



Impact of Selected Environmental and Climatic Factors in the Pre-Aral Region on the Progression of Chronic Kidney Disease

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Abstract

This study presents the results of a correlation analysis evaluating the relationship between selected natural and climatic factors characteristic of the Aral Sea region and specific laboratory and instrumental parameters in patients with chronic kidney disease (CKD) residing in this area. In addition to conventional (modifiable and non-modifiable) risk factors for CKD, the significance of region-specific “non-traditional” environmental risk factors was assessed, including proximity to the Aral Sea, quality of drinking water, and degree of solar insolation.

Keywords: Chronic Kidney Disease; Aral Sea Region; Traditional Risk Factors; Non-Traditional Environmental Risk Factors

Background

Recent decades have been characterized by progressive climate change across multiple regions of the world, accompanied by an increasing negative impact of environmental factors on population health. According to the World Health Organization, approximately 24% of global morbidity and 23% of mortality are attributable to adverse environmental exposures, the majority of which are potentially preventable.

The Aral Sea region represents one of the most environmentally compromised areas in Central Asia. The desiccation of the Aral Sea has resulted in a complex ecological crisis affecting nearly all aspects of human life, including public health. The principal environmental stressors in this region include an extremely continental arid climate, excessive solar radiation, frequent dust storms associated with high wind activity, limited access to safe

drinking water with elevated mineralization, contamination of soil and groundwater with pesticides and mineral fertilizers, and progressive desertification.

These unfavorable environmental conditions have contributed to a high prevalence of chronic diseases among the local population, particularly affecting organ systems responsible for barrier and homeostatic functions, including the respiratory, gastrointestinal, urinary, and immune systems.

In response to these challenges, a comprehensive governmental strategy aimed at transitioning to a “green economy” has been implemented, focusing on the reduction of pollutant emissions from the energy, industrial, and construction sectors. Within this framework, healthcare research plays a critical role in elucidating the impact of environmental exposures on the incidence and progression of internal organ diseases.

With respect to renal pathology in the Aral Sea region, previous studies [1] have reported a 4.2-fold increase in the incidence of urolithiasis over a 10-year period, largely attributed to high mineralization and chemical contamination of drinking water. Chronic pyelonephritis, frequently associated with urolithiasis, may subsequently lead to chronic kidney impairment and renal failure.

Objective

The objective of the present study was to perform a correlation analysis between selected laboratory and instrumental indicators and non-traditional environmental risk factors for CKD progression, and to evaluate the strength and significance of these associations in patients with CKD residing in the Aral Sea region. The ultimate aim was to develop evidence-based strategies for risk factor modification and prevention of CKD progression in this population.

Materials and Methods

A prospective observational study was conducted over a 12-month follow-up period in primary healthcare settings. The study included 115 patients with CKD aged 25–65 years (mean age 48.8 ± 3.4 years) permanently residing in the Aral Sea region. CKD was diagnosed according to internationally accepted clinical criteria.

Participants were identified using a structured questionnaire incorporated into a computerized screening program designed for early detection and prevention of CKD progression (Sobirov M.A., Daminova K.M.; Certificate DGU No. 12090, 12.08.2021) [2]. In accordance with the study objectives, an additional section assessing region-specific non-traditional risk factors was integrated into the questionnaire.

The following environmental exposures were classified as non-traditional CKD risk factors:

- Poor quality of drinking water (regular consumption of well and artesian water with elevated mineralization and chemical impurities); High cumulative solar insolation; Proximity of residence to the Aral Sea and duration of residence in the region.

- The Aral Sea region experiences approximately 300 sunny days per year (82.2%), with a mean monthly solar radiation dose of 180–200 kWh/m². Continuous outdoor exposure exceeding six hours per day surpasses recommended safe exposure thresholds and may result in suppression of local and systemic immune responses. Chronic ultraviolet overexposure has been implicated in the pathogenesis of infectious, autoimmune, and malignant diseases, including renal pathology.
- Proximity to the Aral Sea and prolonged residence in the region may potentiate the cumulative impact of multiple environmental stressors, thereby influencing CKD progression.
- To determine the clinical relevance of these non-traditional risk factors, correlation analysis was performed between environmental exposures and selected laboratory and instrumental parameters considered prognostically significant for CKD progression (see Table 1).

