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DRINKING WATER QUALITY AND ITS IMPACT ON PUBLIC HEALTH IN THE KHOREZM REGION, UZBEKISTAN: A NARRATIVE REVIEW OF EVIDENCE FROM 2008 TO 2025

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Abstract

Safe drinking water is a fundamental human right, yet millions of people in Central Asia remain exposed to poor-quality water sources. The Khorezm region of Uzbekistan faces compounding environmental challenges, including the consequences of the Aral Sea ecological disaster, agricultural runoff containing persistent organic pollutants, climate-driven salinization, and deteriorating water infrastructure. This narrative review synthesizes evidence from peer-reviewed literature published between 2008 and 2025 to characterize the current state of drinking water quality in Khorezm and its associations with public health outcomes, particularly in children. The review identifies three principal water quality concerns: (1) fluoride deficiency (0.14–0.38 mg/L; WHO recommended range: 0.7–1.5 mg/L), associated with elevated dental caries prevalence; (2) excessive total dissolved solids (TDS) and water hardness, linked to urolithiasis and cardiovascular disease; and (3) microbial contamination in groundwater wells, directly associated with diarrhoeal disease burden in children under five (4.6 episodes/child/year). Organochlorine pesticide residues (DDT, γ-HCH) and heavy metals detected above international thresholds further compound health risks. We conclude with evidence-based recommendations for water fluoridation programmes, sanitary protection of groundwater sources, and seasonal microbiological surveillance.

Keywords: *drinking water quality; public health; Khorezm; Aral Sea; fluoride deficiency; microbial contamination; children's health; water hygiene; Uzbekistan*

Annotatsiya (O'zbek tilida)

Xavfsiz ichimlik suvi inson huquqlarining asosiy elementidir. Xorazm viloyatida ichimlik suvi sifatiga bir-birini kuchaytiruvchi bir necha omillar ta'sir ko'rsatmoqda: Orol dengizi ekologik falokati oqibatlari, qishloq xo'jaligi yuvilmalari, iqlim o'zgarishi va suv infratuzilmasining eskirishi. Ushbu sharh maqolasida 2008–2025 yillarda nashr etilgan ilmiy adabiyotlar asosida mintaqadagi suv sifatining holati va uning — birinchi navbatda bolalar — salomatligiga ta'siri tahlil qilingan. Uchta asosiy muammo aniqlandi: (1) ftor etishmasligi (0,14–0,38 mg/l; JSST me'yori: 0,7–1,5 mg/l) — tish kariesi bilan bog'liq; (2) TDS va qattiqlikning me'yordan oshishi — urolitiaz va yurak-qon tomir kasalliklari bilan bog'liq; (3) yer osti quduqlarida mikrobiologik ifloslanish — 5 yoshgacha bolalarda diareya (yiliga 4,6 epizod). Ilmiy asoslangan tavsiyalar ishlab chiqilgan.

Kalit so'zlar: *ichimlik suvi sifati; jamoat salomatligi; Xorazm; Orol dengizi; ftor etishmasligi; mikrobiologik ifloslanish; bolalar salomatligi; suv gigienasi; O'zbekiston*

1. Introduction

Access to safe drinking water is recognised as a fundamental human right by the United Nations General Assembly [1]. Despite significant global progress, approximately 2 billion people remain without access to safely managed drinking water services, and unsafe water contributes to more than 485,000 deaths annually [2]. In Central Asia, this challenge is exacerbated by the legacy of Soviet-era agricultural policy, which diverted the Amu Darya and Syr Darya rivers to irrigate cotton fields, causing the near-total desiccation of the Aral Sea — one of the twentieth century's most severe man-made ecological disasters [3].

The Khorezm region of Uzbekistan lies at the epicentre of this ecological crisis. The region borders the shrinking Aral Sea and depends primarily on Amu Darya water for both irrigation and domestic supply. Decades of intensive pesticide application have left persistent organochlorine residues (DDT, lindane, heptachlor) in soils and aquifers [4]. Climate change is further intensifying water scarcity and salinization: mean annual temperature in Uzbekistan has risen by approximately 1.5–2.0°C over three decades, while precipitation has declined by 10–15% [5].

Despite the established link between water quality and health in Central Asia [6], systematic reviews specifically addressing Khorezm's drinking water quality and its associations with measurable health outcomes remain scarce. A comprehensive review

is essential to inform targeted public health interventions and to provide a foundation for future primary research.

1.1. Objectives

This narrative review aims to: (i) synthesise evidence on the physico-chemical and microbiological quality of drinking water in Khorezm; (ii) describe associations between water quality parameters and health outcomes, particularly in children; and (iii) identify evidence-based recommendations for water safety improvement.

