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Assessment of the water quality state in the downstream portion of Syr-Darya using the water quality index arithmetic method

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Abstract. This research study's overarching goal is to assess the effects of industrial (chemical components) and agricultural (Pesticide residues) activities on the Syr-Darya. This study has the following specific goals: 1. Assess the current state of Syr-Darya's water quality; 2. Examining the agricultural and industrial activities in the Syr-Darya (Kazakhstan) downstream portion. In this study we aimed to assess the current state of water quality in the downstream portion of Syr-Darya using the Water Quality Index (WQI) arithmetic method. The study specifically focuses on the effects of industrial and agricultural activities on water pollution, including metallic and non-metallic chemical components, PH, TDS, other minerals, and pesticide residues. The importance of this research lies in the lack of up-to-date evaluations of water quality classification and the potential impact of pollutants (industrial and agricultural activities) over the Syr-Darya. The literature review highlights the high levels of pollution in the river due to industries and agricultural activities. Both upstream and downstream countries contribute to the pollution, with upstream countries adding pesticides and downstream countries polluting the water through industrial activities. The research will involve collecting secondary data from existing studies on water pollution and indicators of water quality in the region. The methodology involves calculating the WQI using the Weighted Arithmetic Index Method, which provides an overall index number representing the water quality. This research is important for understanding and managing water pollution in the Syr-Darya river basin.

Keywords: *water quality assessment, WQI, Water Quality Index, arithmetic method, chemical compounds, water pollution, the concentration of minerals, water quality index.*

1. Introduction

Despite the Syr-Darya River's significance and its long history of agricultural production, few researches have examined the effects of agricultural and industrial pollutants in the present day [5]. Although, water contamination in the Syr-Darya is a major cause for concern, there are few research papers on the subject, which emphasizes the significance of this work.

Water pollution in Kazakhstan is more important than water scarcity. Water contamination closely linked to agriculture in the irrigated regions along the Syr-Darya. Soviet initiatives to boost agricultural output in the Syr-Darya basin led to a dramatic increase in water diversion, which had a substantial negative impact on the water's suitability for irrigation, fisheries, and other uses [8]. There are various older research studies that rated the Syr-Darya's water quality, for example according to [1]: the Syr-Darya River is classified over its whole course as a moderately contaminated water body (III class water quality) by the water pollution index. Though, in this study, we tend to provide an update.

According to a comprehensive report produced as a result of joint work between the United Nations Economic Commission for Europe (UNECE), and the International Water Assessment Centre (IWAC), during 2021 - 2023, the major source of pollution in the basin is agricultural activities accounts for 90% pollution of water volume. Although industrial pollutants have a significantly smaller volume it is more poisonous, making them more harmful [9].

When the polluted water is released into the rivers untreated or poorly treated, it is difficult to restore its previous status. The issue of water quality is more important than climate change, water availability, and other issues because water quality can have major impacts on urban but also agricultural water use. There should be stricter rules for companies to take water treatment precautions. If other countries are capable of good regulations on industrial water use, then Kazakhstan can also do so. Then we can conclude that one important source of pollution in Kazakhstan is industrial use.

In general, water volume in Kazakhstan is not such a critical problem, there is not so little water overall in the country, but, it is unequally distributed. Kazakhstan is an economically powerful country, and it has a huge potential for improving water management by also showing a good paradigm for the neighboring countries. This management is also applicable to water quality issues in the same way [3]

Both upstream (Tajikistan and Kyrkyzstan) and downstream countries (Uzbekistan and Kazakhstan) are responsible for the river's pollution. Upstream countries mainly pollute the water by adding pesticides, which residues return to the water because flooding irrigation is usually common in Central Asian countries and downstream countries by mining and quarrying that pollute the water and use water to dilute by everyday activities.

Industrial accidents at hazardous chemical facilities, including at tailings management facilities, as well as other industrial activities can cause water pollution and can have a significant transboundary impact when they occur in a transboundary river basin. The integration of industrial risks, notably tailings risks, in river basin management plans, as well as the enhancement of cooperation between industrial safety and water experts are key for effectively preventing water pollution and its negative impact in the Syr-Darya river basin [4].

