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The hydro-ecological state assessment of piedmont rivers of the Republic of Uzbekistan in the climate change context

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Abstract. This article describes the dynamics of the spatial and temporal distribution of pollutants and the main sources of surface water pollution by household and industrial wastewater. It emphasizes that water pollution increases from the headwaters to the river mouth, and in lower reaches of the river, there is not natural river water, but wastewater. Industrial, household and agricultural wastewaters discharged into water bodies without treatment, or often after inefficient treatment, change the hydro-chemical and hydro-biological regimes that affect the quality of water and disrupt the normal functions of aquatic flora and fauna. The data obtained from 1991 to 2019 were used as the basis for this article.

1. Introduction

Protection of water from pollution, preservation, and improvement of water quality is associated with a complex set of issues. The solution to these issues can be achieved through the mandatory consideration of both natural and artificial causes of deterioration of water quality to use as a reason for developing and implementing measures to ensure the preservation and improvement of natural river water quality.

In current conditions, providing the population with good-quality water is an urgent, hygienic, scientific, technical, and social problem due to the intensive contamination of drinking water sources, the low level of implementation of advanced technologies for drinking water treatment and the increasing deterioration of water supply networks. At present, human economic activity is progressively becoming the main source of water pollution.

This problem is particularly relevant to arid climate conditions. A necessary component of assessing the impact of pollutants on the environment is revealing of changes in the ecological and hydro-chemical state of the river basin experiencing increased anthropogenic pressure.

The Chirchik River Basin is located in the Northeast of Tashkent and extends from the Northeast to the Southwest. The Chirchik River is formed by the confluence of the Chatkal and Pskov Rivers. Moreover, at present the Charvak Reservoir with annual water flow used for energy and irrigation purposes with a volume of 2 million m³ has been established there.

According to climatic conditions, the Tashkent region is located in a continental climate zone with comfortable indicators of bioclimatic characteristics. On the other hand, the study area is located in the area with a high potential for climate pollution. The Chirchik-Akhangaran Basin was not chosen by chance: in the middle reaches of Syrdarya, Chirchik and Akhangaran Rivers, their tributaries meet a



great anthropogenic pressure, due to the large industrial centers such as Tashkent, Chirchik, Yangiyul, Almalyk, Angren, and other cities, that are located in the territory of Tashkent region where these watercourses flow. It should also be noted that the Tashkent region is one of the most densely populated regions in the Republic. This determines the need to study and assess the quality of the Chirchik River's waters and their impact on the surrounding areas. This is the most economically developed region of Uzbekistan, where 40% of the country's gross output is being produced. The main share is contributed by mechanical engineering, metallurgical and chemical industries, and the electric power industry.

The water of the Chirchik River is used for centralized drinking water supply for cities and non-centralized water supply of several rural settlements and irrigation purposes in the Tashkent region.

About 70% of the industrial capacity of the Republic of Uzbekistan is concentrated in cities. This region is home to more than 25% of the Republic's population. Municipal and industrial wastewater contaminates reservoirs and watercourses with various specific pollutants, including heavy metal ions. Some of them are carcinogenic, while others are toxic. The World Health Organization warns that 80% of diseases on the planet are caused by the consumption of poor-quality drinking water.

2. Methods

Studies to assess the hydrological and hydro-chemical characteristics of the Chirchik River were carried out in different periods by the SRHI of Uzhydromet. However, before independence the targeted monitoring studies were not carried out in full capacity in Uzbekistan. Currently, Uzhydromet monitors surface water pollution at 37 observation points in the Tashkent region. The generally accepted methods of hydrology and hydrochemistry field research and mathematical statistics were used in these studies.

3. Results and discussion

Anthropogenic pollution of river waters is canceled out by the processes of self-cleaning of the reservoir mainly due to the adsorption and sedimentation of suspended particles.

To characterize the anthropogenic pollution of surface watercourses with organic substances, we have chosen the following indicators: BOD, ammonium nitrogen, nitrates, and nitrites.

Nitrogen is one of the most important biogenic elements. The concentration of its compounds in water mainly determines the biological productivity of the water body. Nitrogen content can serve as one of the main indicators of potential eutrophication of water bodies and therefore there is a high interest in studying the behavior of nitrogen compounds and, in addition, their toxicity [1 – 8].

