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Integrated Chemical-Geoecological Monitoring and Engineering Approaches for Pollution Reduction in the Yertis River

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Abstract

Within the framework of this research, an assessment of the surface water quality of the Yertis River was conducted using physicochemical indicators such as suspended solids, pH, dissolved oxygen, nutrients, organic matter, heavy metals, and pesticides. The results indicated significant surface water pollution, particularly in the Oskemen area, which is linked to industrial emissions and wastewater discharges. Exceedances of maximum allowable concentrations were recorded for several pollutants, including nitrites, copper, zinc, manganese, and phosphates. Additionally, remote sensing data was used to assess water conditions, with the calculation of spectral indices such as normalized difference water index (NDWI), modified normalized difference water index (MNDWI), and normalized difference turbidity index (NDTI) to monitor the water bodies. Analysis of the spatial distribution of these indices identified the most polluted sections of the river within Oskemen. The integration of ground-based research data on the Yertis River with satellite imagery provides a more detailed understanding of the dynamics of changes, including variations in water turbidity levels. A channel cleaning device is proposed as an engineering solution to improve river conditions and reduce turbidity. This device effectively removes pollutants at depths of up to 1.5 meters, ensuring consistent water clarity and enhancing the safety of navigation.

Keywords: Surface water quality monitoring; Chemical-geo-ecological assessment; Yertis River; Remote sensing analysis; Industrial pollution impact; Geoecological monitoring.
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1. Introduction

Water resources are essential for supporting life, ecosystems, and economic development. Despite its vast land area, the Republic of Kazakhstan faces critical challenges in water availability and quality, primarily due to its arid climate, reliance on transboundary rivers, and high demands for water from agricultural and industrial sectors. Kazakhstan ranks ninth globally in land area, yet the country is classified among the regions with limited water resources, with significant pressures placed on its major water bodies, including the Yertis River (also known as the Irtysh).[1,2] This dependence on transboundary rivers for freshwater necessitates robust water management strategies to ensure sustainable use and protection from pollution.

The Yertis River flows through China, Russia, and Kazakhstan, making it a vital transboundary water source. Kazakhstan's Water Legislation classifies the Yertis, along with other major water bodies such as the Caspian Sea and Lake Balkhash, as a water body of special state importance due to its role in meeting the country's water needs.[3] However, the river's ecosystem faces multiple threats from industrial wastewater, agricultural runoff, urban effluents, and other pollutants, leading to significant environmental degradation, especially in heavily industrialized regions like Oskemen.[4,5] These pollutants, including heavy metals, pesticides, nutrients, and organic matter, pose severe risks to both aquatic life and human health, thus highlighting the urgent need for monitoring and pollution reduction efforts.[6-8]

The assessment of pollution in transboundary rivers like the Yertis requires an integrated approach combining chemical, ecological, and technological methods to comprehensively monitor and manage water quality. Chemical-geo-ecological monitoring, which includes the analysis of pollutants and

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ecological impact assessments, provides essential insights into pollution dynamics over time and space.[9-13] Recent advancements in remote sensing have enabled more effective water quality monitoring, allowing researchers to use satellite-derived indices such as the Normalized Difference Water Index (NDWI) and the Modified Normalized Difference Water Index (MNDWI) to track water pollution and turbidity changes across large areas.[14-17] These tools facilitate the identification of pollution hotspots and temporal changes, which are critical for managing and mitigating environmental impacts in complex transboundary water systems.

It's well known that the presence of organic matter, biogenes, and algal blooms is a strong indication of surface water turbidity.[18] Aquatic ecosystems contain a variety of organic matter, including plant remains, animal excreta, and decomposing organisms. These substances can increase water turbidity because they create suspended particles that make it difficult for light to pass through. The more organic matter in the water, the higher the level of turbidity, which can negatively affect the health of the aquatic ecosystem. Measuring turbidity using traditional methods requires sampling and laboratory analysis, which can be time-consuming and costly, especially in large reservoirs with hard-to-reach areas. In this context, the use of aerial and satellite imagery (remote sensing data) is becoming increasingly popular, both for operational monitoring and for predicting changes in aquatic ecosystems. Space images from various satellites provide data that can be used to analyze indicators such as water turbidity, which directly affects the ecological condition of surface waters and their suitability for economic use. Landsat satellites, especially Landsat 8, are widely used in turbidity assessment studies due to the availability of high-resolution data. Numerous researches have demonstrated a high correlation between Landsat data and ground-based turbidity measurements.[19,20] For example, researchers evaluated the dynamics of surface water change and turbidity variability in the semi-arid Sobradinho reservoir in Northeast Brazil during the drought years (2013-2017).[21] Using 109 Landsat-8 Operational Land Imager (OLI) images, a time series of data was created to map the water volume in the reservoir. The results showed that surface water changes were spatially distinct throughout the reservoir. The Sentinel-2 satellite is widely used in Europe to monitor the turbidity of rivers and lakes.[22,23] For example, Sentinel-2 data were used to estimate turbidity changes along the river course in research on the Danube River. This research demonstrated that due to the high spatial resolution of Sentinel-2, turbidity can be effectively mapped, allowing the detection of both seasonal and anthropogenic impacts on water quality.[24]

In addition to monitoring, engineering solutions play a crucial role in pollution mitigation and water quality improvement. Engineering approaches, such as sediment removal and channel cleaning devices, can significantly reduce sedimentation, turbidity, and the accumulation of contaminants in river systems.[25-29] Research has shown that such interventions, when combined with regular monitoring, can help maintain water quality and enhance the ecological resilience of rivers affected by industrial and urban activities.[30-33] Furthermore, bioengineering techniques and sustainable land-use practices can also contribute to reducing nutrient runoff and improving water quality in the Yertis River basin.

This study aims to present an integrated approach to pollution assessment and reduction in the Yertis River by combining chemical-geo-ecological monitoring with engineering interventions. Through the use of field data and remote sensing technologies, we evaluate the current state of pollution, identify priority pollutants, and assess the effectiveness of engineering solutions in mitigating pollution. This approach not only contributes to the understanding of pollution dynamics in the Yertis River but also provides a framework for sustainable water management in Kazakhstan's transboundary river systems, offering valuable insights for other regions facing similar challenges.

2. Materials and research methods

In this study of the surface waters of the Yertis River, various physicochemical quality indicators were measured from collected water samples. Key parameters included suspended solids, hydrogen index (pH), dissolved oxygen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), major salt ions, nutrients, organic substances (*e.g.*, oil products, phenols), heavy metals, and pesticides. The analysis of these chemical parameters followed established testing protocols, including ST RK ISO 10523-2013, MVI 20658-1917-TOO NPO 002-2020, GOST 26449.1-85, and MVI 20658-1917-TOO NPO 002-2019. Laboratory analyses were conducted at the certified laboratory of the Center of Excellence "VERITAS" at Serikbayev East Kazakhstan Technical University (EKTU). Concentrations of heavy metals were specifically measured using atomic absorption with inductively coupled plasma mass spectrometry (ICP-MS), employing the Agilent 5700 cx manufactured by Agilent Technologies (USA). The assessment of water quality in Kazakhstani water bodies followed the standards outlined in the "Unified System of Classification of Water Quality in Water Bodies".

2.1 Remote sensing data and spectral indices

To complement the laboratory data, Earth remote sensing (ERS) data were utilized to assess the spatial distribution and pollutant levels in the surface waters. The remote sensing analysis employed several spectral indices, which allow for effective monitoring of water properties across large geographical areas.
The following spectral indices were used.

2.1.1 Normalized difference water index

It is well known that NDWI is used to detect and monitor changes in surface water content and is particularly effective for assessing water turbidity.[34] The index ranges from -1.0 to 1.0, where positive values indicate the presence of water. The NDWI is calculated using the following formula:

$$NDWI = (Green - NIR) / (Green + NIR) \quad (1)$$

where *Green* represents reflectance in the green spectral region, and *NIR* represents reflectance in the Near-Infrared Region.

