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State of water quality in the Prut River for the period of 2019-2021

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***Abstract*— The paper addresses the issue of water quality of the Prut River between 2019 and 2021. The data on pollution of the Prut River and its tributaries are analyzed. The negative influence of detected pollutants on human health is discussed. The statistical analysis of the data is performed through the help of statistical methods using the R language. The obtained results are presented. As a result, it is proposed to develop prediction scenarios exceptional situations of water pollution.**

Keywords*— *prediction scenarios, quality classes, statistical analysis, the Prut river, water pollution, water quality.

I. Introduction

The Prut River has a total area of 27540 km^2, in the Republic of Moldova it covers an area of 8123,35 km^2. The Prut water is also used for irrigation. The river is navigable only on a small portion from the delta to the small town of Leova [1].

The Prut is a transboundary river which begins on the slopes of Mount Goverla, 15 km southwest of the village of Vorhota, on the Carpathian massif with Montenegrin forests (Ukraine). The Prut River is the last important tributary of the Danube river, flowing 174 km from the mouth of the river [2].

In the Republic of Moldova, the waters of the Prut River are mostly used for drinking water supply. It is also worth noting that the results of the water quality check give rise to greater concerns. The Prut River, being also a transboundary waterway, in this case represents a collector that stores polluting substances that contribute to the reduction of water quality [3]. The Prut River is more polluted than the Dniester [4]. Pollutants of organic origin, descended from sewage discharge from urban areas or manure brought into the river by tributaries, predominate in the composition of the water of the Prut River [2].

The main causes of pollution of the river Prut are unpurified or partially purified wastewater from rural or urban locations discharged into the tributaries of the rivers, unpurified meteoric water, inappropriate sanitation of the territories of localities, non-compliance with sanitary protection zones of water basins, arrangement of polluting objects in sanitary protection zones of water basins [5].

II. Problem Formulation

For the Prut River, it is attested a decrease in samples assigned to class I (very good) from 30% in 2018 to 9% in 2019 and an increase in samples assigned to class IV (polluted) from 9% in 2018 to 39 % in 2019 [6]. For bacteriological parameters, the share of samples assigned to class IV (polluted) of quality for the Prut River increased from 8% in 2018 to 12% in 2019 [7].

Classes IV and V (polluted and highly polluted) are attributed to the water samples, which integrate the content of basic pollutants – ammonium, nitrites, nitrates, oxygen content, petroleum products and phenols, in relation to their inadmissible concentrations [5].

The water quality deterioration in terms of sanitary-chemical and mainly microbiological parameters can place the waters of the Prut River in category IV-polluted and V-th - highly polluted, but their use for water supply, recreation and irrigation can constitute a public health problem [6].

The existence of ammonia and nitrites in water is an indirect indicator of bacterial contamination of wastewater. They can have severe toxic effects if humans are exposed to high doses. High concentrations of nitrates cause acute health disorders, determined by the high affinity of these chemical compounds to haemoglobin in the blood. The interaction of nitrates with haemoglobin leads to the formation of methemoglobin, which loses the ability to transport oxygen to the tissues. Especially sensitive to the toxic effects of nitrates are infants who are fed with artificial food prepared on the basis of water with an excess of nitrates [8].

Based on the stated objectives of the work were defined, which consists in analyzing the water quality of the Prut River based on a statistical analysis of data on exceptional situations of water pollution for the period 2019-2021.

III. SOLVING THE PROBLEM

In order to assess the state of water quality in the Prut River, the monthly reports about the quality of the environment on the territory of the Republic of Moldova for the period of 2019-2021 provided by the Environment Agency were analyzed [9].

The subject of the investigation was the quality of water from the Prut River. Eight fixed observation points were analyzed (town Cahul, town Leova, town Lipcani, town Ungheni (upstream), village Branişte, village Giurgiuleşti, village Pererîta (downstream), village Valea Mare). In order to achieve the objectives presented in the study, statistical investigation methods were used.

The water quality was investigated considering 18 chemical parameters (NO_2, ammonium nitrogen, mineral phosphorus, petroleum products, dissolved O_2, CCO_{Cr}, total phosphorus, magnesium ion, $Na^+ + K^+$, hardness, nitrate-nitrogen, nitrite-nitrogen, mineralization, orthophosphates, total iron, NH4+, nitrogen of nitrite, substances in suspension).

Figure 1 shows the shares of pollutants in the Prut River by localities in the period 2019-2021.