A correlation analysis was performed to evaluate the associations between selected demographic and environmental variables (age ≥ 48 years, sex, duration of daily insolation, distance of residence from the Aral Sea, quality and source of drinking water, and duration of residence in the Aral Sea region) and key laboratory and instrumental indicators reflecting renal functional status (24-hour proteinuria, serum creatinine, serum urea, estimated glomerular filtration rate [eGFR], hemoglobin level, renal parenchymal thickness, and microalbuminuria [MAU]).

Hemoglobin levels demonstrated correlations of varying strength with non-traditional risk factors. The strongest positive association was observed with regular consumption of well water ($r = 0.61$). Moderate correlations were identified between hemoglobin level and residence in the region for >10 years ($r = 0.54$), female sex ($r = 0.52$), use of tap water ($r = 0.52$), residence at a distance of 100 km from the Aral Sea ($r = 0.48$), age ≥ 48 years ($r = 0.34$), residence at 100–200 km from the Aral Sea ($r = 0.35$), and daily insolation ≥ 6 hours ($r = 0.31$). Weak correlations were observed with age < 48 years ($r = 0.22$), residence ≥ 300 km from the Aral Sea ($r = 0.24$), daily insolation < 6 hours ($r = 0.28$), and use of filtered water ($r = 0.23$).

Parameters	Age		Sex		Insolation		Distance of Residence from the Aral Sea (km)			Source of Drinking Water			Duration of residence in the Aral Sea region	
	≥48	<48	m	f	Exposure for ≥6 hours	Exposure for <6 hours	100 km	100–200 km	≥300 km	Well water	Municipal water supply	Filtered water	5–10 years	>10 years
1.Hemoglobin (g/L)	0,34	0,22	0,33	0,52	0,31	0,28	0,48	0,35	0,24	0,61	0,52	0,23	0,44	0,54
2. Urea (mmol/L)	0,54	0,23	0,51	0,22	0,56	0,28	0,55	0,31	0,21	0,59	0,36	0,21	0,48	0,61
3.Creatinine (μmol/L)	0,56	0,22	0,53	0,2	0,53	0,24	0,57	0,31	0,25	0,62	0,26	0,14	0,41	0,57
4.eGFR (mL/min/1.73 m ²)	-0,71	-0,31	-0,48	-0,21	-0,58	-0,32	-0,72	-0,58	-0,22	-0,64	-0,49	-0,19	-0,39	-0,62
5.24-hour Proteinuria (g/24 h)	0,69	0,31	0,45	0,25	0,51	0,35	0,64	0,38	0,22	0,71	0,53	0,12	0,31	0,56
6.MAU (mg/L)	0,67	0,29	0,43	0,23	0,49	0,33	0,61	0,34	0,2	0,68	0,51	0,11	0,28	0,56
7.RPT (mm)	0,52	0,21	0,5	0,24	0,48	0,24	0,56	0,32	0,22	0,46	0,27	0,18	0,35	0,56

Table 1: Correlation coefficients between selected clinical and instrumental parameters and “non-traditional” risk factors for the development and progression of chronic kidney disease in residents of the Aral Sea region.

Correlation coefficients were interpreted according to the following scale: $r < 0.30$ indicated a weak correlation, $0.30–0.69$ a moderate correlation, and $r \geq 0.70$ a strong correlation.

Serum urea demonstrated strong positive correlations with residence in the region for >10 years ($r = 0.61$), regular well water consumption ($r = 0.59$), and daily insolation ≥ 6 hours ($r = 0.56$). Moderate correlations were observed with residence 100 km from the Aral Sea ($r = 0.55$), age ≥ 48 years ($r = 0.54$), male sex ($r = 0.51$), residence duration of 5–10 years ($r = 0.48$), and regular use of tap water ($r = 0.36$). Weak correlations were found with residence 100–200 km from the Aral Sea ($r = 0.31$), insolation <6 hours per day ($r = 0.28$), age <48 years ($r = 0.23$), residence ≥ 300 km from the Aral Sea ($r = 0.21$), use of filtered water ($r = 0.21$), and female sex ($r = 0.22$).

Serum creatinine exhibited the strongest positive correlations with well water consumption ($r = 0.62$), residence 100 km from the Aral Sea ($r = 0.57$), residence duration >10 years ($r = 0.57$), age ≥ 48 years ($r = 0.56$), male sex ($r = 0.53$), and insolation ≥ 6 hours daily ($r = 0.53$). Moderate

correlations were identified with residence 100–200 km from the Aral Sea ($r = 0.31$) and duration of residence 5–10 years ($r = 0.41$). Weak associations were observed with age <48 years ($r = 0.22$), residence ≥ 300 km from the Aral Sea ($r = 0.25$), insolation <6 hours ($r = 0.24$), regular tap water use ($r = 0.26$), filtered water use ($r = 0.14$), and female sex ($r = 0.20$).

