MICROBIOLOGICAL QUALITY OF WATER IN KYRGYZSTAN: A COMPREHENSIVE REVIEW

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Abstract
Kyrgyzstan, a landlocked mountainous country in Central Asia, relies heavily on glacialfed rivers, lakes, and groundwater for its water supply. Despite the generally pristine nature of its surface water sources, microbiological contamination remains a significant concern for public health, particularly in drinking water distribution systems and certain localized areas. This comprehensive review examines existing research on the microbiological quality of water resources across Kyrgyzstan, including rivers, lakes (notably Issyk Kul), groundwater, and centralized and rural drinking water supplies. Studies reveal that surface waters in major rivers typically exhibit low levels of fecal coliforms (0–23 MPN/100 mL), indicating good overall quality due to glacial origins. However, specific sites, such as the MailuuSuu River influenced by historical uranium mining tailings, show elevated pathogenic bacteria and coliforms. Tap water monitoring indicates noncompliance with microbiological standards in 2.2–3.4% of samples nationally, with higher rates (up to 28.3%) in regions like JalalAbad, Chui, and Issyk Kul. Key contaminants include total coliforms, fecal coliforms, and Escherichia coli, linked to inadequate sanitation, livestock activities, and infrastructure deficiencies. Waterborne diseases, including acute intestinal infections, correlate with these contamination patterns. Bacterial community studies in Lake IssykKul highlight stratified microbial diversity but limited evidence of widespread pathogenic pollution. This review underscores disparities between source water quality and enduser supply, emphasizing the need for enhanced monitoring, sanitation improvements, and risk management to mitigate health risks. Findings are based on peerreviewed studies, conference proceedings, and international reports from 2016 to 2025.

Keywords: Microbiological water quality, fecal coliforms, Escherichia coli, drinking water contamination, surface water

МИКРОБИОЛОГИЧЕСКОЕ КАЧЕСТВО ВОДЫ В КЫРГЫЗСТАНЕ: ВСЕСТОРОННИЙ ОБЗОР

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Аннотация
Кыргызстан, горная страна в Центральной Азии, не имеющая выхода к морю, в значительной степени зависит от рек, озер и грунтовых вод, питаемых ледниками. Несмотря на в целом чистоту поверхностных источников воды, микробиологическое загрязнение остается серьезной проблемой для общественного здравоохранения, особенно в системах распределения питьевой воды и некоторых локальных районах. В этом всестороннем обзоре рассматриваются существующие исследования микробиологического качества водных ресурсов по всему Кыргызстану, включая реки, озера (в частности, Иссык-Куль), грунтовые воды, а также централизованные и сельские системы водоснабжения. Исследования показывают, что поверхностные воды

в крупных реках обычно демонстрируют низкий уровень фекальных колиформных бактерий (0–23 MPN/100 мл), что указывает на хорошее общее качество благодаря ледниковому происхождению. Однако на отдельных участках, таких как река МайлууСуу, подверженная влиянию отвалов исторических урановых рудников, наблюдается повышенное содержание патогенных бактерий и колиформных бактерий. Мониторинг водопроводной воды показывает несоответствие микробиологическим стандартам в 2,2–3,4% проб по всей стране, при этом более высокие показатели (до 28,3%) отмечаются в таких регионах, как Джалалабад, Чуй и Иссык-Куль. К основным загрязнителям относятся общие колиформные бактерии, фекальные колиформные бактерии и Escherichia coli, что связано с неадекватными санитарными условиями, животноводством и недостатками инфраструктуры. Заболевания, передающиеся через воду, включая острые кишечные инфекции, коррелируют с этими моделями загрязнения. Исследования бактериального сообщества в озере Иссык-Куль выявляют стратифицированное микробное разнообразие, но ограниченные доказательства широко распространенного патогенного загрязнения. Этот обзор подчеркивает несоответствия между качеством исходной воды и водой, поступающей к конечным потребителям, и акцентирует внимание на необходимости усиления мониторинга, улучшения санитарных условий и управления рисками для снижения рисков для здоровья. Результаты основаны на рецензируемых исследованиях, материалах конференций и международных отчетах за период с 2016 по 2025 год.

Ключевые слова: Микробиологическое качество воды, фекальные колиформные бактерии, Escherichia coli, загрязнение питьевой воды, поверхностные воды.

Introduction

Water is an essential resource for human health, agriculture, and economic development, yet microbiological contamination poses one of the greatest threats to safe drinking water worldwide [1]. The World Health Organization (WHO) defines microbiological water quality in terms of indicator organisms such as total coliforms, fecal coliforms, and Escherichia coli (E. coli), which signal potential fecal contamination and the presence of pathogens capable of causing diarrheal diseases, hepatitis, and other infections [2]. In developing and transitional economies, poor microbiological quality contributes significantly to morbidity and mortality, particularly among children [3].