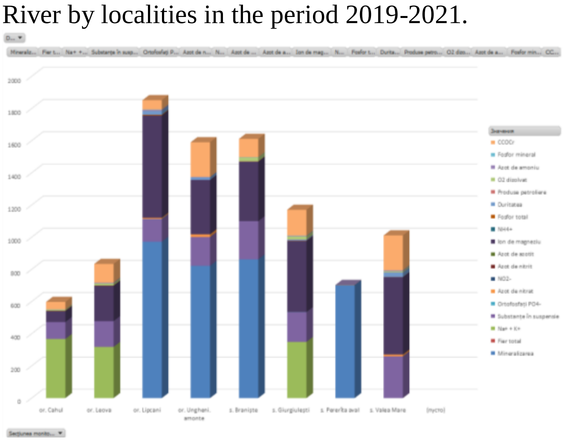


Figure 1. Shares of pollutants in the Prut River by localities in the period 2019-2021

During monitoring the water quality of the Prut River according to the hydrochemical parameters, exceeded values were detected for CCO_{Cr} and total phosphorus.

In the period 2019-2021, the largest number of pollutants was registered in the city of Leova on 19.06.19: ammonium nitrogen (3,85 *mg/l)*, dissolved O_2 (5,8 *mgO_2/l)*, CCO_{Cr} (44,5 *mgO_2/l)*, total phosphorus (0,82 *mg/l)*, magnesium ion (153,2 *mg/l)*, $Na^+ + K^+$ (317,9 *mg/l)*, substances in suspension (138,4 *mg/l)***.** Figure 2 shows the share of the mentioned pollutants.

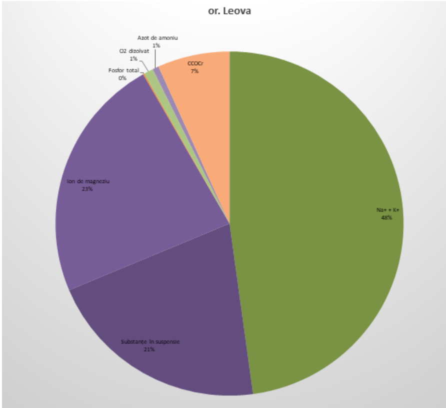


Figure 2. Locality with the maximum number of pollutants between 2019 and 2021

The highest pollution for the period 2019-2021 was detected in the following localities:

1. Lipcani (figure 3)
   - 30.10.19: petroleum products (0,46 *mg/l)*, magnesium ion (252,9 *mg/l)*, hardness (13,4 *Mmoli/l)*, substances in suspension (33 *mg/l)*.
   - 06.11.19: mineral phosphorus (0,66 *mg/l)*, total phosphorus (0,68 *mg/l)*, magnesium ion (209,2 *mg/l)*, hardness (10,9 *Mmoli/l)*.
   - 12.12.19: mineral phosphorus (0,16 *mg/l)*, total phosphorus (0,21 *mg/l)*, magnesium ion (64,4 *mg/l)*, nitrate-nitrogen (3,17 *mg/l)*.
   - 23.03.21: ammonium nitrogen (0,94 *mg/l)*, total phosphorus (0,21 *mg/l)*, mineralization (972 *mg*/l), orthophosphates (0,13 *mgP/l)*.

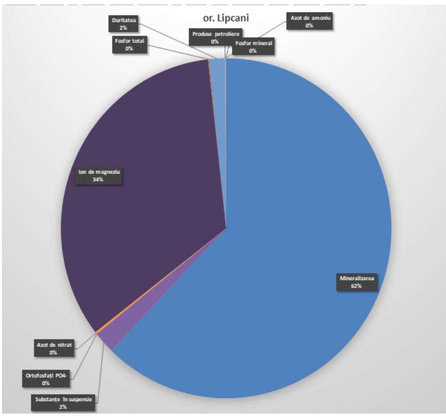


Figure 3. The share of polluting substances in the sector of the Prut river in Lipcani

2. Branişte (figure 4)
   - 07.08.19: dissolved O_2 (6,22 *mgO_2/l)*, CCO_{Cr} (18, *mgO_2/l)*, magnesium ion (51,07

mg/l), substances in suspension (222,4 *mg/l)*.