High NDWI values, closer to +1, indicate water-rich areas, while lower values down to -1 are characteristic signs of non-water surfaces or drought conditions. NDWI maps, displayed using color palettes, allow the visualization of changes in water availability and turbidity over time.

2.1.2 Modified normalized difference water index

The algorithm effectively suppresses and even eliminates noise effects from surfaces, soil, and vegetation.[35] The index is more effective compared to NDWI if the investigated shoreline is close to any structure. In this case, the result of water body allocation will be more accurate; all negative indicators are not taken into account. The Modified Normalized Difference Water Index (MNDWI) is calculated according to formula 2.[2,4-7]

$$MNDWI = (Green - SWIR2)/(Green + SWIR2) \quad (2)$$

where *Green* represents reflectance in the green spectral region and shortwave infrared (*SWIR2*).

Remote sensing also offers the possibility of measuring turbidity by analyzing the spectral characteristics of reflected solar radiation. The basic principle is that different wavelengths are absorbed and reflected differently by turbid and clear water. Turbid water has a high concentration of suspended particles, which change the optical properties of the water body, increasing the reflectance in the visible and near-infrared spectral ranges.

Various spectral indices have been developed to estimate turbidity, such as the Normalized Difference Turbidity Index (NDTI), which uses red and green channel data from satellite imagery.[36,37] Other indices are based on a combination of near-infrared and red bands to more accurately estimate reflectance from turbid water.

Since the NDWI and MNDWI indices provide a general measure of water balance compared to the other indices, the NDTI is used to predict survey results that are close to empirical values and to determine the level of water pollution.[38]

The NDTI characterizes a decrease in water clarity due to the presence of inorganic and organic impurities or the development of plankton in a water body. The erosion can be caused by land runoff, pollution, and shoreline erosion. The NDTI can take values from -1.0 to 1.0. The higher the value of this index, the higher the turbidity of the water body. The index is used to detect water turbidity and to predict drought, as the index carries a more global indicator - it is more sensitive to changes in water storage in plants. In the calculation of this index, only the visible range of the spectrum is used and is calculated according to formula 3

$$NDTI = (Red - Green)/(Red+Green) \quad (3)$$

where *Green* and *Red* represent reflectance in the green and red spectral regions.

2.1.3 Turbidity and pollution assessment

Remote sensing of turbidity enables analysis of the spectral properties of reflected solar radiation to identify turbid water zones. By analyzing visible and near-infrared reflectance, researchers can monitor changes in turbidity related to both natural and anthropogenic influences. Turbidity dynamics, which can indicate increased suspended particles from pollution sources, are particularly useful in early detection of environmental issues. Spectral indices like NDWI, MNDWI, and NDTI facilitate real-time tracking of turbidity and water quality in the Yertis River. Combining these spectral indices with in-situ data enables a comprehensive assessment of surface water quality. The use of ERS data, such as that from Landsat and Sentinel satellites, allows for the efficient monitoring of large and remote areas, providing timely insights into turbidity patterns and pollution distribution. This integration of ground-based data with satellite imagery strengthens the approach to sustainable water quality management, ensuring early detection of pollution and enabling rapid response in transboundary rivers.

3. Results and discussion

Table 1 presents a summary of the chemical composition of water at different sampling stations along the Yertis River in Oskemen (Ust-Kamenogorsk) city. Key water quality indicators were measured, including suspended solids, BOD, COD, pH, petroleum products, major ions (such as chlorides and sulphates), nutrients, and various heavy metals. Each parameter is compared against the maximum allowable concentrations (MAC) for water bodies intended for fisheries. The table provides insight into the spatial distribution of pollutants along the river, highlighting specific stations where certain contaminants exceed regulatory thresholds, indicating potential hotspots for pollution.

Analysis of Table 1 reveals several key pollution concerns in the Yertis River. Nitrite nitrogen levels exceed the MAC at 3.2 km downstream of the Ulbi River confluence on the left bank. Copper concentrations are above the MAC at all sampling sites, while zinc also exceeds the MAC across all six locations. Manganese levels surpass the MAC at multiple points, including 3.2 km downstream of the Ulbi River on both banks, as well as in Praporshchikovo and Predgornoe villages. Additionally, phosphate and ammonium salt concentrations exceed the MAC at 3.2 km downstream of the Ulbi River on the left bank. These findings indicate significant pollution hotspots in the river, particularly in the areas influenced by municipal discharges and local industrial activity (Fig. 1).

The NDWI index is an important indicator for assessing water turbidity and ranges from -1.0 to 1.0, with water values generally greater than 0. This index is calculated using a combination of channels (formula 1). Differences in the water

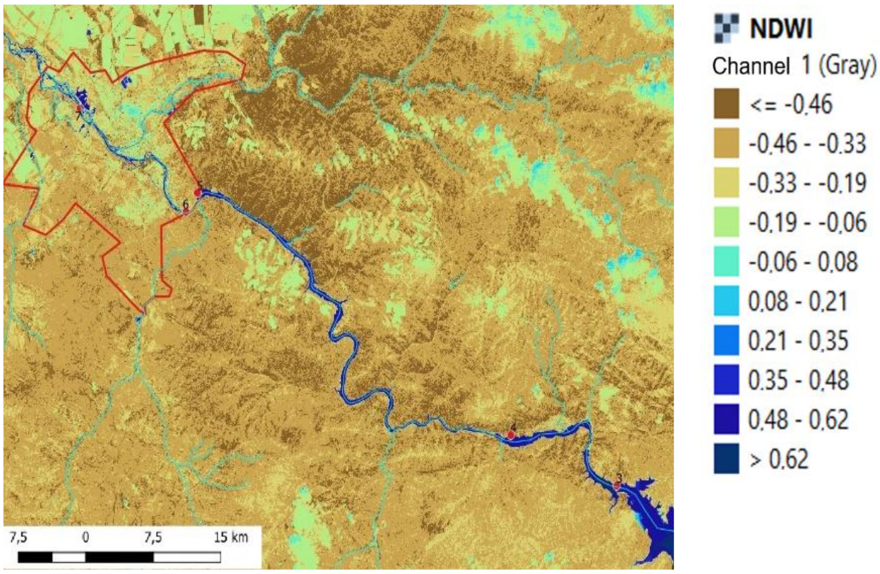


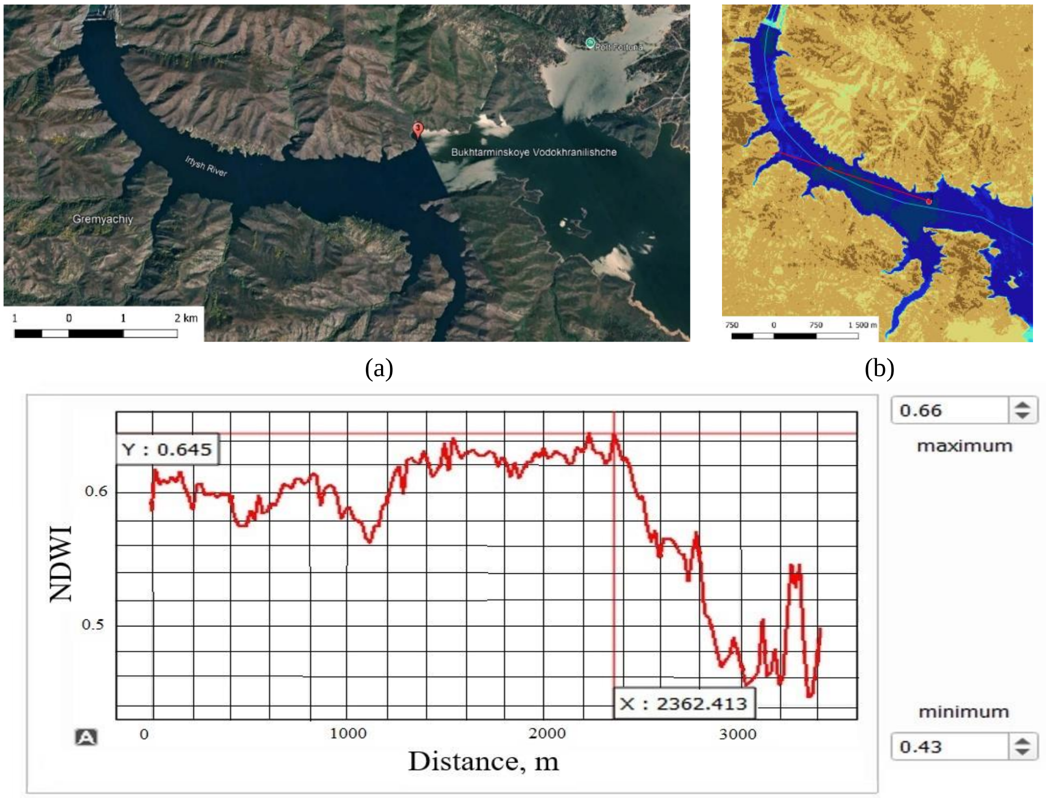
Fig. 1 NDWI (based on total data).

