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Health Impact Assessment of the Surface Water Pollution in Nukus, Karakalpakstan

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Abstract This manuscript assessed the water quality of the Doslik Canal in the city of Nukus, Karakalpakstan using the water quality index for the period from 2016 to 2024. Three methods were used to calculate the water quality index: the weighted arithmetic water quality index, the National Sanitation Foundation water quality index, and the Canadian Council of Ministers of the Environment water quality index. The research looked at some parameters to develop the water quality index: for WAWQI pH, fluoride, copper, alkalinity, turbidity, nitrate-nitrogen (NO3-N), total hardness, biological oxygen demand (BOD) and dissolved oxygen (DO). For NSFWQI, pH, DO, BOD5, phosphate (PO43-), nitrate-nitrogen (NO3-N), dry matter and temperature, and for determining CCMWQI, the parameters pH, DO, BOD5, nitrate-nitrogen (NO3-N), fluoride, copper, alkalinity, total hardness, chloride and turbidity measured at three different points (S1-S2-S3) of the Doslik Canal. The water quality of the Doslik Canal was observed to vary from excellent to good in summer and winter, and from poor to unfit for human consumption during the rainy season. Recommendations are proposed for improving water quality and effective management of water systems resources in the period under review. The data obtained can be used to develop measures to protect the environment and ensure sustainable development of the region in the future.

Keywords Water quality assessment, Doslik Canal, Physico-chemical parameters, Water quality indicators, Diseases

1. Introduction

Surface water is any liquid water that is found on the surface of the earth, including ocean water and water contained in inland bodies of water such as rivers, streams, lakes, swamps and ponds. Liquid surface water makes up more than 97% of the Earth's hydrosphere, 96% of which is salt water from the oceans, and only 1.1% is fresh liquid water [1,2]. Of this 1.1% fresh water, 99% is groundwater, while only 1% is fresh surface water [1,3]. However, fresh surface water plays a key role in shaping the environment and supporting diverse life forms on the Earth [4]. Freshwater is fundamental to all living organisms, human health, food production and most industrial processes [4,5].

Surface water pollution is a significant environmental issue that has far-reaching consequences on human health and well-being. The indiscriminate dumping of industrial effluents and other waste materials into water bodies has led to the deterioration of water quality, with serious implications for public health. Understanding the sources, fate, and concentrations of contaminants in surface water is crucial for assessing the health risks associated with exposure to these pollutants. [6]. Examining the surface water environment with a focus on protecting public health can help emphasize the importance of pollution control efforts. Assessing the health benefits of controlling surface water pollution can help gauge the impact of policies and actions, offering valuable guidance for water management practices. Past research has laid the groundwork for understanding the connection between surface water pollution and health risks at both national [7,8] and localized levels [9,10].

However, due to rapid population growth and socio-economic development, the demand for limited fresh surface water is rapidly increasing. Due to emissions caused by human and industrial activities, the condition of water in rivers and canals is deteriorating, negatively affecting the lives of people and aquatic life.

Therefore, continuous monitoring and control of the quality of fresh surface waters is a priority for all countries of the world [11,12]. Water quality monitoring is a mandatory procedure, including analysis of physicochemical and microbiological parameters. There are several statistical approaches to the study of water parameters, including multivariate methods that identify factors that have a significant impact on water quality, as well as analysis of spatiotemporal variations, data reduction, data sampling and grouping [13,14,15,16,17].

Water quality index includes a variety of physical, chemical and biological parameters to evaluate water quality using various mathematical equations [18]. WQI was first

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proposed by Horton (1965) [19], Brown and colleagues (1970) [20], and since then many different methods for calculating WQI have been developed. Most often, calculating water quality indicators requires two steps. First, it is necessary to convert the selected water quality characteristics into sub index values. These values are then aggregated to produce an overall water quality index. A new method for calculating WQI was proposed by researchers [21,22]. The following water quality indices are used worldwide: National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), British Columbia Water Quality Index (BCWQI), Oregon Water Quality Index (OWQI), Weighted Arithmetic Water Quality Index (WAWQI) [23,24,25].

In this paper, we use the systematic data on main diseases and water quality of the city of Nukus. Research has been carried out to study the influence of various physicochemical and biological indicators on the water quality of the Doslik Canal, and the suitability of this water for human consumption is also discussed based on the water quality index indicators. Methods such as the Weighted Arithmetic Water Quality Index (WAWQI), the National Sanitation Foundation Water Quality Index (NSFWQI), and the Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) were used to calculate WQI [26,27]. At the same time, the results of the water quality index and disease data received from the Ministry of Health of the Republic of Karakalpakstan were analyzed.

