

Correlation Analysis of Drinking Water and Atmospheric Air Pollution with Public Health Indicators in the Republic of Karakalpakstan

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Abstract

This article analyses the dynamics of chemical pollution in open water bodies, well water, and tap water systems across various regions of the Republic of Karakalpakstan (Western, Northern, Central, and Southern zones) and the impact of water pollution on public morbidity. The study compares statistical data from 2011–2020, focusing on the increasing concentration of nitrates, sulfates, and chlorides, as well as the level of public access to safe drinking water. Additionally, the paper examines atmospheric air pollution caused by dust and transport emissions, highlighting regional variations in environmental degradation. The findings emphasize the growing impact of chemical pollution on the social sphere and public health, identifying it as a critical environmental challenge for the region. The findings reveal a strong correlation between drinking water quality and public health in the Turtkul district, with moderately strong correlations identified in most other districts and the city of Nukus. Furthermore, a high correlation between air pollution and morbidity was recorded in the Northern medical-geographic zone, particularly in the Takhtakupir district. The study highlights the regional medical-geographic distribution of environmental health risks across the republic.

Keywords: *Chemical Pollution, Environmental Pollution, Incidence Rate, Medical-Geographical Region, Public Health*

Introduction

The Republic of Karakalpakstan is surrounded by the Kyzylkum, Karakum, and Ustyurt plateaus in the lower reaches of the Amudarya, and its territorial location possesses unique geographical and socio-economic characteristics. The rapid development of the oil and gas industry, the commissioning of plants for the production of soda ash, liquefied gas, synthetic film, and others, as well as the construction of the "Silk Road" highway, have attracted new funds to the region's international trade and economy, and in the future, they will signify the rapid development of the region. Therefore, studying the landscape and medical-geographical features of the republic is becoming increasingly important.

It is known that in previous centuries, humanity has led to an improvement in the quality of life due to scientific and technological progress, medical achievements, and significant changes in living conditions. Significant progress has been made in medicine in the field of combating infectious diseases, but somatic diseases associated with changes and environmental pollution have taken the lead. According to official statistical data from the Karakalpak branch of the Institute of Health and Medical Statistics of the Ministry of Health of the Republic of Uzbekistan (currently the Medical Statistics Department), infectious diseases account for 2.94% of the total morbidity, injuries account for 3.64%, and non-infectious diseases account for more than 70%.

Risk factors for the occurrence of environmental diseases are not the same in different territories, and preventive measures developed for a specific territory are not effective for other territories (Schwarzenbach et al., 2016; Cohen et al., 2017). Environmental pollution affecting public health in the Republic of Karakalpakstan is expressed in the deterioration of drinking water quality, its pollution, soil and food contamination, disruption of the biogeochemical situation, and air pollution. New foci of infectious diseases arise through mineralisation, the formation of an unfavourable climate, and the disruption of landscape formation (Erkudov et al., 2023).

Within the complex of anthropogenic factors affecting public health, the "water factor" occupies a key place. In the Republic of Karakalpakstan, Khorezm, and Bukhara regions, as well as in the Dashoguz region of Turkmenistan, the Amudarya is the only source of drinking and domestic water supply. The shallowing of this river is causing the reduction and disappearance of surface and groundwater in the region. More than a third of the wells contain water with a mineralisation of more than 3 mg/l, which is considered unfit for drinking by humans and animals (Tleumuratova, 2024).

In the article, we studied the Republic of Karakalpakstan by dividing it into four medical-geographical zones: Western, Northern, Southern, and Central. The western zone includes the Muynak, Kungrad, Qanlikul, and Shumanay districts. The Northern zone includes the Takhtakupir, Qarauzak, Chimbay, and Kegeyli districts; the Central zone includes the city of Nukus and its district, as well as the Khodjeyli and Takhiatash districts; and the Southern zone includes the Amudarya, Beruni, Turtkul, and Ellikkala districts. The aim of the study is to investigate the causes of morbidity among the population of Karakalpakstan and their correlation with water and air pollution.

Review of Related Literature

Research on environmental health and ecological change in the Aral Sea region highlights the intersection of global climate processes, local ecological crises, and human well-being. Cohen et al. (2017) provided a global perspective by quantifying the burden of disease attributable to ambient air pollution, establishing a framework for understanding health risks linked to environmental degradation. Schwarzenbach et al. (2016) further emphasized the challenge of micropollutants in aquatic systems, underscoring the complexity of water contamination and its long-term ecological consequences.