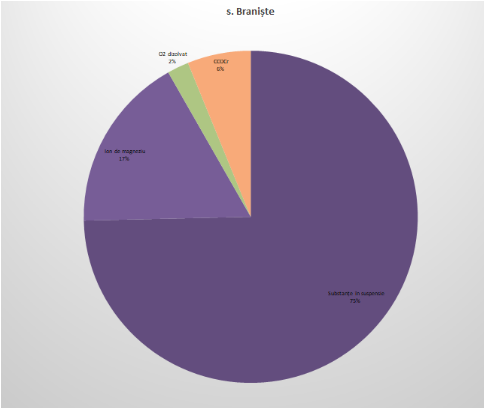


Figure 4. The proportion of polluting substances in the sector of the Prut River in Braniște

3. Valea Mare (figure 5)
   - 15.05.19: ammonium nitrogen (0,5 *mg/l)*, mineral phosphorus (0,14 *mg/l)*, petroleum products (0,13 *mg/l*), substances in suspension (153,2 *mg/l)*.
   - 23.10.19 mineral phosphorus (0,13 *mg/l)*, magnesium ion (133,8 *mg/l)*, hardness (7,2 *Mmoli/l)*, substances in suspension (49,2 *mg/l)*.
   - 11.08.21: dissolved O_2 (6,96 *mg*O_2*/l)*, CCO_{Cr} (34,84 *mg*O_2*/l)*, total phosphorus (0,5 *mg/l)*, orthophosphates (0,16 *mgP/l)*.

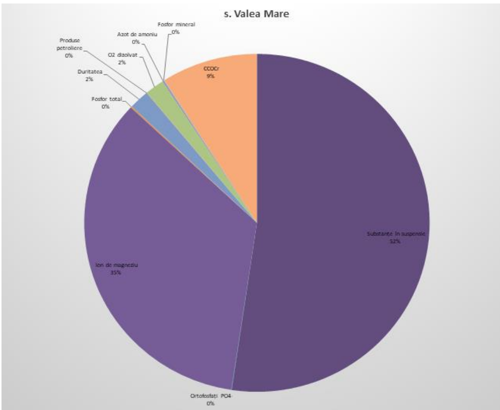


Figure 5. The proportion of polluting substances in the sector of the Prut river in Valea Mare

4. Cahul (figure 6)
   - 20.11.19: mineral phosphorus (0,25 *mg/l)*, total phosphorus (0,27 *mg/l)*, magnesium ion (68,1 *mg/l)*, substances in suspension (20 *mg/l)*.

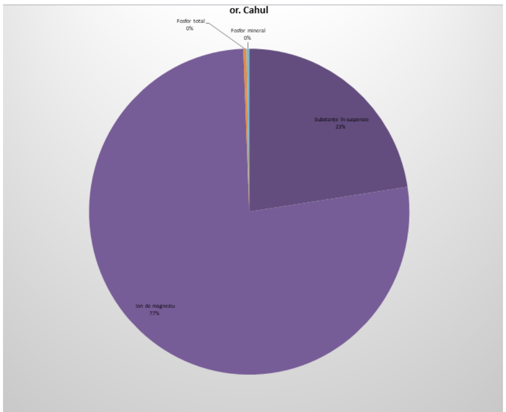


Figure 6. The proportion of polluting substances in the sector of the Prut river in Cahul

5. Leova (figure 7)
   - 21.11.19: mineral phosphorus (0,27 *mg/l)*, total phosphorus (0,39 *mg/l)*, magnesium ion (66,9 *mg/l)*, substances in suspension (22 *mg/l)*.
   - 18.08.21: dissolved O_2 (6,92 *mg*O_2*/l)*, CCO_{Cr} (21,32 *mg*O_2*/l)*, total phosphorus (0,34 *mg/l)*, orthophosphates (0,11 *mgP/l)*.

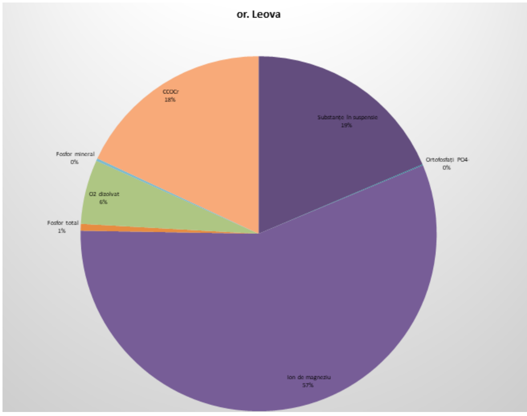


Figure 7. The proportion of polluting substances in the sector of the Prut river in Leova

6. Giurgiulești (figure 8)
   - 19.06.19: dissolved O_2 (6,96 *mg*O_2*/l)*, magnesium ion (68,1 *mg/l)*, $Na^+ + K^+$ (349,1 *mg/l)*, substances in suspension (11,6 *mg/l)*.
   - 20.11.19: ammonium nitrogen (0,55 *mg/l)*, mineral phosphorus (0,2 *mg/l)*, total phosphorus (0,25 *mg/l)*, magnesium ion (76,6 *mg/l)*.
   - 18.08.21: dissolved O_2 (6,23 *mg*O_2*/l)*, CCO_{Cr} (17,16 *mg*O_2*/l)*, total phosphorus (0,38 *mg/l)*, orthophosphates (0,12 *mgP/l)*.