2. Research Methodology

2.1. Research Area

Urban areas play a central role in driving Nukus's economic growth and efforts to manage water pollution. As a result, this study evaluates the health implications of surface water pollution on a city-specific scale. This research focused on the Doslik Canal, which is the source of drinking water in the city of Nukus. The Doslik Canal is a main canal in the Republic of Karakalpakstan. It takes water from the Amu Darya. The length of the canal is 25.2 kilometers, the maximum throughput is 500 m^3/s (according to other sources - 900 m^3/s). The average water flow in 1993 was 153 m^3/s, in 1994—128 m^3/s. The depth of the channel is 5 meters. It is located between 59°36'45' to 59°38'15' East longitude and 42°22'38' to 42°34'27' North latitude [28]. For 2022, water flow is 63.34 m3/s [29].

3. Materials and Methods of Analysis

In this research, a total of 311 water samples were collected from three different sampling points (S1–S3) between 2016 and 2023 using standard sampling methods (GOST 31861-2012) [30]. Selection was carried out monthly with an interval in the middle of the month.

Site-1: located next to the Tashkent hotel (42°27′2819″ latitude and 59°36′05.1″ longitude). There is no serious anthropogenic impact.

Site-2: (42°28′16.7″ latitude and 59°35′50.0″ longitude). This place is located next to the madrasah “MUHAMMAD IBN AHMAD AL-BERUNIY”.

Site-3; (42°30′44.5″ latitude and 59°35′21.5″ longitude). This place is located next to “Karakalpak Suw Tamiynati” LLC.

3.1. Laboratory Analysis

Laboratory tests were carried out in the laboratory of Sanitary Epidemiological Welfare and Public Health of the city of Nukus. Observations were carried out regularly to analyze parameters such as temperature, pH, dissolved oxygen and turbidity to assess the extent of contamination. Other parameters including total dissolved solids (TDS), total hardness, alkalinity, chloride, phosphate (PO43−), nitrate (NO3−) and biochemical oxygen demand were analyzed according to established standards and procedures. Fluoride, copper, phosphate, nitrate and turbidity were measured by UV spectrophotometry (UV 1200. China), and BOD_5 and DO were determined by iodometric titration. pH was measured using a 150 pH meter. All measuring instruments were calibrated using standard solutions from Uzhydromet.

3.2. Weighted Arithmetic Water Quality Index (WAWQI)

One of the most commonly used approaches to calculate WQI is the weighted arithmetic index method. This method allows water to be classified according to purity based on the most commonly analyzed water quality parameters. This approach is entirely based on the importance of each parameter. This study took into account 9 parameters and their compliance with drinking standards of SanRaN of the Republic of Uzbekistan No. 0200-06 [31], which are presented in Table 1. Relative weights are determined by values inversely proportional to the level of the standard for each parameter.

Table 1. WAWQI parameters and drinking water standards [all values are measured in mg/l, except pH and total hardness (mg.eq/l)

Parameters	Standards	Specific gravity
pH	8.5	0.0323
DO	4≤	0.0687
BOD	3	0.09169
Turbidity	20	0.01375
Fluorine	0.7-1	0.3929
Alkalinity	3	0.09169
Copper	1	0.27509
Nitrate	45	0.0061
Overall hardness	7-10	0.0275095
Total	**Σ** Wi = 1,000	

$$Wi = K\sum \frac{1}{S\text{standard}} \quad (1)$$

Step 1: The value of the proportionality constant K in the above equation can be determined from the following equation:

$$K = \frac{1}{\sum \frac{1}{S1} + \frac{1}{S2} + ... + \frac{1}{Sn}} \quad (2)$$

Step 2: Compute the quality rating scale (Qi) of the i-th parameter for all n water quality parameters assessed utilizing this equation:

$$Qi = \left(\frac{Qactual - Qideal}{S\text{standard} - Qideal} \right) \times 100 \quad (3)$$

Step 3: Ultimately, the overall quality score was calculated by linearly aggregating the quality rating with the unit weight using the following equation:

$$WAWQI = \frac{\sum_{i=1}^{i=n} QiWi}{\sum Wi} \quad (4)$$

In this study, WQI was considered for human consumption or use, where

- W i = specific gravity for each water quality parameter;
- K = proportionality constant;
- Q i = quality assessment scale for each parameter;
- Q fact = calculated concentration of the i-th parameter in the analyzed water;
- Q ideal = optimal value of this parameter in pure water, Q ideal = 0 (except pH = 7.0 and DO = 14.6 mg/l);
- S standard = recommended standard value of the i-th parameter;
- n = total count of water quality parameters.