2. Methods

A narrative literature review was conducted following standard methodological principles for reviews in environmental health [7]. Electronic databases searched included PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar. Search terms included combinations of: Khorezm, Uzbekistan, Aral Sea, drinking water quality, water contamination, public health, dental caries, fluoride, diarrhoeal disease, groundwater, nitrate, pesticides, and children health. The search was restricted to publications in English and Russian from January 2008 to March 2025. Additional sources included WHO technical reports, UNECE national assessments, World Bank documents, and Cochrane systematic reviews.

Inclusion criteria: primary research studies, systematic reviews, and authoritative reports addressing drinking water quality or water-associated health outcomes in Khorezm, Uzbekistan, or the broader Aral Sea basin. Exclusion criteria: editorials, letters, conference abstracts without full-text data, and studies lacking measurable outcomes.

Table 1. Summary of key studies included in the review

Authors / Year	Design	Main Focus	Key Finding
Herbst et al. (2008, 2012)	Cross-sectional	Diarrhoea risk factors, Khorezm	4.6 episodes/child/year; domestic domain primary driver
Crighton et al. (2011)	Systematic review	Children's health, Aral Sea area	Anaemia, diarrhoea, toxic contaminants; infant mortality 56/1000

Bekturganov et al. (2016)	Narrative review	Water-related health, Central Asia	Salinization, pesticides, diarrhoea, anaemia linked to water
Khaibullina et al. (2022)	Retrospective cohort	One Health, Khorezm / Aral Sea	Asthma 113/100,000 — 3× national average; cancer risk rising
Jin et al. (2023)	Environmental assess.	PAHs and OCPs, Amu Darya basin	DDT, γ-HCH above WHO limits in 100% of water samples
Vdovenko S. & D. (2025)	Cross-sectional	Water quality, Samarkand	Fluoride 0.14–0.28 mg/L (below WHO minimum of 0.7 mg/L)
Iheozor-Ejiofor et al. (2024)	Cochrane meta-analysis	Water fluoridation and dental caries	Fluoridation reduces caries by 30–50% in children
Fornasaro et al. (2024)	Environmental assess.	River water quality, Tashkent province	Zn, Mo, As, Pb above global river water averages
PubMed (2025)	Environmental assess.	Pesticides, Karakalpakstan	OCPs above US reference levels in 100% water samples; TDS 563–3852 mg/L

3. Results

3.1. Physico-chemical Water Quality

Total dissolved solids (TDS) is a primary concern in Khorezm, where groundwater mineralization can reach 2–3 times the WHO guideline of 1000 mg/L [2]. Environmental assessment data from Karakalpakstan — the adjacent autonomous republic — recorded TDS values ranging from 563 to 3852 mg/L across 140 water samples [8]. Water hardness frequently exceeds the O'zDSt 950:2011 limit of 7 mg-eq/L, contributing to urolithiasis and cardiovascular disease risk observed in the region.

Fluoride deficiency represents a particularly pressing concern. The WHO recommends 0.7–1.5 mg/L of fluoride in drinking water for dental caries prevention. Vdovenko & Vdovenko (2025) documented fluoride concentrations of only 0.14–0.28

mg/L across 720 water samples in western Uzbekistan — approximately 5-fold below the lower threshold [9]. Marya et al. (2014), analysing data from 3007 school children, demonstrated that caries prevalence decreased from 48.0% to 28.1% as fluoride levels increased from 0.5 to 1.13 ppm, illustrating the dose-dependent protective effect [10].

Nitrate contamination, primarily driven by agricultural fertiliser use, poses additional health risks. The Amu Darya basin receives substantial nitrogen inputs from irrigated cotton and wheat cultivation across Uzbekistan [4]. Elevated nitrate concentrations are associated with methaemoglobinaemia in infants, thyroid dysfunction, and gastrointestinal cancers with chronic exposure [11]. Jin et al. (2023) confirmed the presence of PAHs (polycyclic aromatic hydrocarbons) and organochlorine pesticides (OCPs), including DDT and γ-HCH, in Amu Darya surface and groundwater at concentrations exceeding Uzbekistan national standards [4].

3.2. Microbiological Quality

Microbiological contamination is consistently more severe in decentralised groundwater sources than in piped distribution systems. Herbst et al. (2008) documented diarrhoeal disease incidence of 4.6 episodes per child per year in children under five in Khorezm — exceeding global median values — with rates of 6.7 episodes/child/year in children under two [12]. Multiple regression analysis identified visible drinking water contamination during household storage as a statistically significant predictor of diarrhoeal episodes.