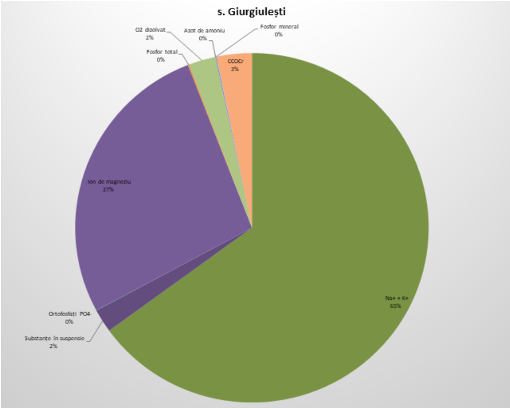


Figure 8. The proportion of polluting substances in the sector of the Prut river in Giurgiulești

7. Pererîta (figure 9)
   - 08.06.21: NO_2 (0,09 *mgN/l)*, total phosphorus (0,32 *mg/l)*, orthophosphates (0,32 *mgP/l)*, NH_4 (0,5 *mgN/l).*

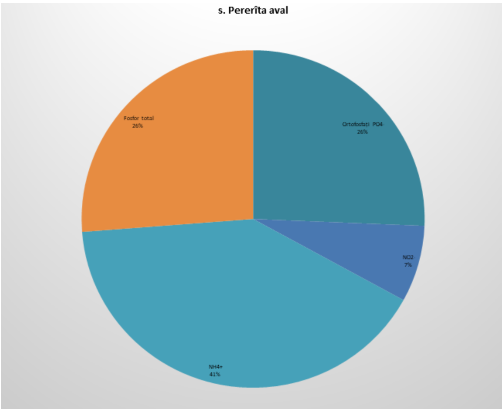


Figure 9. The proportion of polluting substances in the sector of the Prut river in Pererîta

The negative effect of the tributaries of the Prut River is depicted in figure 10 [9]. There were analyzed 6 tributaries of the Prut River: the Lăpușna river left tributary - Sărata Răzeși village, the Camenca river, left tributary - Gvozdovo village, the Gîrla Mare river, left tributary - Sărata Nouă village, the Larga river, left tributary - Chircani village, the Racovăț river, left tributary - Gordinești village, the Sărata river, left tributary - Vîlcele village.

The water quality was investigated for 19 chemical parameters (substances in suspension, dissolved O_2, CBO_5, CCO_{Cr}, ammonium nitrogen, nitrite-nitrogen, total phosphorus, mineral phosphorus, magnesium ion, Na^+ + K^+, hardness, petroleum products, chloride ion, nitrate-nitrogen, sulfate ion, orthophosphates, total iron, nitrogen of nitrite, mineralization).

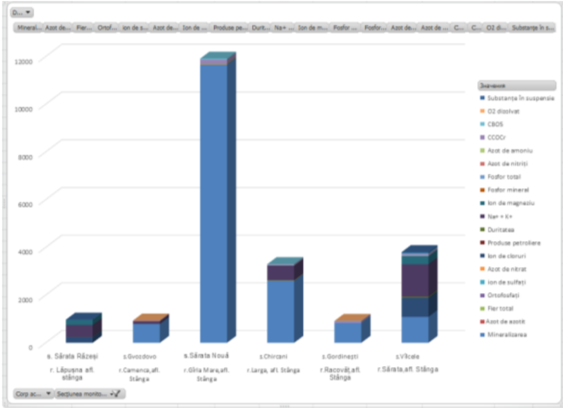


Figure 10. The share of polluting substances in the tributaries of the Prut River by locality in the period 2019-2021

The highest level was recorded for the following pollutants: CBO_5 ammonium nitrogen, total phosphorus.