Table 1. Summary table of chemical composition by stations of the Yertis River in Oskemen city.

№	Indicators	0.8 km downstream of the U-Ka HPP dam	0.5 km below the discharge of the Condenser Plant	3.2 km below Ulbi River, left bank	3.2 km below Ulbi River, right bank	Prapo-schikovo village	Pred gornoe villege	MACpx
1	Suspended solids	6.579	6.854	8.286	12.035	14.628	11.902	0.25
2	BOD	1.537	1.506	1.673	1.712	1.514	1.532	3
3	COD	9.157	9.104	9.171	10.073	8.213	8.32	30
4	PH	8.022	8.035	7.968	7.999	7.973	8.051	
5	Petroleum products	0.019	0.019	0.025	0.024	0.024	0.022	0.05
6	Chlorides	6.474	6.292	10.618	10.685	9.516	7.299	300
7	Sulphates	22.272	22.58	30.91	25.798	31.705		100
8	Calcium	27.432	27.846	32.884	32.111	33.169		180
9	Magnesium	7.72	8.143	8.902	8.276	9.21		40
10	Ammonium salts	0.123	0.142	0.58	0.174	0.19		0.5
11	Nitrate nitrogen	0.506	0.504	2.204	0.985	1.148		9
12	Nitrite nitrogen	0.005	0.006	0.044	0.015	0.009		0.02
13	Phosphates	0.029	0.02	0.742	0.159	0.027		0.25
14	Total iron	0.023	0.04	0.034	0.126	0.098		0.3
15	Copper	0.002	0.002	0.002	0.002	0.002		0.001
16	Zinc	0.005	0.005	0.009	0.026	0.015		0.01
17	Cadmium	0.0003	0.0002	0.0003	0.001	0.0004		0.001
18	Manganese	0.006	0.008	0.012	0.021	0.019		0.01

index in the study area are determined from the profile data, which is drawn along the direction of water flow in the reservoir upstream of the dam (Fig. 2). In the vicinity of the dam, turbidity remains at the average index value, while in the receding part of the reservoir the index decreases to 0.2 (profile in Fig. 2), indicating a gradual increase in turbidity.

The next stage of the research is to analyze the NDWI index, which is designed to assess turbidity in the area after the dam (Fig. 3). From the data obtained, it can be seen that near the dam and in the area away from the dam, the NDWI index decreases to -0.4, indicating an increase in turbidity in the main part of the watercourse channel. This indicates the need for the development of a water filtration device for the post-dam section within the city.



(c)

Fig. 2 NDWI at reference point 3 (upstream of the weir) (a) location of the control point; (b) NDWI map; (c) chart of changes in the NDWI index.