Crighton et al. (2011) synthesised 26 peer-reviewed studies on children's health in the Aral Sea area, identifying infant mortality of 56/1000 and under-five mortality of 65/1000 in Karakalpakstan and Khorezm — above national averages. Anaemia affected the majority of women and children in the region, driven by a combination of micronutrient-deficient diet and polluted water sources [13].

Zorina (2018), reviewing the situation in neighbouring post-Soviet countries, found that non-centralised water supplies consistently showed microbiological non-compliance rates several times higher than centralised systems — a pattern directly applicable to rural Khorezm, where 30–35% of the population relies on unregulated groundwater [14].

3.3. Climate Change and Infrastructure Deterioration

Climate modelling indicates that temperature increases of 1.5–2.0°C and precipitation reductions of 10–15% are expected to intensify salinization of Khorezm's

water sources over the coming decades [5]. Akhmedova et al. (2020) documented deteriorating hydro-ecological conditions in Uzbekistan's piedmont rivers under climate change scenarios, forecasting reduced dilution capacity and increased pollutant concentrations [15].

Water supply infrastructure presents an additional challenge. UNECE and WHO-Europe (2022) reported that 30–35% of Khorezm's rural population relies on non-centralised sources. According to UNDP Uzbekistan (2023), only 52.2% of the region's population had access to centralised water supply in 2017 — a figure improving under ongoing government programmes but still leaving significant gaps in rural areas. The most recent UNECE National State of the Environment Report (2024) documented progressive water quality degradation in urban canals, with classifications shifting from 'clean' to 'very dirty' in parts of the region between 2022 and 2024 [16].

4. Discussion

This review identifies a convergence of physico-chemical and microbiological water quality deficits in the Khorezm region that collectively generate a substantial preventable disease burden. Three inter-related patterns emerge from the literature.

First, fluoride deficiency is a pervasive and systematically underaddressed problem. Despite clear evidence that community water fluoridation reduces dental caries prevalence by 30–50% in children [17], no fluoridation programme currently operates in Khorezm or western Uzbekistan. The implementation of targeted fluoridation at centralised treatment facilities represents a cost-effective public health intervention, consistent with WHO recommendations and endorsed by the Cochrane Collaboration [17].

Second, microbiological risk is concentrated in groundwater-dependent communities. Wolf et al.'s (2014) meta-analysis demonstrated that safe water access reduces diarrhoea by 25–30%, and improved sanitation by a further 36–38% [18]. In Khorezm, where groundwater wells lack sanitary protection zones and are frequently located near livestock areas, priority interventions include systematic sanitary inspection, community hygiene education, and household water treatment.

Third, the legacy of Soviet-era pesticide application creates a distinctive hazard profile that distinguishes Khorezm from other water-stressed regions. Persistent organochlorine compounds bioaccumulate and have been associated with immunotoxicity, endocrine disruption, and cancer risk [4,8]. Standard physico-chemical

water quality indices do not capture this hazard; targeted organochlorine surveillance is required.

Several limitations of this review should be acknowledged. Khorezm-specific primary data on water quality are sparse; most studies address the broader Aral Sea region or Uzbekistan as a whole. Standardised epidemiological data linking specific water quality parameters to disease incidence in Khorezm's two districts remain unavailable. This evidence gap motivates the primary research currently underway by the authors.

5. Conclusions

Drinking water quality in the Khorezm region of Uzbekistan presents a complex, multi-hazard public health challenge shaped by ecological disaster, agricultural contamination, climate change, and infrastructure decay. The review identifies fluoride deficiency, microbial contamination of groundwater, and persistent organochlorine pesticide residues as the three most critical and actionable concerns.

Evidence-based recommendations include: (i) introduction of water fluoridation at centralised treatment plants (target: 0.7 mg/L); (ii) establishment of sanitary protection zones around groundwater wells in both Khonqa and Urgench districts; (iii) mandatory seasonal microbiological surveillance of all public water supply points; (iv) targeted organochlorine monitoring in Amu Darya-fed groundwater; and (v) modernisation of ageing water treatment infrastructure, prioritised in Khonqa district where the main treatment station dates from 1988.

Primary research conducting standardised physico-chemical and microbiological sampling across water source types, linked to district-level paediatric morbidity data, is urgently needed to provide the local evidence base required for effective policy.

Author Contributions

Conceptualisation: Sh.B. Sa'dullayeva and D.B. Aknazarova; methodology: Sh.B. Sa'dullayeva; formal analysis: Sh.B. Sa'dullayeva; writing — original draft preparation: Sh.B. Sa'dullayeva; writing — review and editing: D.B. Aknazarova; supervision: D.B. Aknazarova. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest.

Institutional Review Board Statement

Not applicable (this is a review article based on previously published data).

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