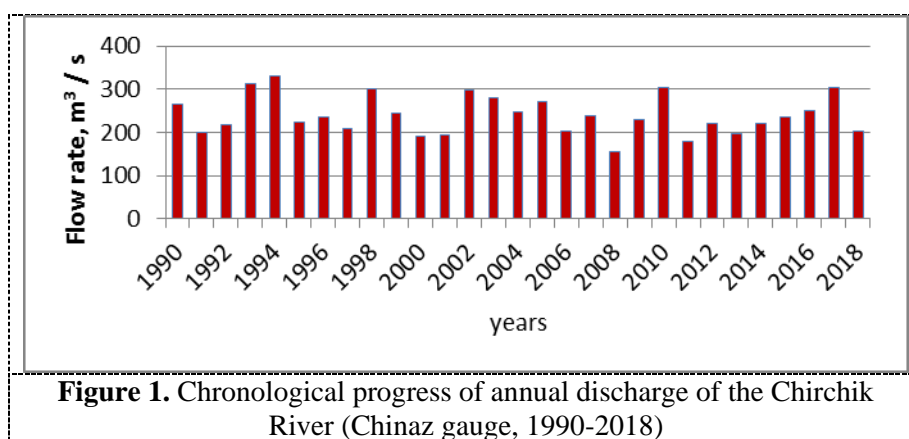
Nitrogen is contained in natural waters as a variety of inorganic and organic substances. In the system of hydro-chemical monitoring, ammonium nitrogen NH_4^+ , nitrite NO_2^- and nitrate NO_3^- are studied. They are a product of the conversion of ammonia, which appears as a final inorganic substance in the process of converting organic substances into inorganic ones (feces, excretions of hydrobionts). Ammonium ions NH_4^+ are unstable and first they transfer into nitrites NO_2^- under the influence of nitrifier bacteria in the presence of oxygen. Nitrite ions are also unstable and transfer into one of their most stable compounds in water – nitrate ions O_3^- .

Specialized Inspections of Analytical Control (SIAC) of the Regional Committee of Nature of Tashkent region are studying the chemical composition of wastewater from treatment facilities of municipal and industrial sewerage systems in Chirchik, Tashkent, Almalyk, Angren, Yangul, Bekabad cities. The SIAC reports also provide information on the amount of wastewater at some point source. However, since the number does not change in the SIAC reports over the past five years, it can be assumed that these values of maximum permissible discharges (MPD) were calculated for enterprises at the time of their commissioning, and the actual amount of wastewater is not being measured constantly. According to these data, 46720 m³ of industrial and municipal wastewater is discharged to Akhangaran River, 40150 m³ to Chirchik, and 2454 m³ per year to the Syrdarya from Bekabad to

Chinaz. However, the largest amount of wastewater flows to the following watercourses in Tashkent: the Salar collector – 316563.4 m³, the Karasu channel -16718.7 m³, the Bozsu channel – 201297.3 m³, the Karakamysh collector – 6221.7 m³, the Chirchik River – 6303 thousand m³ per year.

Besides, the chemical composition of water is influenced by the flow of numerous reservoirs that discharge water from irrigated lands into rivers and channels in the Tashkent region. The Hydrogeological Reclamation Expedition (HRE) of the Tashkent region keeps records of runoff and determines water salinity (dense residue) and chlorine content in the largest of them (24 reservoirs). 9 out of 24 collectors discharge water into the Karasu canal (left-bank) and one – into the Morgunenko canal. The largest of them are Achisai, Yayilma.

According to the “Yearbook of Uzhydromet on Surface Water Quality”, the chemical composition of the river water is largely influenced by pollution from sewage systems from industrial enterprises in Gazalkent, Chirchik, Tashkent and Chinaz cities and agricultural runoff.