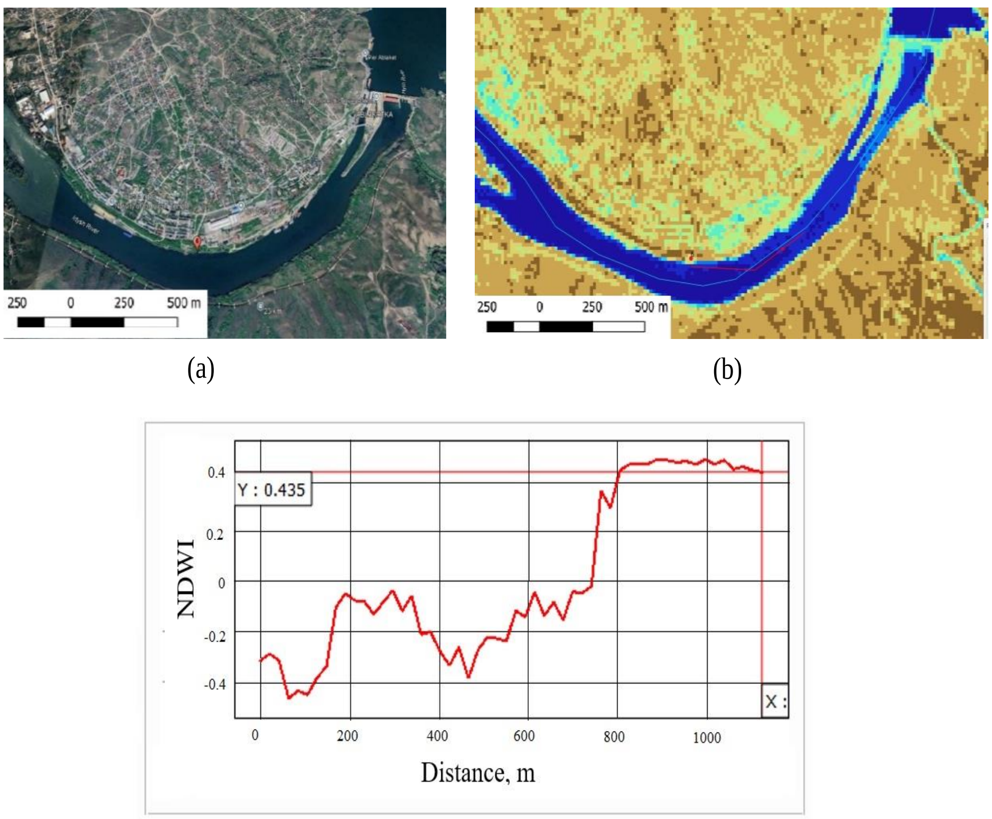


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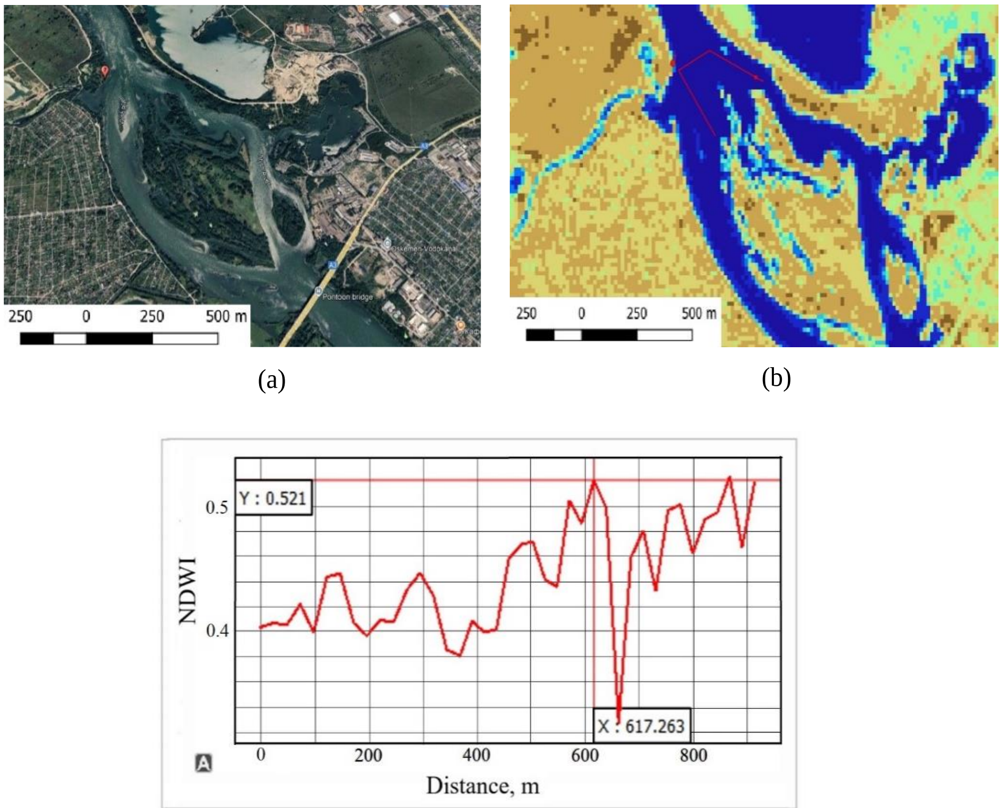
Fig. 3 NDWI at reference point 6 (post dam) site (a) location of the control point; (b) NDWI map; (c) chart of changes in the NDWI index.



(a) (b)

(c)

Fig. 4 NDWI at reference site 7 (a) location of the control point; (b) NDWI map; (c) chart of changes in the NDWI index.

Table 2. Summary of NDWI calculation data.

№	Distance, m	Control points			
		General	CP3	CP6	CP7
1	0	-0.46	0.57	-0.3	0.41
2	200	-0.33	0.64	-0.1	0.4
3	400	-0.19	0.62	-0.3	0.42
4	600	-0.06	0.55	-0.1	0.52
5	800	-0.08	0.66	0.42	0.48
6	1000	0.21	0.53	0.44	0.42
7	1200	0.35	0.6	0.46	0.45
8	1400	0.48	0.66	0.49	0.50
9	1600	0.62	0.62	0.51	0.45
10	1800	0.7	0.66	0.52	0.41

The next object of research is the section of the sewage canal outside the city and the turbidity of water sampled from the area adjacent to the canal after passing through the gravity filter of the municipal wastewater treatment plant. The NDWI index measured along the profile covers both the main canal and the small canal connected to the sewer (Fig. 4, Table 2). The results showed that in the main channel, the turbidity of water remains at natural levels, while the small channel has the highest water index of 0.521 (Fig. 4(c)) at the point of discharge of urban sewage (having an axis value of x=617.263 m, y=0.521). At the transition to the lower channel, due to the turbulence of the flow, the turbidity of water decreases, passing to the value of normal turbidity, which is 0.4.

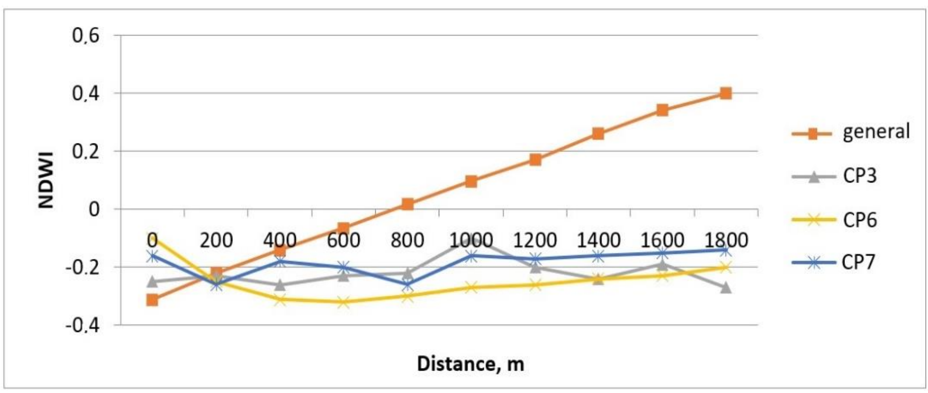


Fig. 5 Distribution graph of NDWI values.

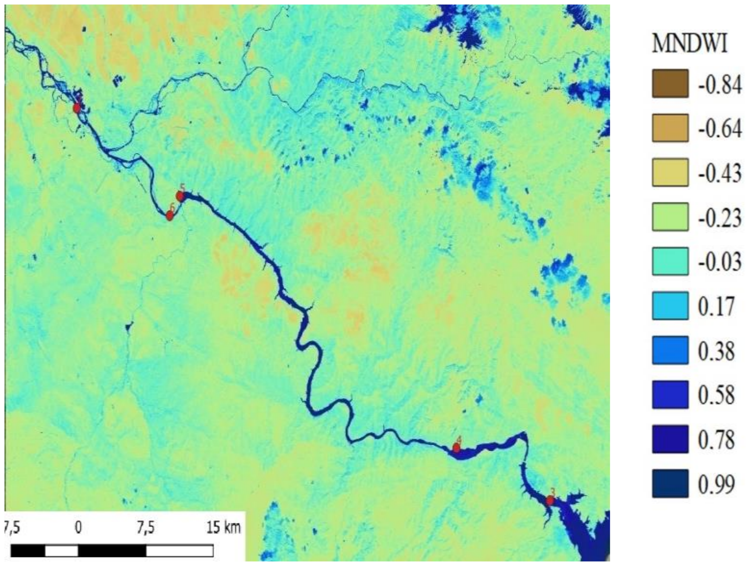
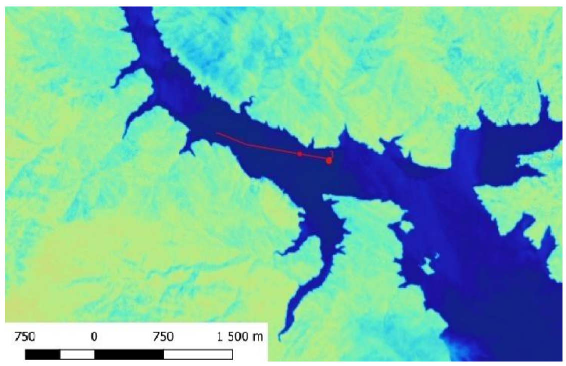


Fig. 6 MNDWI based on total data.

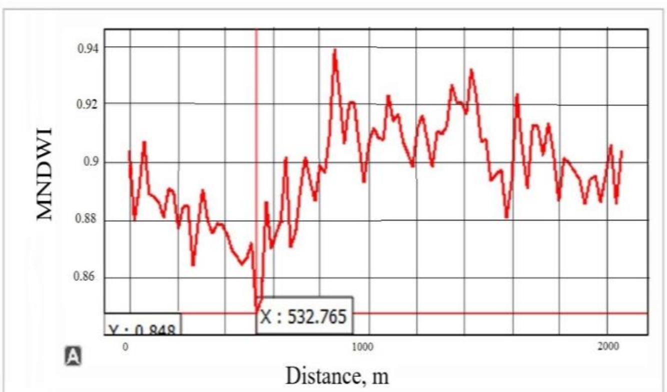
In the study area, the values of the NDWI vary, showing higher values at control point 7, lower values at control point 3, and fluctuating values at control point 6 depending on the flow velocity downstream of the water (Fig. 5). The results of the MNDWI calculations are summarized below for the control sites (Figs. 6-9, Table 3).

In contrast to the NDWI index, the MNDWI index reduces correlation with other open water indices and increases the accuracy of recognizing water bodies in the study areas. Using MNDWI data, more accurate data for analyzing water features can be obtained, as all negative values are excluded from the calculation. The range of MNDWI index values is from -1.0 to 1.0, with water values greater than 0. The MNDWI values below (Figs. 6-9) complement the accuracy of the survey results at the locations listed above (Figs. 1-4).