On 15.09.2021, a maximum volume of pollutants represented in figure 11 was detected in the Gîrla Mare river, Sărata Nouă village: CBO_5 (23,1 *mgO_2/l)*, CCO_{Cr} (140,4 *mgO_2/l)*, ammonium nitrogen (0,47 *mg/l)*, total phosphorus (0,42 *mg/l)*, hardness (9,1 *Mmoli/l)*, orthophosphates (0,3 *mgP/l)*, total iron (0,12 *mg/l)*, nitrogen of nitrite (0,08 *mgN/l*), mineralization (4815,2 *mg/l).*

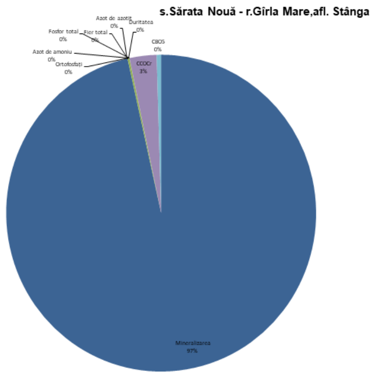


Figure 11. The proportion of polluting substances in the Gîrla Mare river, tributary of the Prut River

In the period 2019-2021, the most polluted tributaries were:

1. Sărata river, Vîlcele village on 19.12.19 (figure 12): CBO_5 (5,36 *mgO_2/l)*, ammonium nitrogen (1,69 *mg/l)*, total phosphorus (0,24 *mg/l)*, magnesium ion (170 *mg/l)*, Na^+ + K^+ (303 *mg/l)*, hardness (9,15 *Mmoli/l)*, chloride ion (437,2 *mg/l).*

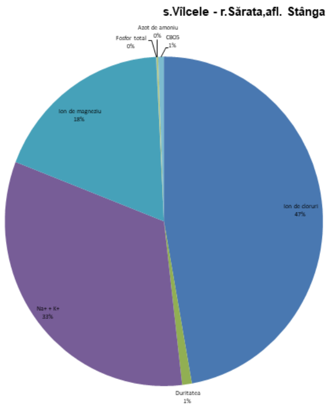


Figure 12. The proportion of polluting substances in the Sărata river, tributary of the Prut River

2. Gîrla Mare river, Sărata Nouă village on 10.03.21 (figure 13): CBO_5 (9,56 *mgO*$_2$*/l),* CCO_{Cr} (25,19 *mgO*$_2$*/l),* ammonium nitrogen (2,46 *mg/l),* total phosphorus (0,28 *mg/l),* hardness (8,6 *Mmoli/l),* nitrate-nitrogen (14,50 *mg/l),* mineralization (3489,6 *mg/l)***.**

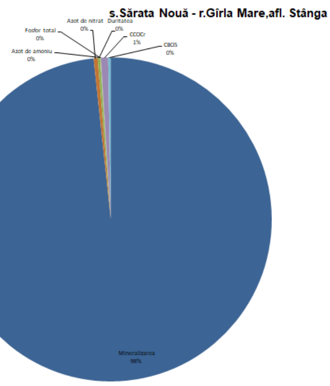


Figure 13. The proportion of polluting substances in the Gîrla Mare river, tributary of the Prut River

3. Racovăț river, Gordinești village on 07.07.21 (figure 14): dissolved O_2 (4,05 *mgO*$_2$*/l),* CBO_5 (6,46 *mgO*$_2$*/l),* CCO_{Cr} (36,49 *mgO*$_2$*/l),* total phosphorus (0,29 *mg/l),* orthophosphates (0,11 *mgP/l),* nitrogen of nitrite (0,19 *mgN/l*), mineralization (825,4 *mg/l).*

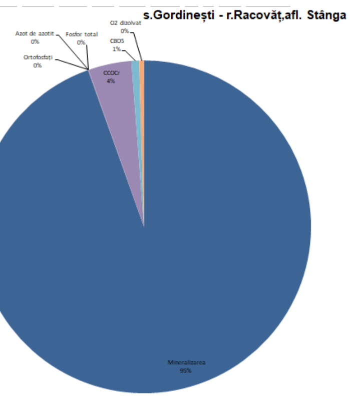


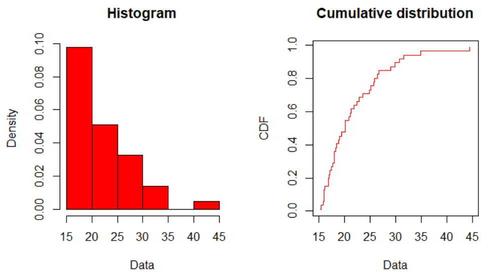
Figure 14. The proportion of polluting substances in the Gîrla Mare river, tributary of the Prut River

Based on the analysis and evaluation of the results obtained for 2019-2021, the Prut River water quality in all the observed sections corresponds to classes III, IV and V, which means medium and high pollution. [9].