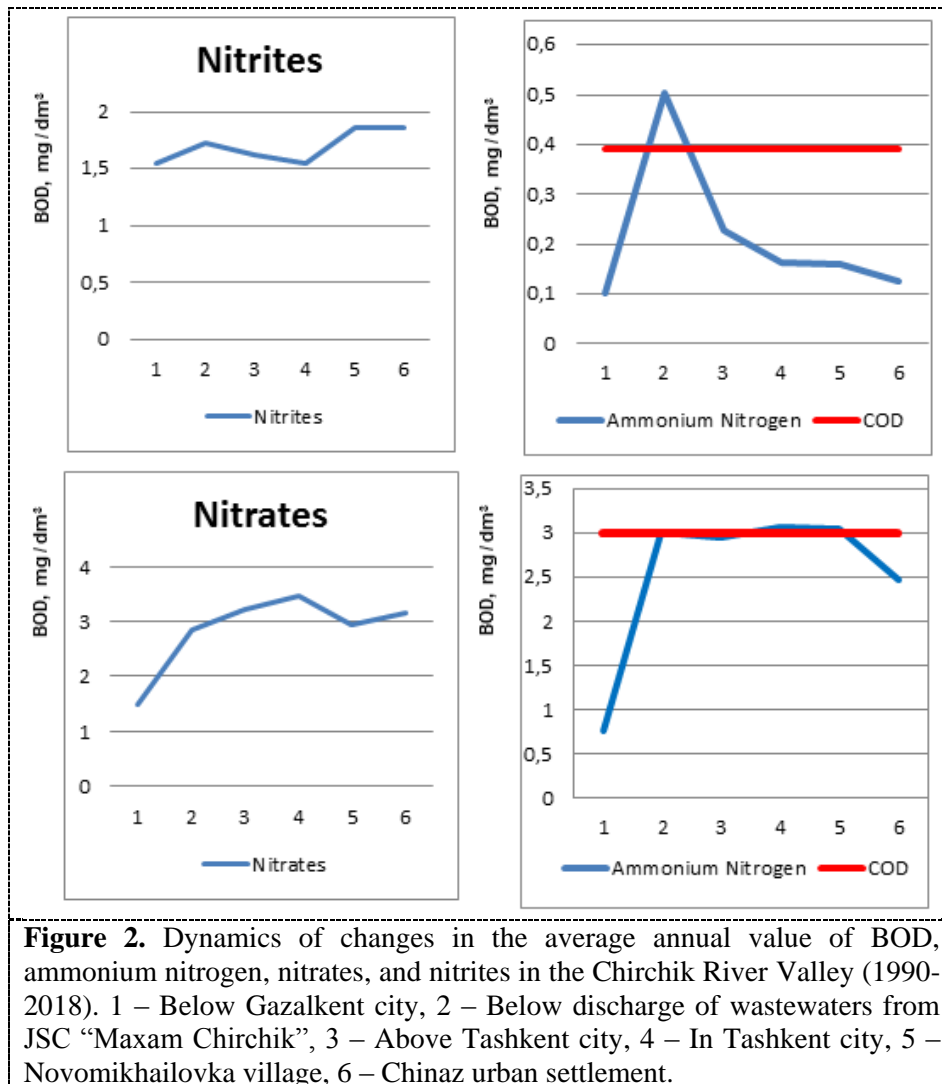
The river can be attributed to watercourses with low mineralization. The average content of mineral salts along the river is 360 – 380 mg/dm³.

During the study period, the hydrological regime of the Chirchik River is characterized by three low-water years – 2000, 2008, 2011, and three high – water years – 1994, 2010, 2017.

The upper water stream gauge of the Chirchik River is located outside of the zone of anthropogenic influence and characterizes the natural regime of the river.

Figure 2 clearly shows the intra-annual content of the studied substances. As a result of the study on surface water pollution in the Tashkent region with nitrogen-containing substances, several zones where the level of some elements exceeds the maximum permissible concentration (MPC) were identified. The dynamics of changes in the length of the Chirchik River in the average annual values of BOD, ammonium nitrogen, nitrates, and nitrites are presented in the figure. By analyzing the visual information, it is possible to assume with a high probability that the river receives the largest amount of nitrites specifically on the way from the Maksam-Chirchik River’s gauge to the Chinaz urban settlement’ gauge.

Increased content of ammonium nitrogen and nitrites in the “Maksam-Chirchik” gauge can be caused both by the discharge of polluted effluents and by intensive nitrification-denitrification processes. Besides, it can be assumed that the main sources of such organic substances are industry and municipal services taking into account the uniqueness of economic activity on this river site.



In other words, these two industries make the greatest contribution to the pollution of the river with organic substances. Besides, the dynamics of changes in ammonium nitrogen and nitrites in the middle and lower reaches indicate the presence of some free absorption capacity and the presence of self-cleaning capacity of the river [8 – 14]

Distribution of nitrogen pollution, including the contamination of mineral and organic origin in the conditions of the Chirchik River should be considered in conjunction due to previously mentioned reasons, namely high turbulence and as a result, high dissolved oxygen, which under certain conditions, participates in the processes of nitrification and de-nitrification, which, in turn, reduce the content of certain types of nitrogen-containing substances. Thus, there is a stable decline throughout the river in nitrate-nitrogen concentrations from the upper reaches of the river to the mouth. Moreover, it is possible to distinguish both areas where the sources of pollution are concentrated, and areas that are relatively “clean” [14 – 20].