(a)

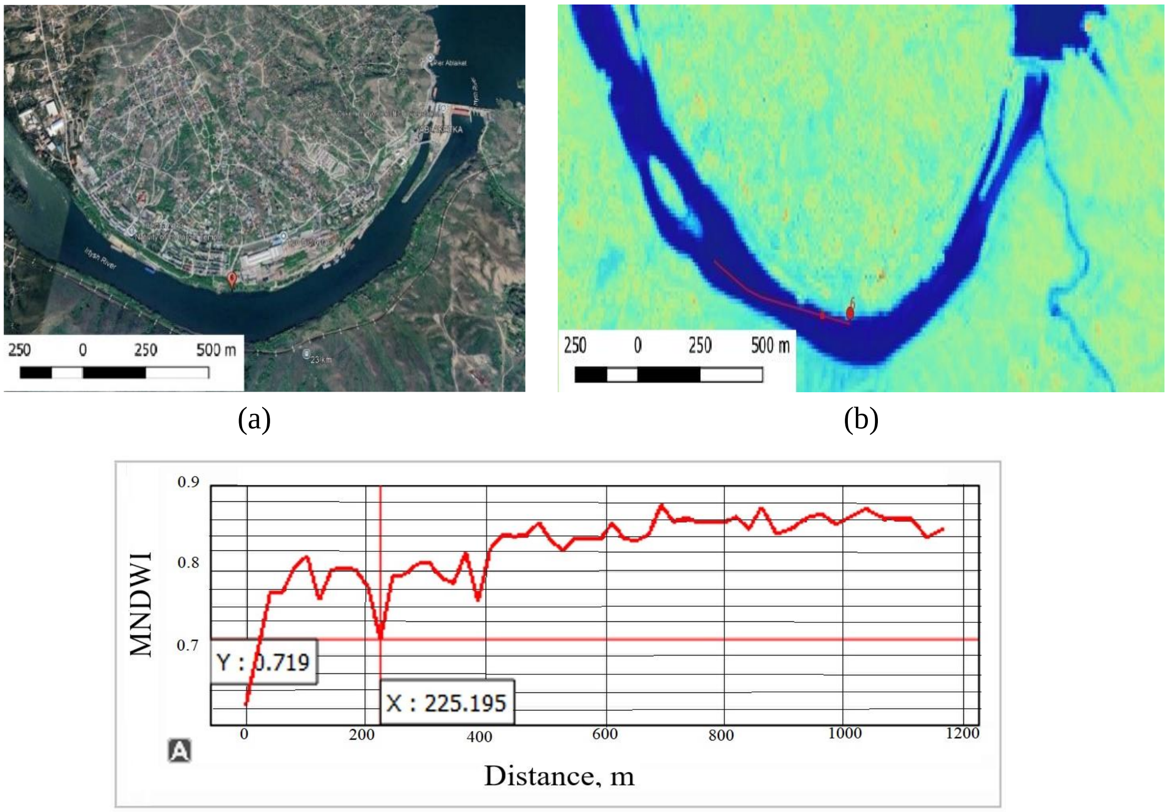


(b)



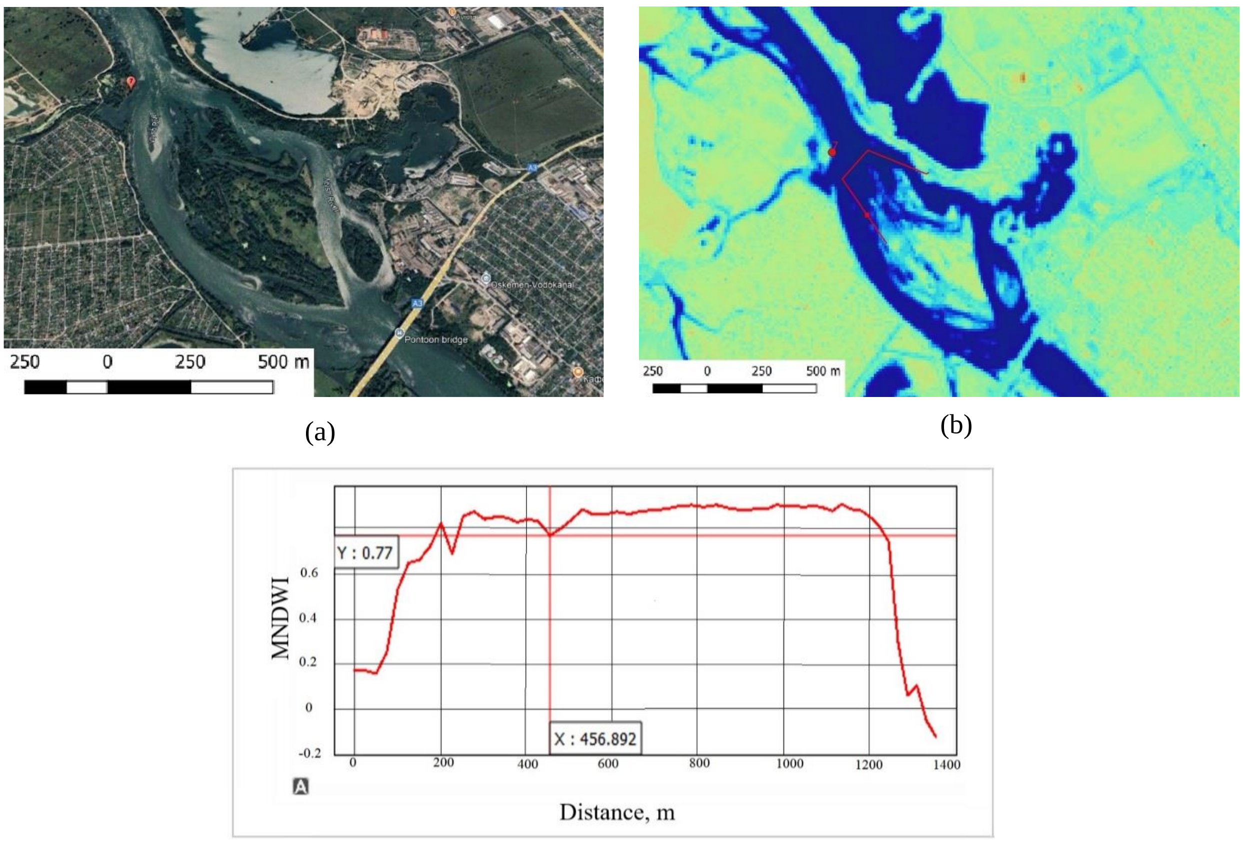
(c)

Fig. 7 MNDWI upstream of the dam (3 control points) (a) location of the control point; (b) MNDWI map; (c) chart of changes in the MNDWI index.



(c)

Fig. 8 MNDWI at site 6 of the control site (after the dam) (a) location of the control point; (b) MNDWI map; (c) chart of changes in the MNDWI index.



(c)

Fig. 9 MNDWI at reference point site 7 (a) location of the control point; (b) MNDWI map; (c) chart of changes in the MNDWI index.