Following the analysis of the mentioned data, it was found that the most frequently encountered pollutants were: CCOcr, total phosphorus, ammonium nitrogen, mineral phosphorus, magnesium ion. Thus, the data on the water pollution of the Prut River with the mentioned pollutants were subjected to statistical analysis. The samples with the values of the mentioned pollutants were analyzed and processed with statistical methods from the R language.

The obtained results are presented in figures 15-19. For each pollutant, the histogram of the data, the distribution function, the minimum and maximum values regarding the values of the mentioned pollutant, the first quartile and the 3rd quartile, the average value and the median value of the examined data are observed.

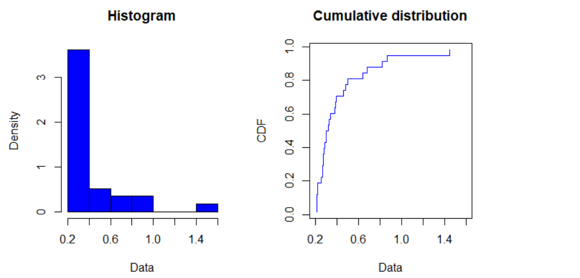
The estimated parameters related to the CCOcr pollutant are presented in figure 15.



Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
15.34	17.29	20.10	21.65	25.05	44.50

Figure 15. CCOcr

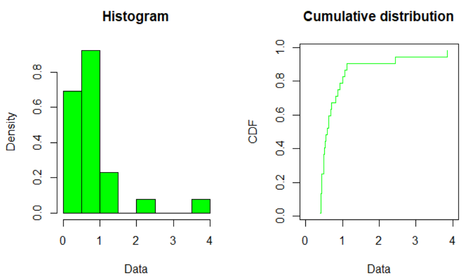
The results of the statistical analysis regarding the total phosphorus pollutant are presented in figure 16.



Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
0.2100	0.2630	0.2980	0.4069	0.4600	1.4480

Figure 16. Total phosphorus

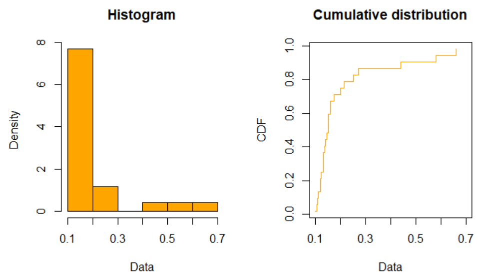
The results of the statistical analysis regarding the ammonium nitrogen pollutant are presented in figure 17.



Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
0.4020	0.4535	0.5670	0.8229	0.8570	3.8500

Figure 17. Ammonium nitrogen

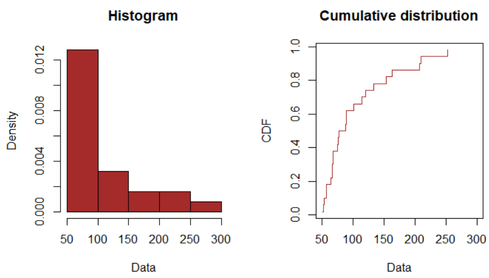
The data on the mineral phosphorus pollutant was also subjected to statistical analysis (figure 18)



Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
0.1000	0.1240	0.1480	0.1984	0.1933	0.6600

Figure 18. Mineral phosphorus

Figure 19 shows the data obtained for magnesium ion.



Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
51.07	66.90	77.82	102.20	120.40	252.90

Figure 19. Magnesium ion

The results allow more detailed analysis of pollutant behavior, including examining the probability with which each value is taken. Knowing how often the relevant values for the pollutant occur under investigation, as well as the cumulative density function and some calculation parameters, we can take measures related to the prevention of water pollution.

CONCLUSIONS

A study of the Prut River water quality was carried out, which revealed a high degree of pollution with various pollutants. Thus, it has been established that the quality of water in the Prut River varies depending on the geographical area of the country.

Statistical analysis of the data was carried out using special software designed for statistical analysis, the R language. The most common pollutants in the Prut River for the period 2019-2021 were subjected to statistical analysis.

The results of the study, including the results of statistical data analysis, allow developing scenarios for predicting water pollution, which will make a significant contribution to reducing water pollution.

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