2. Materials and methods

In this study, we adopted a secondary data collection approach to gather and analyze data. This approach allowed us to leverage previously collected information and focus on analyzing, interpreting, and drawing meaningful conclusions from the available data. For analyzing purpose, it is important to understand the extent of water pollution in the basin. Some (few) researches has already stated the amount of water pollution in the river. For example, in all the sampling events for Syr-Darya, residues of lindane (γ-HCH) which is ranged from 0.014 to 0.24 µg/L detected in water samples, are among the highest concentrations reported for rivers globally. Lindane is a chemical compound that is used both as an agricultural insecticide and as a pharmaceutical treatment for lice and scabies [5]. Hence, literature review was an effective tool for data collection procedure.

According to [1], as presented in table 1, water quality indicators for Syr-Darya is indicated. MAC 1 and 2 is for fisheries and agriculture, and MAC 3 is for drinking uses in open water bodies. These indications served as the basis for each parameter's standard values in our analysis. The parameters' indicators and mean concentration values described in the following tables and paragraphs.

Table 1. Priority indicators of water quality in Syr-Darya River Basin Ref [1]

No.	Indicator	Unit	MAC1	MAC2	MAC3
1	Oxygen	mg/l	6	-	0.005
2	BOD	mgO^2/l	3	-	6
3	COD	mgO^2/l	15	-	-
4	Nitrite Nitrogen	mg/l	0.02	-	3
5	Salinity	mg/l	1000	-	up to 1000
6	Chlorides	mg/l	300	350	350
7	Sulphates	mg/l	100	-	500
8	Magnesium	mg/l	40	-	< 40
9	Sodium	mg/l	120	-	120
10	Total hardness	ml/l	7	7	7
11	Copper	µg/l	1	1	1
12	Zinc	µg/l	10	5	1
13	Chrome VI	µg/l	1	-	0.5
14	Phenol	mg/l	0.001	-	No more than 0.01
15	Oil products	mg/l	0.05	-	No more than 0.05
16	Fluoride	mg/l	0.75	1.5	1.5

Furthermore, the most recent study, which was published in 2023 by [6], also examined the amount of metallic, non-metallic chemical compounds, other minerals, and total dissolved solids on three different bases: minimum, average, and maximum as shown in Table 2. In this study we used the mean values. In this research the approach is calculation of WQI (Water Quality Index) using Weighted Arithmetic Index Method [11], which indicates the extent of water pollution or quality of water.

Table 2. Major ions and TDS (in mg L^{-1}) collected for Syr Darya waters in August 2021 [6]

Mineral	TDS	HCO_3^-	$CO^2_3{}^-$	CL^-	SO^2_4	Ca^{2+}	Mg^{2+}	Na^+	K^+
Metal/ Non-metal ions	NA	NA	N	N	N	M	M	M	M
Average	1359	140	-	125	737	130	95	175	4.1
Maximum	1502	247	9	147	804	170	109	213	4.8
Minimum	1257	98	ND	113	661	116	89	158	2.4

This unique parameter will help us better understand the current water quality of Syr-Darya in terms of an index number, which represents overall quality of water for any intended use. It defined as a rating that reflects the composite influence of different water quality parameters taken into consideration for the calculation of water Quality index (WQI). The indices are among the most effective ways to communicate the information on water quality trends to the public or to the policy makers and in water quality management. In formulation of water quality index, the relative importance of various parameters depends on intended use of water. Arithmetic index method [11] used to calculate WQI (Table 3):

Step 1: In the present study, the unit weight (Wn) values for each parameter calculated by using the following formula taken from [12].

$$W_n = \frac{k}{S_n},$$

where, $K = \dfrac{1}{\frac{1}{S_1}+\frac{1}{S_2}+\frac{1}{S_3}+...+\frac{1}{S_n}} = \dfrac{1}{\sum \frac{1}{S_n}}$;

S_n – standard permissible value for the nth parameters;

W_n – unit weight for nth parameter;

k – proportionality constant.

Step 2: Calculation of Sub index (Qn) value by using the formula:

$$Q_n = \frac{(V_n - V_o)}{(S_n - V_o)} \times 100,$$

Q_n – quality rating;

n – water quality parameter;

V_n – mean concentration of observed value;

V_s – standard value;

V_o – ideal value, in most cases $V_o = 0$ except in certain parameters like PH, dissolved oxygen, etc.