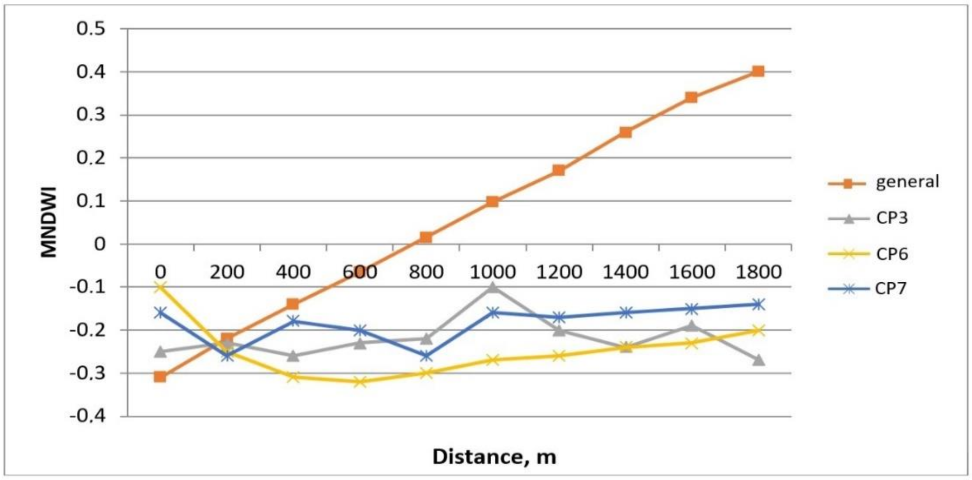


Fig. 10 Distribution graph of MNDWI values.

Table 3. Summary of MNDWI calculation data.

№	Distance, m	Control points			
		General	CP3	CP6	CP7
1	0		0.85	0.7	0.9
2	200	-0.64	0.87	0.8	0.82
3	400	-0.43	0.88	0.76	0.8
4	600	-0.23	0.90	0.88	0.84
5	800	-0.003	0.95	0.87	0.83
6	1000	0.17	0.90	0.86	0.85
7	1200	0.38	0.88	0.85	0.81
8	1400	0.58	0.93	0.84	-0.1
9	1600	0.78	0.89	0.82	-0.3
10	1800	0.99	0.087	0.79	-0.41

The analysis of the distribution of MNDWI values (Fig. 10) shows that overall water composition, according to this index, deviates from control points and approaches maximum values in areas with high turbulence (near the center of the channel). However, the values are not uniform across the control points. At control point 3, located upstream of the weir, there is a noticeable deviation, while values improve as the flow nears the weir. At control point 6, downstream of the dam, the water index shows a higher value due to increased turbulence, whereas within the city limits and at the outlet (control point 7), there is a decrease in index values. The results of the NDTI calculations are presented below for the control sites (Figs. 11-14, Table 4).

The NDTI index takes values from -1.0 to 1.0: the higher the index value, the higher the water turbidity in the water body, including the shoreline of the watercourse. The results of the comparative analysis for the study period showed low water transparency on the coast of the study area, in particular near the coast at the section before the reservoir (Fig. 12) and after the reservoir (Fig. 13), as well as at the section of the connection of the main watercourse with the small canal on the edge of the urban area, where changes are clearly visible in the profile of the sampling line along the water canal (Fig. 15).

Despite the difficulties in scaling satellite data, it can be concluded that there is an increasing trend of coastal pollution in the study area. Water turbidity is lower in the main river channel, but significantly higher on the coast, which indicates that the watercourse is subject to the eutrophication process. The results of the research have shown that there is a need to use treatment devices (Fig. 16) to eliminate coastal pollution and obtain optimal results. At the same time, the study of territories with calculation of indices allows to identify areas with accurate coordinate data, which provides a differentiated approach to the application of treatment devices in the study area and to reduce the volume of treatment works.

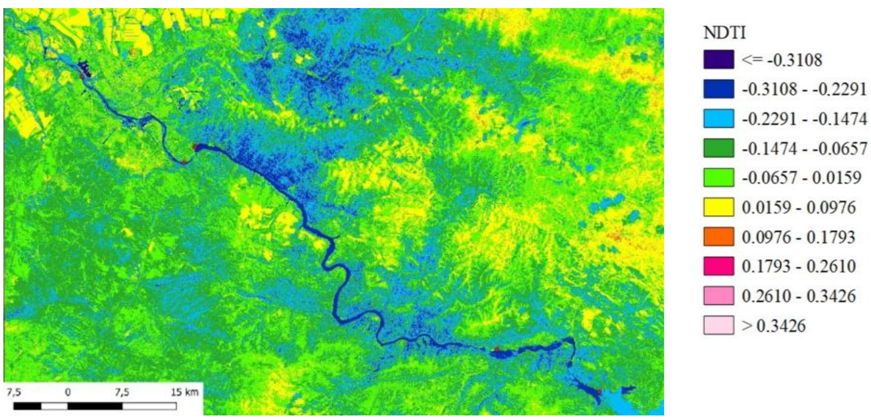


Fig. 11 NDTI based on total data.

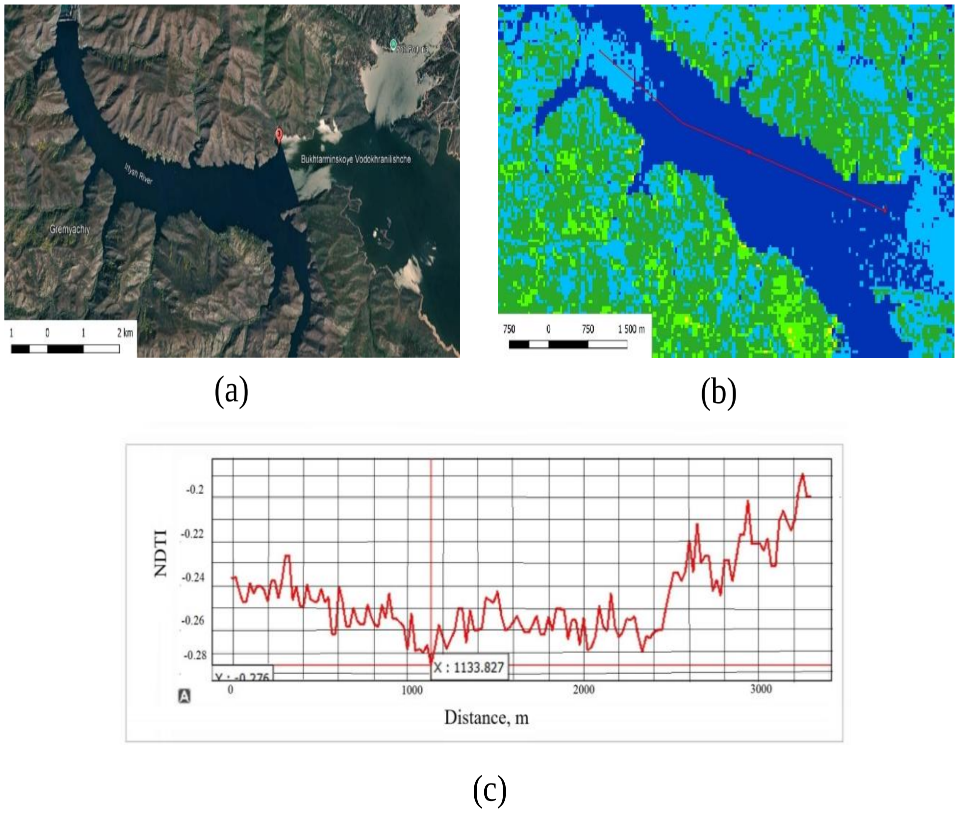


Fig. 12 NDTI upstream of the dam (3rd reference point) (a) location of the control point; (b) NDTI map; (c) chart of changes in the NDTI index.