Within the Aral Sea basin, recent studies have focused on localized impacts. Erkudov et al. (2023) assessed youth fitness under prolonged exposure to toxic conditions caused by pesticides, revealing significant health vulnerabilities. Turdimambetov et al. (2021) examined the influence of adverse ecological factors on malignant neoplasms, linking environmental stressors to rising health risks. Reports from the Ministries of Health of

Uzbekistan and Karakalpakstan, as well as the Committee for Sanitary and Epidemiological Well-Being, provide further evidence of deteriorating public health conditions in the region.

Parallel investigations have addressed hydrological and climatic dimensions. Fuladipanah et al. (2025) analysed long-term groundwater trends in Karakalpakstan using statistical methods, highlighting water scarcity as a critical issue. Tleumuratova et al. (2024) studied the multiyear dynamics of Aral Sea desiccation and its impact on the Southern Priaralie climate, while Imanmurzaev et al. (2022) documented climatic conditions in the southern basin. Together, these studies demonstrate that ecological degradation, water resource depletion, and climate variability are closely tied to public health and socio-economic stability.

Overall, the literature reveals dual focus global environmental challenges such as pollution and climate change, and region-specific crises in the Aral Sea basin. This convergence underscores the urgent need for integrated approaches to environmental restoration, public health protection, and sustainable resource management.

Objectives

This study aims to investigate the medical-geographical features of the Republic of Karakalpakstan, focusing on the relationship between environmental pollution and public health. The region's unique territorial location, surrounded by the Kyzylkum, Karakum, and Ustyurt plateaus, combined with rapid industrial development and anthropogenic pressures, has created complex ecological challenges. By examining morbidity patterns and their correlation with water and air quality, the research seeks to clarify how environmental factors shape health outcomes across different districts.

Another objective is to analyse the role of the water factor as a critical determinant of health in Karakalpakstan and neighbouring regions. With the Amudarya River serving as the sole source of drinking and domestic water, its shallowing and increasing mineralization have led to significant risks for both humans and animals. The study intends to assess how deteriorating water quality, alongside soil and food contamination, contributes to the prevalence of non-infectious diseases, which account for more than 70% of total morbidity.

The research also aims to provide a zonal analysis by dividing Karakalpakstan into Western, Northern, Central, and Southern medical-geographical zones. This approach will help identify localized risk factors and variations in disease occurrence, offering insights into the effectiveness of targeted preventive measures. Ultimately, the study seeks to establish a comprehensive framework for environmental health management, ensuring that ecological restoration and public health strategies are aligned with the region's socio-economic development.

Methodology

The data for the study were obtained from the reports of the Ministries of Health of the Republic of Uzbekistan and the Republic of Karakalpakstan, as well as the results of investigations conducted by the laboratory complex of the Department of the Committee for Sanitary and Epidemiological Well-Being and Public Health of the Republic of Karakalpakstan between 2011 and 2021. The results of these laboratory tests reflect the percentage of samples in which the chemical contamination of open water bodies, expressed as a percentage, exceeds the permissible norms of "Sanitary Rules and Norms" No. 0318-15 "Hygienic and Anti-Epidemic Requirements for the Protection of Water

Bodies in the Territory of the Republic of Uzbekistan". Intensive indicators, or the modern name "incidence," are generally calculated per 100 000 population. Indicators of individual age-sex and social groups of the population were calculated per 1000 people in the corresponding group. To achieve the completeness of the dynamics of population movement, we additionally used data from the statistical department on internal and external population migration. When studying disease dynamics, primary morbidity rates were compared, i.e., the number of newly diagnosed patients per 100 000 population was calculated for each studied year (Turdimambetov et al., 2021). The primary morbidity indicators of the population in the Republic of Karakalpakstan and districts, conventionally designated districts, zones, and years for 2011–2021 were analysed.

Findings and Discussion

It is known that in the dynamics of the analysed years, the level of chemical (nitrate, sulfate, and chloride) pollution of open water bodies in the Republic of Karakalpakstan and its Northern, Central, and Southern zones is increasing, while no significant changes have occurred in the Western zone. Taking into account the fact that the pollution of open water bodies during the period under study has very diverse changes, and the trends are not clear, the average indicators for the two five-year periods of 2011-2015 and 2016-2020 were calculated and a certain clarity was achieved (Table 1).

The highest rates of chemical pollution of open water bodies are observed in the Qanlikul district of the Western zone (2011-2015 – 99.3%; In 2016-2020 – 72.2%), Takhtakupir (100 and 100 respectively) of the Northern zone, Beruni (75.7% and 67.6%) and Turtkul (92.3% and 69.4%) of the Southern zone, and the lowest indicator was found in the Chimbay district of the Northern zone.

