hydrographic network. Sampling was carried out evenly across the region. These are the confluences of the Bolshoy Tsivil, Unga, Maly Tsivil, Tsivil, Kubnya, Sura, Anish, Bula, Kirya, Bula, Abyss, Ryksha, Orbashka, Unga, Kidarka rivers (see Table 1).

Table 1. Chemical composition of the studied water in the rivers of the Chuvash Republic

№	River	Coordinates	Hardness	pH	Ammonium	Ferrum	Nitrites	Sulfates
1	Bolshoy Tsivil	55,675161; 46,926338	3,1	8,0	3,4	0,37	3,4	40
2	Bolshoy Tsivil	55,73153; 47,19849	3,1	7,7	2,8	0,5	1,0	40
3	Unga	55,863737; 47,384358	3,6	8,1	1,0	0,42	2,3	60
4	Malyy Tsivil	55,463839; 47,024946	2,9	8,2	1,5	0,2	2,9	50
5	Malyy Tsivil	55,580424; 47,478252	2,9	8,0	2,5	0,45	4,5	50
6	Tsivil	55,961157; 47,591193	2,9	7,9	2,6	0,35	4,6	50
7	Tsivil	56,003169; 47,572530	2,9	7,9	2,9	0,36	4,6	50
8	Kubnya	55,271771; 47,521639	3,3	8,3	3,1	0,4	4,4	60
9	Sura	54,977978; 46,573853	3,4	7,8	12,0	0,37	4,7	70
10	Sura	55,278022; 46,267544	3,4	7,8	3,5	0,40	4,5	60
11	Lyulya	54,936139; 46,654663	2,0	7,7	0,5	0	0	40
12	Sura	55,458090; 46,397610	3,5	7,9	3,7	0,45	5,0	70
13	Sura	56,000085; 46,288517	3,6	7,9	3,9	0,48	5,0	60
14	Bula	55,075124; 47,331905	4,1	7,7	6,1	0,3	4,0	80
15	Bula	55,078330; 47,820444	4,2	8,2	9,0	0,4	6,0	90
16	Kirya	55,243253; 46,426627	3,4	7,8	0	0	0	60
17	Anish	55,941852; 47,838164	5,6	7,6	1,5	0,1	2,0	80
18	Anish	55,834322; 47,963023	5,3	7,7	2,0	0,25	2,0	80

19	Bezdna	54,693791; 47,182502	8,1	7,8	0,5	0,0	0,0	110
20	Ryksha	55,982056; 47,532840	3,5	8,1	3,8	0,4	3,0	90
21	Orbashka	55,784264; 46,758437	3,7	8,1	3,7	0,42	3,2	70
22	Unga	55,932242; 47,068544	3,5	8,1	3,8	0,35	3,2	60
23	Kidyarka	55,938496; 46,812274	3,1	7,9	3,7	0,38	3,0	70

Table 1 shows that the spread of the obtained indicators is quite significant. In some cases, the permissible values are exceeded by more than 2 times.

The turbidity of water in rivers and springs should be mentioned separately. In all the studied cases (71 samples), the spring water was clear and colorless [9]. Water samples from small rivers taken in the summer are characterized by a characteristic yellowish color. Presumably, this is due to the large amount of dissolved organic substances and iron oxides [10].

4 Discussion

The analysis showed that the total number of polluted springs does not exceed 5% of the total number of sources studied. All spring water samples taken have a minimum amount of suspended particles. The water is colorless and transparent. The excess of the permissible parameters is observed for only one component. Most often, this is the ammonium content. No complex contamination of springs covering several parameters was detected (Figure 1).

The opposite situation is developing on the small rivers of the region. Most of the samples taken are characterized by an increased content of one or more components. Of the 23 rivers, only 5 do not exceed the permissible values for the content of chemical components. These are the Rivers Anish, Abyss, Kirya, Lyulya, the sources of the Small Civil. The main reason for the high water quality of these rivers is that their basins are located in a forest area where there is no significant anthropogenic pressure. Two rivers have an excess of one component, ammonium. These are the Unga River and the middle course of the Anish River.