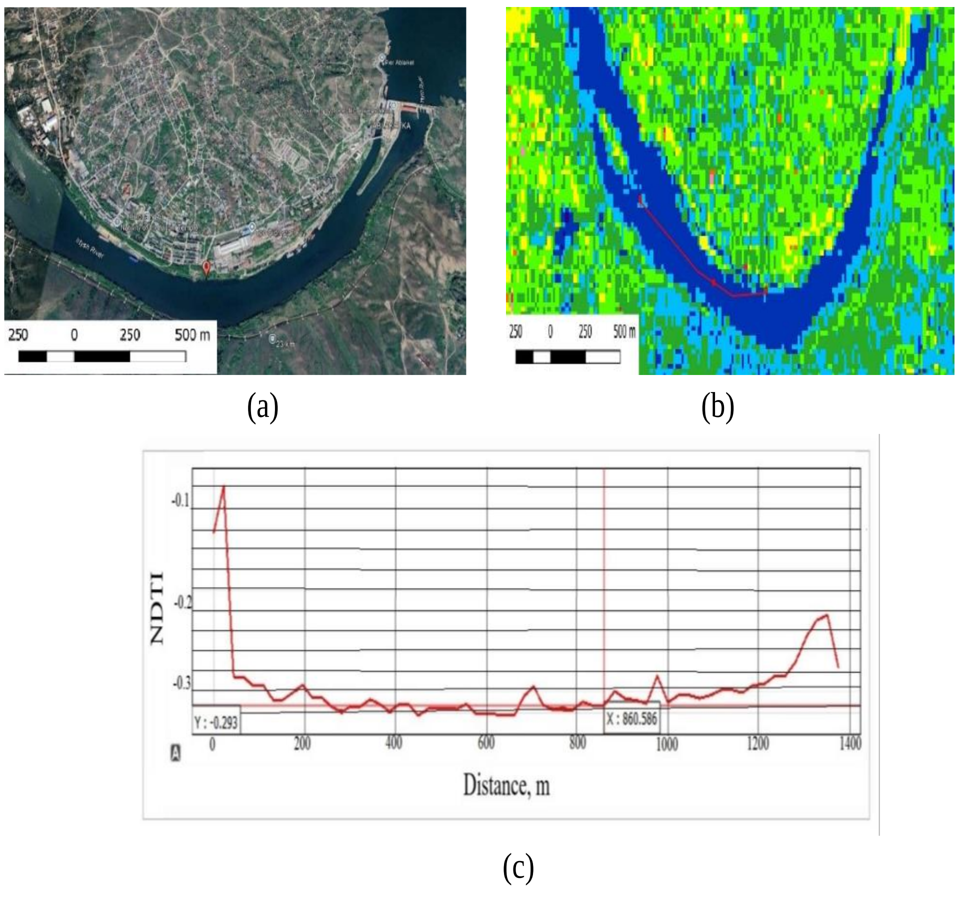
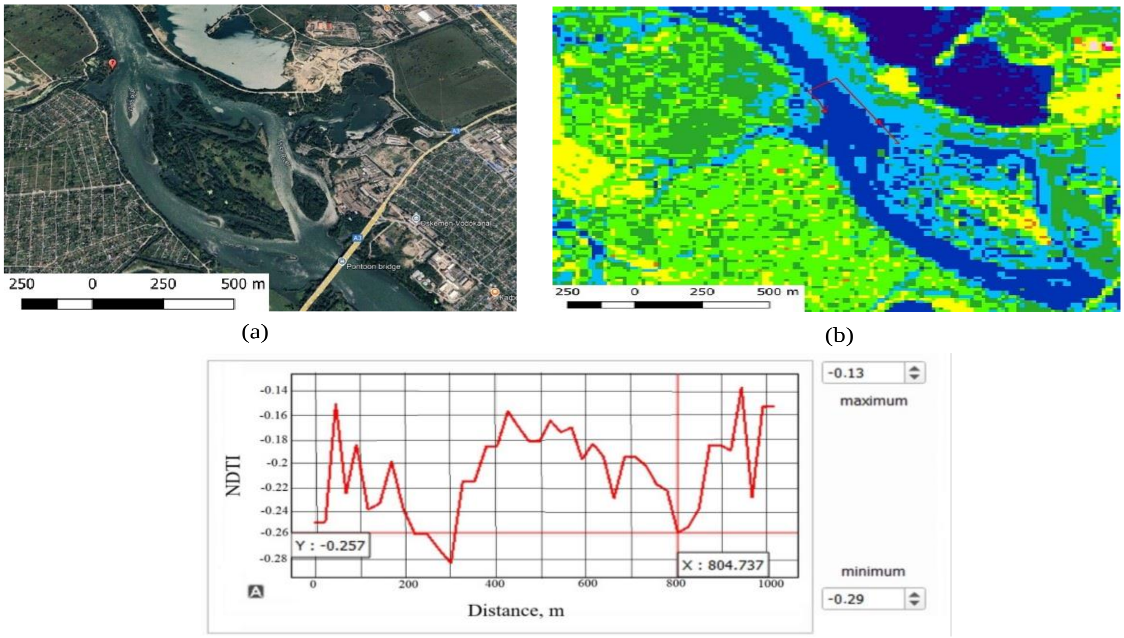


Fig. 13 NDTI at site 7 of the control site (after the dam) (a) location of the control point; (b) NDTI map; (c) chart of changes in the NDTI index.



(a) (b)

(c)

Fig. 14 NDTI at site 6 control point (after weir) after dam (6 control point) (a) location of the control point; (b) NDTI map; (c) chart of changes in the NDTI index.

Table 4. Summary data on NDTI calculation.

№	Distance, m	Control points			
		General	CP3	CP6	CP7
1	0	-0.31	-0.25	-0.1	-0.16
2	200	-0.22	-0.23	-0.,25	-0.26
3	400	-0.14	-0.26	-0.31	-0.18
4	600	-0.065	-0.23	-0.32	-0.20
5	800	0.016	-0.22	-0.30	-0.26
6	1000	0.097	-0.1	-0.27	-0.16
7	1200	0.17	-0.2	-0.26	-0.17
8	1400	0.26	-0.24	-0.24	-0.16
9	1600	0.34	-0.19	-0.23	-0.15
10	1800	0.40	-0.27	-0.20	-0.14

Analyzing water bodies, building index models, carrying out visual assessments based on them, and analyzing erosion and pollution processes of water bodies belong to periodic works. By evaluating water quality during a month, year, and time with the help of spectral indices, it is possible to accurately determine the factors affecting them. The indices also allow tracking of the main months of entropy and seasonal flow into the river. Since the conducted research is divided into three stages, and currently, the data of the primary research have been processed and analyzed by comparing the results of laboratory tests of water samples and calculation of spectral indices from space images, the results of the subsequent research will determine the pollution zones of the actual river bed and the main polluting factors.

The experimental data presented above confirmed the existence of the problem of surface water turbidity, which primarily affects navigation. High water turbidity makes navigation difficult and reduces the wear and tear of ships, reducing their economic efficiency.

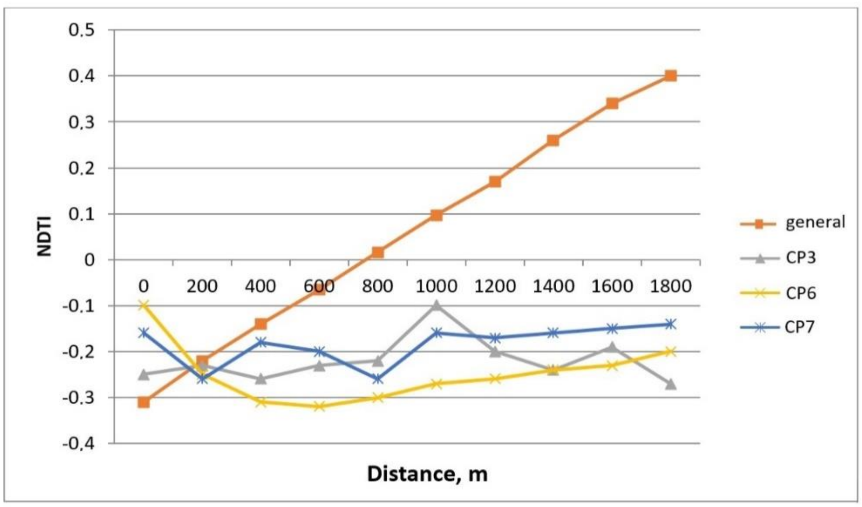


Fig. 15 Distribution graph of NDTI values.