Table 1. Dynamics of excessive chemical pollution of open water bodies by medical-geographical zones of the Republic of Karakalpakstan (in %).

Zones	2011-2015	2016-2020	Increase/decrease
Western zone	45,5	45,4	-0,2%
Northern zone	42,2	51,3	+17,7 %
Central zone	38,6	48,6	+21,6%
Southern zone	69,1	72,4	+5 %
Karakalpakstan	43,3	49,5	+14,3 %

Source: The table was compiled by the author based on data from the Department of the Committee for Sanitary and Epidemiological Well-Being and Public Health of the Republic of Karakalpakstan

Due to the fact that the water supply and quality of open water bodies are not constant throughout the year, the population that uses open water also uses well water in certain months of the year. It was established that in the dynamics of the analysed years, the level of chemical (nitrate, sulphate, and chloride) contamination of well waters in the Western, Northern, and Southern zones is increasing, while in the Central zone, it has decreased by 19% (Table 2).

Table 2. Dynamics of excessive chemical pollution of well waters by medical-geographical zones,

Zones	2011-2015	2016-2020	Increase/decrease
Western zone	57,6	64,5	+12%

Northern zone	51,0	62,7	+22,9%
Central zone	92,1	74,7	-19%
Southern zone	63,0	70,1	+11,1%
Karakalpakstan	54,3	59,8	9,2%

Source: The table was compiled by the author based on data from the Department of the Committee for Sanitary and Epidemiological Well-Being and Public Health of the Republic of Karakalpakstan

Over these two five-year periods, the proportion of well water samples with identified chemical contamination increased by 45.9% in the Qanlikul district of the Western zone, by 41.3% in the Qarauzak district of the Northern zone, by 33.1% in the Kegeyli district, and by 26% in the Khodjeyli district of the Central zone.

Furthermore, if the chemical contamination of well water continues to grow in Karakalpakstan, especially in settlements with low water supply coverage, the use of well water as drinking water may become a serious problem. Forecasts for the annual decrease in the water flow rate of the Amudarya indicate that the problem may worsen further. Thus, the highest levels of chemical pollution of open water bodies over the two analysed five-year periods were observed in the Qanlikul district of the Western Zone (2011–2015 – 99.3%; in 2016-2020 - 72.2%), Takhtakupir (100 and 100 respectively) of the Northern zone, Beruni (75.7% and 67.6%) and Turtkul (92.3% and 69.4%) districts of the Southern zone.

As of January 1, 2024, the provision of the population of Karakalpakstan with tap water amounted to 72.2%. The lowest indicators of the rural population's water supply were 16 percent in Kungrad, 37 percent in Chimbay, 40 percent in Beruni and Amudarya, 41 percent in Qarauzak, 44 percent in Turtkul, and 45 percent in Kegeyli (Fuladipanah, 2025). Based on the results of laboratory tests by the Department of Sanitary and Epidemiological Well-being and Public Health, the percentage of chemical contamination of tap water was determined in accordance with the "Drinking Water. Hygienic requirements and quality control", which reflects the proportion of samples exceeding permissible standards. It was established that in the dynamics of the two analysed five-year periods, the level of chemical (nitrate, sulfate, and chloride) pollution of tap water in the Republic of Karakalpakstan and its Western and Northern zones decreased by 12.8%, while in the Central and Southern zones, it increased by 3-4% (Table 3).

Table 3. Dynamics of excessive chemical pollution of tap water by zones, (in %)

Zones	2011-2015	2016-2020	Increase/decrease
Western zone	34,5	22,5	-53,3%
Northern zone	18,3	16,4	-11,5%
Central zone	22,2	23,1	22,2
		+4%	
Southern zone	30,3	31,3	+3,3%
Karakalpakstan	26,5	23,5	-12,8%

Source: The table was compiled by the author based on data from the Department of the Committee for Sanitary and Epidemiological Well-Being and Public Health of the Republic of Karakalpakstan

It is known that the research data were obtained from the annual reports of the Ministry of Health of the Republic of Karakalpakstan and the results of inspections of the laboratory complex of the Committee for Sanitary and Epidemiological Well-being and Public Health of the Republic of Karakalpakstan for 2009-2021. Until recently, enterprises that chemically pollute the atmospheric air were not developed in the Republic of Karakalpakstan. The Kungrad Soda Plant, which has been operating for more than 15 years, also practically does not emit chemicals that pollute the environment and is located 100-150 km away from settlements that may be exposed to wind currents.