These findings strongly suggest that high water mineralization and prolonged residence in the Aral Sea region adversely affect serum creatinine levels and, consequently, renal functional status and CKD progression.

eGFR demonstrated pronounced negative correlations with several environmental parameters. The strongest inverse associations were observed with residence 100 km from the Aral Sea ($r = -0.72$), age ≥ 48 years ($r = -0.71$), and residence duration >10 years ($r = -0.62$). Moderate negative correlations were found with well water use ($r = -0.64$), insolation

≥6 hours ($r = -0.58$), residence 100–200 km from the Aral Sea ($r = -0.58$), tap water use ($r = -0.49$), male sex ($r = -0.48$), and residence duration 5–10 years ($r = -0.39$). Weak inverse correlations were observed among individuals <48 years ($r = -0.31$), insolation <6 hours ($r = -0.32$), residence ≥300 km from the Aral Sea ($r = -0.22$), filtered water use ($r = -0.19$), and female sex ($r = -0.21$).

These data confirm a significant decline in eGFR in CKD patients exposed to unfavorable environmental conditions and prolonged residence in the Aral Sea region.

Daily proteinuria demonstrated the strongest positive correlations with regular well water consumption ($r = 0.71$), age ≥48 years ($r = 0.69$), and residence 100 km from the Aral Sea ($r = 0.64$). Moderate correlations were observed with insolation ≥6 hours ($r = 0.51$), regular tap water use ($r = 0.53$), male sex ($r = 0.45$), residence 100–200 km from the Aral Sea ($r = 0.38$), and residence duration >10 years ($r = 0.56$). Weak correlations were found with insolation <6 hours ($r = 0.35$), age <48 years ($r = 0.31$), residence duration 5–10 years ($r = 0.31$), residence ≥300 km from the Aral Sea ($r = 0.22$), and filtered water use ($r = 0.12$).

MAU levels showed the strongest positive correlations with age ≥48 years ($r = 0.67$) and residence 100 km from the Aral Sea ($r = 0.61$). Moderate correlations were observed with well water use ($r = 0.54$), residence duration >10 years ($r = 0.56$), insolation ≥6 hours ($r = 0.49$), male sex ($r = 0.43$), filtered water use ($r = 0.38$), and insolation <6 hours ($r = 0.33$). Weak correlations were found with regular tap water consumption ($r = 0.11$), residence ≥300 km from the Aral Sea ($r = 0.20$), age <48 years ($r = 0.29$), and residence duration 5–10 years ($r = 0.28$).

These results indicate that advanced age, close proximity to the Aral Sea, and regular consumption of highly mineralized water significantly increase the risk of elevated MAU.

Correlation analysis demonstrated that renal parenchymal thickness exhibited the strongest positive associations with residence 100 km from the Aral Sea ($r = 0.56$) and residence duration >10 years ($r = 0.56$), reflecting the cumulative effect of prolonged adverse environmental exposure. Moderate positive correlations were observed with insolation ≥6 hours daily ($r = 0.48$), male sex ($r = 0.50$), age ≥48 years ($r = 0.52$), regular well water consumption ($r = 0.46$), and residence duration 5–10 years ($r = 0.35$). Weak associations were noted with age <48 years ($r =$

0.21), female sex ($r = 0.24$), residence ≥300 km from the Aral Sea ($r = 0.22$), tap water use ($r = 0.27$), and filtered water use ($r = 0.18$), suggesting minimal influence of these factors on CKD progression [3–10].

Conclusion

The findings convincingly demonstrate the adverse impact of regional climatic and environmental factors—including high water mineralization, proximity to the Aral Sea, prolonged residence in the region, and extended daily insolation exposure—as well as certain demographic characteristics (age ≥48 years and male sex), on renal functional parameters in patients with CKD residing in the Aral Sea region. Identification of the most significant non-traditional risk factors for CKD progression provides a scientific basis for the development of comprehensive regional preventive strategies aimed at mitigating environmental exposure, slowing disease progression, and reducing the incidence of end-stage kidney disease requiring renal replacement therapy, thereby decreasing the associated socioeconomic burden.

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