As an engineering solution to minimize this impact and improve navigation conditions, the installation of a dedicated riverbed cleaning device is recommended. This device will provide a reduction in suspended solids and other pollutants to ensure water clarity at all times and ensure stable and safe navigation.

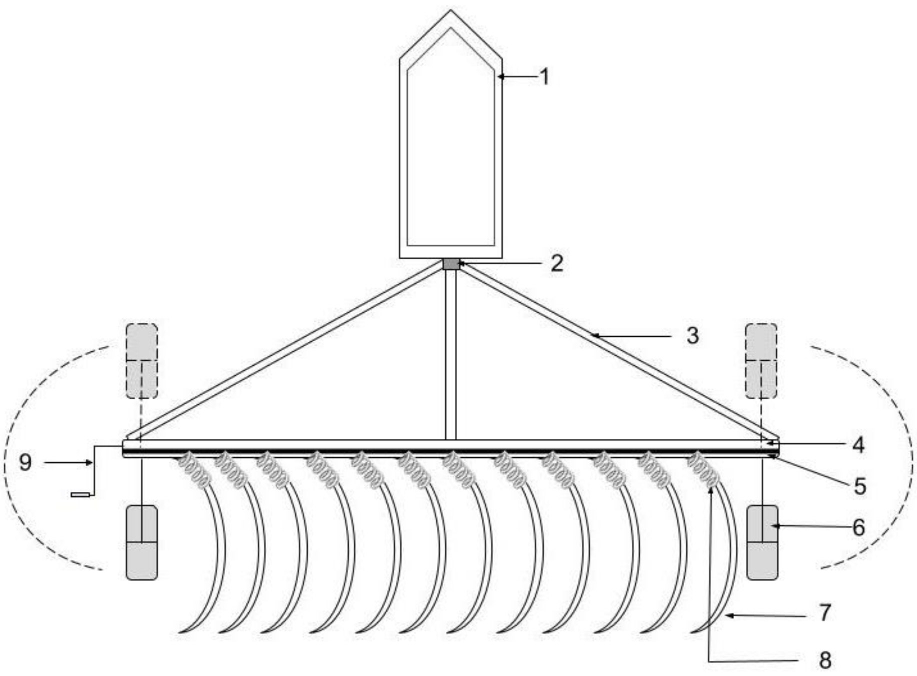
In contrast to this type of devices developed for this purpose are moved on the surface of the water by any water transport and regulated by the rake of the device depending on the capacity of the water channel. The basis for the use of cleaning means is often that forces of effort can only hold the embankment to a depth of 30-50 degrees. The invention is aimed at regulating the geo-ecological system of the territory with the restoration of the stagnant watercourse from anthropogenic, creating accumulations on the banks of sewage water passing through the territory of the settlement, the impact of woody plant residues, and waste.

The device for cleaning the riverbed from waste is designed to clean the banks of watercourses in settlements, which makes it possible to effectively remove various types of waste at a depth of up to 1.5 meters. Unlike existing devices that move along the surface of the water using swimming facilities and are equipped with adjustable rakes to adapt to different depths of the reservoir, this device provides a deeper and more effective cleaning.

In addition, the device effectively removes various organic waste, wood residues, and other types of pollution, which helps to improve the ecological condition of water bodies. It can be used to restore the ecological system of the area through which wastewater flows, including improving the water quality of urban water bodies and preventing their pollution. The proposed device works as follows: iron structures are adjusted to operate at a depth of up to 1.5 meters, collecting waste. A tank filled with air and made in the form of a rubber cylinder is installed along the upper surface of the device, which ensures its buoyancy during operation. Plastic floats located at both ends of the device act as a boat to transport it through the water. A mitten-like mechanism on the left edge of the device controls the raising and lowering of the cleaning rake, and adjusts its depth depending on the characteristics of the water channel.

Figure 16 presents the design of the proposed riverbed cleaning device. The device consists of a motorboat 1, a mounting bracket for registering the device to motorboat 2, connecting shafts holding the device at a safe distance from motorboat 3, a rubber cylinder filled with air providing buoyancy to the device on the surface of water 4, a beam to which the harrow structure is attached for waste removal 5, a plastic torso filled with air floating on the transport of the device 6, a rake with its bottom attached to the sickles for waste removal 7.

The device includes the following elements: a motorboat (1), a suspension mount for attaching the device to the motorboat (2), connecting shafts that maintain a safe distance between the device and the vehicle (3), a rubber cylinder filled with air that keeps the device buoyant on the water (4), a beam with an attached harrow structure for collecting waste (5), a plastic housing filled with air that maintains buoyancy during transport (6), and a rake attached to the sickle to clean the bottom of the waste (7).



1 - Motorboat; 2 - Suspension mount; 3 - Bracket; 4 - Cylinder; 5 - Spring fastening; 6 - Float; 7 - Metal arc; 8 - Spring; 9 - Handle.

Fig. 16 Device for cleaning the riverbed from waste.

The operation of the device is as follows: it is attached to the motorboat (1) through a suspension mount (2), which can be used with any type of water vehicle. Connecting shafts (3) create a safe interval between the device and the vehicle, preventing their collision during maneuvers. A rubber cylinder (4), filled with air and mounted along the structure, allows the device to float on the surface of the water. The rake attached to the beam (5) efficiently collects waste from the bottom, and its flexible part protects it from damage when it collides with underwater solid objects. Plastic floats at both ends of the device (6) provide additional buoyancy. Metal arcs (7) are designed to collect underwater waste at a predetermined depth.

4. Conclusion

This study assessed the water quality and pollution levels in the Yertis River basin, with a particular focus on anthropogenic and transboundary impacts. By analyzing physicochemical indicators, including suspended solids, pH, dissolved oxygen, BOD, COD, nutrients, organic substances, heavy metals, and pesticides, we identified the most polluted sections of the Yertis River and the specific pollutants exceeding MAC. Key findings include:

Heavy Metals: Elevated levels of copper and zinc were consistently found across all sampled sites, indicating widespread contamination likely from industrial sources.

Nutrients and Other Pollutants: Exceedances in phosphates, nitrites, and ammonium salts were observed in areas downstream of Oskemen, especially near the Ulba River confluence. This is likely due to treated wastewater discharges from municipal facilities, contributing to localized pollution and nutrient enrichment.

Spatial Variability of Pollutants: Elevated manganese levels were recorded along both banks near Oskemen and neighboring villages, Praporshchikovo and Predgornoe, reflecting specific pollution hotspots influenced by local industrial and wastewater inputs.

Remote sensing and field data from satellite imagery and Unmanned Aerial Vehicle (UAV) provided further insights, enabling a spatial analysis of pollution distribution through indices like NDWI, MNDWI, and NDTI. These indices helped map water quality and turbidity across control sites, supporting the identification of heavily impacted sections and tracking changes over time.

The practical implications of this study lie in its contribution to geo-ecological monitoring frameworks, especially for high industrial load areas where pollution and turbidity pose challenges to water quality and ecosystem health. The integration of remote sensing technology, UAV imagery, and physicochemical analysis offers a robust approach to the timely detection of pollution hotspots, allowing for targeted interventions. As an engineering solution, the proposed riverbed cleaning device offers a practical method for addressing turbidity and removing pollutants from the river. This device, designed to operate at depths of up to 1.5 meters, enables efficient collection of suspended solids and waste materials, improving water clarity and navigation safety. By enhancing the river's geo-ecological stability and water quality, this approach contributes to the long-term sustainability of the Yertis River, creating favorable conditions for both water use and biodiversity conservation. Implementing these methods and technologies, alongside a systematic geo-ecological monitoring strategy, can help mitigate environmental risks and support the sustainable management of water resources under increasing industrial and transboundary pressures.

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Conflict of Interest

There is no conflict of interest.

Supporting Information

Not applicable.

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