The majority of the samples taken – 16 samples out of 23 – showed a multicomponent excess of the permissible content of chemical elements. These are ammonium, iron, and nitrates. Water samples from rivers located in intensively developed areas of the region show multiple excess. For example, the ammonium content in the middle reaches of the Bula River exceeds the permissible value by 3 times.

The analysis of the collected data on the water quality of small rivers of the Chuvash Republic made it possible to draw up a "Zoning scheme of the Chuvash Republic for river water quality" (Fig. 1).

Figure 1 shows that only 22% of the river basin area is uncontaminated. 6% of the total area of the region is characterized by single-component pollution of water in rivers. Most of the territory of the Chuvash Republic (72%) is characterized by an excess of dissolved substances in many components.

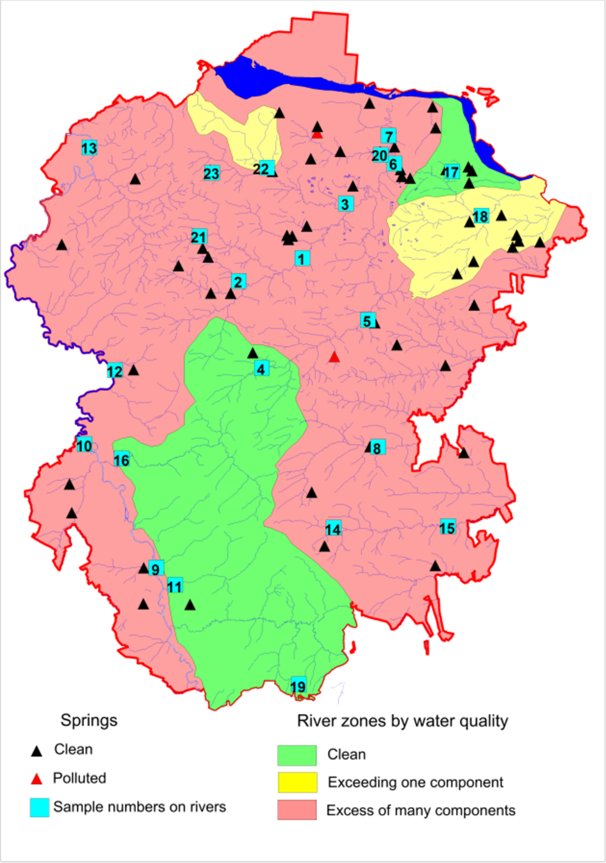

Fig. 1. River water pollution

5 Conclusion

The positive balance of precipitation and the high level of dissection of the relief of the Chuvash Republic led to the appearance of numerous springs. These springs feed the local hydrographic network. This network consists of numerous small rivers that are experiencing a strong anthropogenic load. As a result, all water bodies in the region are polluted. An analysis of the chemical composition of the spring water and a description of the nature reserve area showed that the ecological condition of the springs is characterized as satisfactory. Polluted springs are rare. This is no more than 5% of the total number of sources studied.

Sampling of river water has shown that in most cases the permissible values of dissolved substances are exceeded. Some watercourses are distinguished by multicomponent, multiple excess of permissible parameters. More than 70% of the hydrographic network of the Chuvash Republic can be classified as polluted.

An analysis of the ratio of the quality of spring water and the quality of river water showed that the sources do not have a noticeable effect on the local hydrographic network. It follows from this that pollution of surface waters – small rivers of the Chuvash Republic – occurs due to other factors. Presumably, this is the discharge of industrial water. In rural areas, these are temporary streams of water coming from adjacent fields or livestock complexes during heavy rainfall. In any case, the chemical composition of river water and the level of its contamination depend on springs only partially.

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