$$Q_{PH} = \frac{(V_{PH} - 7)}{(8.5 - 7)} \times 100;$$

Therefore,

$$Q_{PH} = \frac{(8.21 - 7)}{(8.5 - 7)} \times 100;$$

$$Q_{PH} = \frac{(1.21)}{(1.5)} \times 100 = 0.8.$$

Step 3: Calculation of WQI, by combining step 1 and step 2:

$$WQI = \frac{\sum W_n Q_n}{\sum W_n};$$

$$WQI = \frac{89.25}{1} = 89.25.$$

Table 3. Calculation of WQI

Parameters	Standard (Sn)	1/Sn	Σ 1/Sn	K = 1/(Σ1/Sn)	Wi = K/Sn	IDEAL Value (V0)	Mean Con Value (Vn)	Vn/Sn	Qn=Vn/Sn *100	WnQn
PH	8.5	0.118	0.259	3.861	0.454	7	8.21	0.8	80.000	36.342
EC	300	0.003	0.259	3.861	0.013	0	318.4	1.0613	106.133	1.366
TDS	500	0.002	0.259	3.861	0.008	0	1359	2.718	271.800	2.099
Ca2+	75	0.013	0.259	3.861	0.051	0	130	1.7333	173.333	8.924
Mg2+	<40	0.025	0.259	3.861	0.097	0	95	2.375	237.500	22.926
CL-	250	0.004	0.259	3.861	0.015	0	125	0.5	50.000	0.772
Na+	120	0.008	0.259	3.861	0.032	0	175	1.4583	145.833	4.693
K+	12	0.083	0.259	3.861	0.322	0	4.1	0.3417	34.167	10.994
SO(4) 2-	500	0.002	0.259	3.861	0.008	0	737	1.474	147.400	1.138
Sum		0.259			1.000002					89.254

3. Results and discussion

In 2011, a UNECE report conducted by Gapparov B.Kh. and Beglov I.F. provided a numerical analysis of the priority indicators of water quality in Syr-Darya for fisheries, agriculture, and drinking water. These indicators were evaluated based on the maximum acceptable concentration, as shown in Table 1.

Our study determined that the median value for pH in Syr-Darya was 8.21, the median value for electrical conductivity (EC) was 318.4 $\mu S\ cm^{-1}$, and the median value for total organic carbon (TOC) was 2.75 mg/l.

Table 1 and Table 2, which are included in our study, serve as the foundation for calculating the Water Quality Index (WQI) and provide a description of the current water quality status in Syr-Darya. To estimate the WQI, we took the average values from nine different sites, focusing on the concentrations of minerals in the river, as presented in Table 2.

Furthermore, we evaluated the suitability of the WQI values for human consumption according to Mishra and Patel's (2001) study [7]. The ratings for the WQI values are as follows:

Table 4. Classification of Surface Water quality according to Mishra and Patel

Category	Water Quality	WQI Yadav et al.	WOI Ramakrichnaiah et al.
I	Excellent	0-25	<50
II	Good	26-50	50-100
III	Poor	51-75	100-200
IV	Very Poor	76-100	200-300
V	Unsuitable	Above 100	>300

Our calculations and literature analysis revealed that the water quality of the Syr-Darya falls under Mishra & Patel's (2001) IV category, as indicated in Table 4, which is «Very Poor» and unfit for drinking purposes.

4. Conclusions

In conclusion, this research study aimed to assess the water quality in the downstream portion of the Syr-Darya River using the Water Quality Index (WQI) arithmetic method. The study focused on the effects of industrial and agricultural activities on water pollution, specifically metallic, and non-metallic chemical components, and pesticide residues. The findings from the literature review emphasized the high levels of pollution in the river due to agricultural and industrial activities. Both upstream and downstream countries contribute to the pollution, with upstream countries adding pesticides and downstream countries polluting the water through industrial activities.

The research utilized the Weighted Arithmetic Index Method to calculate the WQI, which provides an overall index number representing the water quality. The results showed that the water quality of the Syr-Darya falls under the «IV» Mishra and Patel rating, of the «Very Poor» category, rendering it unfit for drinking purposes, but suitable for agriculture and fisheries.

This research is significant as it provides a modern evaluation of water quality and highlights the potential impact of agricultural and industrial pollutants in the Syr-Darya. It also sheds light on the lack of research studies in this area, emphasizing the importance of further research and the need for stricter regulations to address water pollution in the region. By understanding, monitoring, and managing water pollution in the Syr-Darya River basin, steps should be taken to protect the ecosystem, ensure safe drinking water, and support sustainable agricultural practices.