To determine the statistical significance, two five-year periods were compared, consisting of the 2011–2015 and 2016–2020 years from the period under study (Table 4).

Table 4. Dynamics of excessive chemical air pollution by zones (in %)

Zones	2011-2015	2016-2020	Increase/decrease
Western zone	30,9	26,1%	
Northern zone	14,3	19,8	+38%
Central zone	16,9	-18%	
Southern zone	19,3	20,4	+5,7%
Karakalpakstan	14,6	20,2	+38,4%

Source: The table was compiled by the author based on data from the Department of the Committee for Sanitary and Epidemiological Well-Being and Public Health of the Republic of Karakalpakstan

Sanitary and Epidemiological Well-Being and Public Health of the Republic of Karakalpakstan Chemical air pollution increased in the Republic of Karakalpakstan (38.4 percent), the Northern (38 percent), Southern (5.7 percent) zones, while it decreased in the remaining Western (26.1 percent), and Central (18 percent) zones. Thus, the chemical pollutants of the atmospheric air in the Republic of Karakalpakstan are dust and transport fumes, particularly those emitted by aviation, railway, and road transport, as well as agricultural machinery, which primarily contain tetraethyl lead and CO₂. Analysis of the main environmental and hygienic factors affecting the morbidity level of the population of the Republic of Karakalpakstan in 2011-2021 showed that moderate direct correlations were identified between the primary morbidity level of the entire population and the proportion of water samples taken from open water bodies that do not meet the norms of state standards established in the republic for chemical indicators in the Qanlikul ($r_{xy}=0.40$; $mr=3.32$), Chimbay ($r_{xy}=0.52$; $mr=8.45$), and Kegeyli ($r_{xy}=0.66$; $mr=2.4$) districts of the Western zone, the city of Nukus ($r_{xy}=0.47$; $mr=6.21$) of the Central zone, and a strong correlation was identified in the Turtkul ($r_{xy}=0.71$; $mr=9.89$) district of the Southern zone. Consequently, if the chemical pollution of open water bodies in the specified districts is high, the level of primary diseases will also increase.

A moderate correlation between the dynamics of primary morbidity and chemical pollution of well water was identified in the Western zone ($r_{xy}=0.39$; $mr=1.92$), Kegeyli ($r_{xy}=0.55$; $mr=8.79$), Khodjeyli ($r_{xy}=0.56$; $mr=2.27$) and Turtkul ($r_{xy}=0.63$; $mr=2.95$) districts. It was found that if the chemical pollution of well water in these areas increases, primary diseases will increase. A moderate correlation between the primary morbidity rate and chemical water pollution was identified in the Qanlikul ($r_{xy}=0.43$; $mr=3.67$), Kegeyli ($r_{xy}=0.44$; $mr=1.29$), Nukus ($r_{xy}=0.52$; $mr=3.05$), Khodjeyli ($r_{xy}=0.48$; $mr=6.22$), and Beruni

($r_{xy}=0.41$; $mr=1.46$) districts. If the tap water in these districts does not meet the requirements of state standards, it leads to an increase in primary morbidity. A moderate correlation between the primary morbidity level of the entire population in 2009-2021 and chemical air pollution was identified in the Republic of Karakalpakstan ($r_{xy}=0.66$; $mr=7.95$), Qanlikul ($r_{xy}=0.39$; $mr=5.77$), and Beruni ($r_{xy}=0.59$; $mr=3.66$) districts, the Northern Zone ($r_{xy}=0.46$; $mr=3.99$), and a strong correlation was identified in the Takhtakupir district ($r_{xy}=0.86$; $mr=2.63$). Chemical pollution of atmospheric air with tetraethyllead, CO₂, and dust leads to an increase in primary diseases in the specified regions.

Conclusion

In conclusion, a strong correlation was found in the Turtkul district of the Southern zone between the primary morbidity rate of the population in 2011-2021 and the proportion of water samples taken from various sources of drinking water that do not meet the standards of state standards established in the republic for chemical indicators, while a moderately strong correlation was found in most districts of the Northern, Western, and Central zones and the city of Nukus. In this regard, the Qanlikul, Kegeyli, Khodjeyli, Nukus, and Beruni districts are particularly noteworthy. A strong correlation between the primary morbidity of the population and the level of atmospheric air pollution is noted in the Northern medical-geographical zone, especially in the Takhtakupir district. At the national level, a moderate correlation was found between the level of pollution of drinking water and atmospheric air and primary morbidity.

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