Table 1 presents the classification of water quality status based on the water quality index [36,37,38].

The classification of water quality for drinking purposes is presented in Table 4, and the results in Table 5.

3.3. National Sanitation Foundation Water Quality Index (NSFWQI)

To calculate the Water Quality Index (WQI), the National Sanitation Foundation used nine different parameters: nitrate-nitrogen, pH, dissolved oxygen, chloride, phosphate, biological oxygen demand, turbidity and alkalinity, and the calculation is expressed by the following equation:

$$NSFWQI = \sum_{i=1}^{n} wiqi \quad (5)$$

where:

q_i represents the sub-index value based on the assigned curve for the i-th variable, which ranges from 0 to 100, w_i represents the weighting factor for the i-th parameter, which ranges from 0 to 1 and is described in equation (6),

$$\sum_{i=1}^{n} wi = 1 \quad (6)$$

n — the total number of variables considered. The NSFWQI rating scale is also divided into five quality grades and is considered very poor (0-25), poor (25-50), moderate (50-75), good (70-90) and excellent (90–100) [32,33,34].

Table 2. Surface water quality parameters and its weighting coefficient

Parameters	Standards	Weight coefficient
pH	8.5	0.075
DO	4≤	0.1603
BOD	3	0.2137
Turbidity (mg/l)	2,0	0.013
Phosphate (mg/l)	3,5	0.1832
Nitrate (mg-eq/l)	45	0.014
Temperature (0)	20	0.032
Dry residue (mg/l)	1000-1500	0,00042
Total	Σ Wi = 1,00	

3.4. Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI)

In 2001, the Canadian Council of Environment Ministers introduced the CCMEWQI water quality index, based on the British Columbia WQI concept [35]. The CCMEWQI does not record specific parameters, but they are selected depending on the purpose and data availability [36]. Thus, this index allows you to set various reference goals, which in turn determine the input parameters depending on their availability and local characteristics [37,38,39,40].

The CCMEWQI is determined by selecting specific sets of parameters that are determined by the relevance and availability of the data for potable drinking purposes. For water samples taken in 2016 and 2023, seven parameters were selected (pH, Cl-, HCO3-, TH, F-,NO3-, Cu) respectively. These parameters and their standards are described in Table 3.

Table 3. CCMEWQI parameters and its standards [all values are expressed in mg/l, except pH and total hardness TH (mg.eq/l)

Parameters	Standards
pH	6,5–8,5
DO (mg/l)	4≤
BOD (mg/l)	3
Turbidity (mg/l)	2,0
Fluoride (mg/l)	0,7
Copper (mg/l)	1,0
Nitrate (mg/l)	45
Alkalinity (mg/l)	3
Total hardness (mg-eq/l)	7-10
Chloride (mg/l)	250-350

CCMEWQI can be calculated using the following equation [41]:

$$CCMEWQI = 100 - \frac{\sqrt{F1 + F2 + F3}}{1,732} \quad (7)$$

where F_1 (Volume) = number of variables which goals are not achieved.

$$F1 = (\text{No of failed variables/Total of variables}) \times 100 \quad (8)$$

F_2 (Frequency) = number of times goals are not achieved.

$$F2 = (\text{No of failed tests/Total no of tests}) \times 100 \quad (9)$$

F_3 (Amplitude) = amount by which goals are not achieved.

$$F3 = \left(\frac{nse}{0{,}1nse} + 0{,}1 \right) \quad (10)$$

CCMEWQI is calculated in Table 5, which indicates that the water quality of the Doslik Canal is in the marginal category.

Table 4. Class ranges of water quality indicators

Water quality indicators	Class	Notes	Links
CCME WQI	95–100 80–94 60–79 45–59 0–44	Great Good Satisfactorily Extremely Bad	(SKME, 2001)
WA WQI	<25 25–50 50–75 75–100 >100	Great Good Bad Very bad Not suitable for consumption	(Brown et al., 1970)
NSFWQI	0–25 26–50 51–70 71–90 91–100	Very bad Bad Average Good Very good	(Brown et al., 1970)

4. Results and Discussion

4.1. Water Quality Index (WQI)

Table 5. Assessment of water quality in the study sections of the Doslik Canal using the Weighted Arithmetic Water Quality Index (WAWQI) method, the National Sanitation Foundation Water Quality Index (NSFWQI) method, and the Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) method)

Years	WAWQI	NSFWQI	CCMEWQI	Diseases
2016	62	77	57	32.38
2017	72	77	57	23.50
2018	58	75	55	26.78
2019	80	75	57	19.62
2020	97	45	50	93.86
2021	48	74	60	68.74
2022	60	72	59	75.09
2023	73	73	47	71.4

Taking into account drinking water quality standards of SanRaN No. 0200-06, samples were assessed, which showed that most indicators were within acceptable limits. WQI results for the eight analyzed physicochemical parameters of the Doslik Canal in sections S1–S3 are presented in Table 3.