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Су сапасының индексінің арифметикалық әдісі арқылы Сырдарияның төменгі ағыс бөлігіндегі су сапасының жай-күйін бағалау

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Аңдатпа. Бұл зерттеу жұмысының негізгі мақсаты өнеркәсіптік (химиялық құрамдас бөліктер) және ауылшаруашылық (пестицидтер қалдықтары) әрекеттерінің Сырдарияға әсерін бағалау болып табылады. Бұл зерттеудің келесі нақты мақсаттары бар: 1. Сырдария суының қазіргі жағдайына баға беріңіз; 2. Сырдарияның (Қазақстан) төменгі ағыс бөлігіндегі ауылшаруашылық және өнеркәсіп қызметін зерттеу. Бұл зерттеуде біз Сырдарияның төменгі ағыс бөлігіндегі су сапасының ағымдағы жағдайын Су сапасының индексі (WQI) арифметикалық әдісі арқылы бағалауды мақсат еттік. Зерттеу металл және металл емес химиялық құрамдастарды, PH, TDS, басқа минералдар және пестицидтердің қалдықтарын қоса алғанда, судың ластануына өнеркәсіптік және ауылшаруашылық қызметінің әсеріне ерекше назар аударады. Бұл зерттеудің маңыздылығы су сапасының классификациясы мен ластаушы заттардың (өнеркәсіптік және ауылшаруашылық қызметі) Сырдарияға ықтимал әсерінің қазіргі заманғы бағалауларының болмауында. Әдебиеттерге шолу өнеркәсіптер мен ауылшаруашылық қызметіне байланысты өзеннің ластануының жоғары деңгейін көрсетеді. Ағыстың жоғарғы жағындағы елдер де, төменгі ағыстағы елдер де ластануға үлес қосады, жоғарыдағы елдер пестицидтерді қосады, ал төменгі ағындағы елдер өнеркәсіптік әрекеттер арқылы суды ластайды. Зерттеу аймақтағы судың ластануы мен су сапасының көрсеткіштері бойынша бар зерттеулерден қайталама деректерді жинауды қамтиды. Әдістеме судың сапасын көрсететін жалпы индекс нөмірін беретін Салмаланған арифметикалық индекс әдісін пайдаланып WQI есептеуді қамтиды. Бұл зерттеу Сырдария өзені бассейніндегі судың ластануын түсіну және басқару үшін маңызды.

Негізгі сөздер: *су сапасын бағалау, WQI, су сапасының индексі, арифметикалық әдіс, металдық және металл емес химиялық қосылыстар, судың ластануы, пайдалы қазбалардың концентрациясы, су сапасы индексінің басым көрсеткіші.*

Оценка состояния качества воды в потоке Сырдарьи с использованием арифметического метода индекса качества воды

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Аннотация. Основной целью данного исследования является оценка воздействия промышленной (химические компоненты) и сельскохозяйственной (остатки пестицидов) деятельности на Сырдарью. Данное исследование преследует следующие конкретные цели: 1. Оценить текущее состояние качества воды Сырдарьи; 2. Изучение сельскохозяйственной и промышленной деятельности в нижнем течении Сырдарьи (Казахстан). В данном исследовании мы стремились оценить текущее состояние качества воды в нижнем течении Сырдарьи, используя арифметический метод индекса качества воды (ИКВ). В исследовании особое внимание уделяется влиянию промышленной и сельскохозяйственной деятельности на загрязнение воды, включая металлические и неметаллические химические компоненты, PH, TDS, другие минералы и остатки пестицидов. Важность этого исследования заключается в отсутствии современных оценок классификации качества воды и потенциального воздействия загрязняющих веществ (промышленная и сельскохозяйственная деятельность) на Сырдарью. В обзоре литературы подчеркивается высокий уровень загрязнения реки в результате промышленной и сельскохозяйственной деятельности. Страны верхнего и нижнего течения вносят свой вклад в загрязнение: страны верхнего течения добавляют пестициды, а страны нижнего течения загрязняют воду в результате промышленной деятельности. Исследование будет включать сбор вторичных данных из существующих исследований по загрязнению воды и показателям качества воды в регионе. Методика включает расчет WQI с использованием метода взвешенного арифметического индекса, который дает общее число индексов, отражающее качество воды. Это исследование важно для понимания и управления загрязнением воды в бассейне реки Сырдарья.

Ключевые слова: *оценка качества воды, WQI, индекс качества воды, арифметический метод, химические соединения, загрязнение воды, концентрация минералов, индекса качества воды.*

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