Table 1. Limits of changes in average annual concentrations of pollutants (mcg/dm³) in the waters of the Chirchik River for the period from 1990 to 2018

Stream gauge	BOD		Ammonium		
	min	max	Nitrogen	Nitrites	Nitrates
	0.37	1.5	0.02	0.02	0.46
Below Gazalkent city	1.72	5.1	0.56	0.084	4.43
Below discharge of wastewaters from JSC “Maxam Chirchik”	1.04	2.6	0.03	0.02	0.6
	5.12	12.7	1.77	0.36	12.06
	1.37	3.3	0.143	0.02	1.43
Above Tashkent city	4.06	9.3	1.08	0.2	6.81
	1.94	4.2	0.1	0.03	1.28
In Tashkent city	6.35	12.7	0.53	0.358	10.04
Novomikhailovka village	1.98	2.6	0.008	0.03	0.82
	5.12	11.3	0.53	0.201	12.01
Chinaz urban settlement ⁷	1.27	3.8	0.06	0.046	0.81
	5.29	12.2	0.74	0.363	15.16

4. Conclusion

Based on obtained results the following conclusions were made:

- The highest concentrations of pollutants are recorded below major industrial centers and this factor should be taken into account when placing observation points.
- Taking into account that the main source of such pollution in the Chirchik River Basin is wastewater containing fecal contamination, we can state that the protection of surface waters from untreated or poorly treated municipal wastewater is unsatisfactory.
- There was a noticeable increase of nitrites contained along the length of the river below the “Maksam-Chirchik” discharges. Based on field studies on this site we have detected the negative impact of economic objects to the natural riverbed in the water protection zone of the Chirchik River. In the water protection zone of the Chirchik River, there are unorganized quarries, small farms, summerhouses, and “wild” recreation places that negatively affect the ecological state of the riverbed.
- Inspections of the river banks have shown that there are no sanitary protection zones envisaged by the legislation of Uzbekistan on nature protection. The absence of such zones and the development of banks worsens the ecological condition of both banks and river water.

The results of the analysis revealed that the concentration of nitrogen-containing substances increases during the summer season.

The spatial variation of pollutants is determined by the level of anthropogenic pressure. The highest concentrations are observed below large industrial agglomerates.

Because of the dry hot climate, our soils are not able to accumulate significant amounts of nitrogen, phosphorus, potassium, etc. Therefore, there is a need to apply big amounts of these fertilizers. Phosphorus fertilizers containing cadmium, fluorine, arsenic, selenium, uranium, and others pose a danger: simple superphosphate contains 17 mg/kg of copper, 95 mg/kg of zinc, 300 mg/kg of arsenic, and, there are 18 mg/kg of lead and 1.6 mg/kg of cadmium in phosphorous flour. About 160 kg of fluorine and other harmful substances are applied with each ton of these fertilizers, and a significant quantity of them enters rivers with collector and drainage waters.

Irrigation also leads to an increase in the water table and increases secondary salinization of soils. Also, data from the district and city centers of sanitary protection zones (SPZ), including our findings, prove a poor ecological state not only in the watercourses but also on the river banks. On the river banks there are no sanitary protection zones (SPZ), while the Law of the Republic of Uzbekistan “On Nature Protection”, Art 9. 12. 1992 envisages them.



Figure 3. Place of discharge of industrial runoff from the “Maksam – Chirchik” plant into the river

Drains from the “Maksam-Chirchik” plant are black and significantly differ from river water in color and smell. Water from Bakht Lake, used for recreation purposes by residents of Tashkent, flows with foaming water.

The banks of the Chirchik River are densely populated and there are many restaurants and cafes as our reconnaissance surveys have shown. All household wastes including fecal contaminations are discharged into the river without any treatment; of course, no monitoring on all these discharges is being conducted, and the water quality deteriorates due to this, and especially due to nitrogen-containing ions.

The hygienic assessment showed that the level of water contamination in the Chirchik River in this part of Chirchik city is acceptable, and this water body is suitable for all types of consumption by population almost without any restrictions.

However, enterprises do not properly clean discharged waters, which negatively affect the environment.

In the process of water movement, the content of organic substances varies considerably. In the entrance sites of the river, the content of substances in the water does not exceed the permissible concentrations.

The hydro-chemical regime at the river headwaters almost not distorted by human economic activity and can be considered as a reference point. Many collectors, municipal and industrial wastewaters are discharged into the river. The impact is very significant. As our studies showed the content of many pollutants in the wastewater of some industrial enterprises can exceed MPC by numerous times.

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