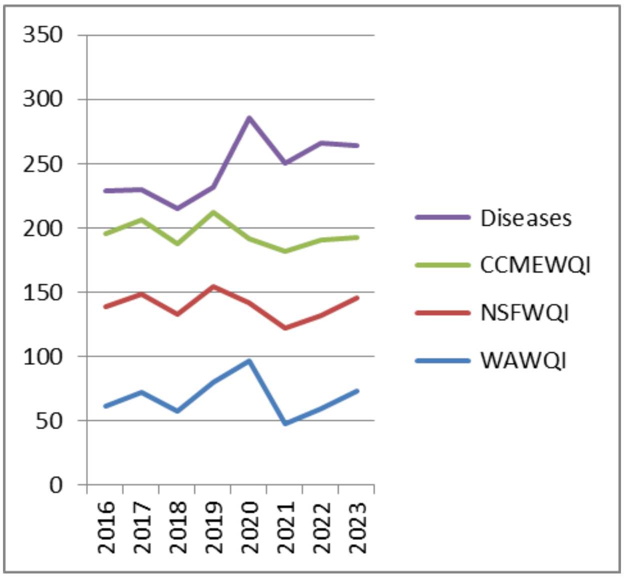

Figure 1. The comparison WQIs of the three methods and diseases

The water quality index values for 2016, 2017, 2018, 2022 and 2023 are in the poor range, 2019 and 2020 are in the very poor range and 2021 are in the good range using the Weighted Arithmetic Water Quality Index (WAWQI) method at the study sites. Application of the National Sanitation Foundation Water Quality Index (NSFWQI) method shows that the water quality index was in the good range from 2016 to 2019 and from 2021 to 2023, with it being rated as poor in 2020. Using the Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) method, water quality is assessed as satisfactory only in 2021, in other years it is within the limit level. The diagram demonstrates a correlation between fluctuations in the water quality index and the incidence of diseases.

Table 5 presents a comparative analysis of three methods for assessing water pollution in the city of Nukus, as well as data on the average overall morbidity rate. The correlation analysis showed the following results:

* The WAWQI method shows a weak positive correlation (0.21) with the number of cases.
* The NSFWQI method has a moderate negative correlation (-0.69) with case counts.
* The CCMEWQI method shows a weak negative correlation (-0.38) with the number of cases.

To determine the extent to which surface water affects the occurrence of diseases, it is necessary to conduct a comprehensive analysis of both water quality and data on each specific disease.

The relationships between multiple cancers and surface water pollutants are complex. The complex and joint health effects of surface water pollution should be considered and discussed. This study further assesses the pollutant-cancer-specific health impacts, trying to reveal the interactive and confounding factors in the comprehensive health impact assessment for surface water pollution [42].

5. Conclusions

During the research of surface water quality, analyzes of various physicochemical and biological parameters were carried out, and various methods for calculating water quality indices were applied. The results obtained allow us to draw the following conclusions:

Assessing surface water quality is an important aspect of environmental sustainability and human health. Methods for calculating water quality indices, such as the Weighted Arithmetic Index (WAWQI), the National Sanitation Foundation Water Quality Index (NSFWQI), and the Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), allow for a comprehensive assessment of water quality. The study results showed that surface water quality may vary depending on the year and assessment methodology, highlighting the need for ongoing monitoring and control of water resources. Further research in the area of assessing the quality of surface waters can contribute to the development of effective measures to protect the environment and ensure the sustainable use of water resources. Thus, the study and assessment of surface water quality plays an important role in maintaining ecological balance and ensuring human well-being, which requires a systematic approach and constant attention to this problem. Improving the quality of surface water has the potential to reduce disease and improve overall community health.

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DISCLOSURE

This section is ONLY for those who requested disclosure. The name of the experts that reviewed your paper, in case they accepted selling disclosure to you, will appear here. Each reviewer is allowed to make their own price for that, since that is a public endorsement of your findings and may be used for varied purposes.

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