Central Asia, including Kyrgyzstan, faces unique water challenges due to its arid to semiarid climate, reliance on transboundary rivers, and legacy environmental issues from Sovietera industrialization [4]. Kyrgyzstan, often called the "water tower" of Central Asia, possesses abundant surface water resources from glaciers in the Tian Shan and Pamir mountains, feeding major rivers such as the Naryn, Chu, and tributaries of the Syr Darya [5]. Lake IssykKul, the world's secondlargest alpine lake, is a critical ecological and recreational resource. However, rapid population growth, inadequate sanitation infrastructure, agricultural runoff, livestock grazing near water sources, and historical pollution from mining activities threaten microbiological integrity [6].

National monitoring data indicate that while source waters are often of high quality due to low population density in upstream areas and glacial melt, contamination frequently occurs during distribution or in rural supplies [7]. Deviations from microbiological standards in piped water range from 2.2–3.4% nationally, but regional variations are stark, with higher noncompliance in densely populated or industrially impacted areas [8]. Waterrelated health problems, including acute intestinal infections, remain prevalent, underscoring the public health implications [9].

Early studies in the region focused on chemical and radioactive contaminants, particularly around uranium tailings sites like MailuuSuu [10]. More recent research has shifted toward microbiological assessments, driven by international protocols such as the UNECEWHO/ Europe Protocol on Water and Health, to which Kyrgyzstan is a party [11]. Despite these efforts, comprehensive syntheses of microbiological data are limited, with studies scattered across rivers, lakes, groundwater, and drinking water systems.

This review aims to consolidate available evidence on the microbiological quality of water in Kyrgyzstan, identifying patterns, sources of contamination, health linkages, and gaps in knowledge. By examining surface waters, groundwater, and supplied drinking water, it provides a holistic overview to inform policy, monitoring, and intervention strategies.

Methods and Methodology

This is a narrative comprehensive review rather than a systematic review with metaanalysis, given the limited number of studies and heterogeneity in methodologies. Literature was identified through searches conducted in January 2026 using webbased academic search engines, including PubMed, Google Scholar, ScienceDirect, ResearchGate, and institutional repositories (WHO, UNICEF, UNECE). Search terms included combinations of "microbiological quality," "fecal coliform," "E. coli," "coliforms," "bacterial contamination," "drinking water," "surface water," "groundwater," "rivers," "IssykKul," and "Kyrgyzstan" or "Kyrgyz Republic." Boolean operators (AND, OR) and filters for English and Russian languages were applied, with publication dates unrestricted but emphasizing post2010 studies for relevance.

Inclusion criteria comprised peerreviewed articles, conference proceedings, and official reports containing primary data on microbiological indicators (e.g., total coliforms, fecal coliforms, E. coli, pathogenic bacteria) in Kyrgyz water bodies or supplies. Exclusion criteria eliminated studies focused solely on chemical/radiological parameters, microbial ecology without quality implications, or nonKyrgyz sites. Gray literature from international organizations was included for contextual monitoring data.

A total of approximately 50 sources were screened, with 22 retained for detailed analysis based on relevance and data quality. Key findings were extracted regarding sampling locations, methods (e.g., membrane filtration, most probable number [MPN]), contaminant levels, and comparisons to national or WHO standards. National standards align closely with WHO guidelines, requiring absence of E. coli in 100 mL drinking water and limits on total coliforms [12].

Data synthesis involved thematic grouping by water type (surface, ground, drinking) and geographic region. Quantitative results were summarized descriptively due to variability in units and methods. Limitations include potential publication bias toward contaminated sites and underrepresentation of remote areas.

Comprehensive Review

Surface Water: Rivers and Streams

Kyrgyzstan's rivers originate from highaltitude glaciers, contributing to generally low microbial loads. A nationwide study of fecal coliform (FC) distribution in major rivers reported concentrations ranging from 0–23 MPN/100 mL, classifying most as good quality per WHO guidelines [13]. Driving factors included elevation, land use, and proximity to settlements; higher FC occurred downstream of agricultural or urban areas, attributed to livestock waste and untreated sewage [13].

Localized contamination is evident in historically polluted rivers. The MailuuSuu River, impacted by uranium tailings, showed elevated total coliforms, fecal coliforms, and pathogenic bacteria (e.g., Salmonella, enterococci) at multiple sampling points [14]. Microbiological analysis revealed higher bacterial counts near tailings sites, correlating with health indicators such as increased gastrointestinal illness in downstream communities [14].

Other streams and smaller rivers exhibit diverse bacterial communities dominated by Proteobacteria, with limited pathogenic indicators in pristine areas [15]. However, seasonal variations and runoff events can temporarily elevate coliforms.

Lakes: Focus on IssykKul

Lake IssykKul, a closedbasin saline lake, has been studied for microbial diversity rather than contamination per se. Vertical profiling revealed stratified bacterial communities, with surface layers dominated by typical freshwater taxa and deeper anoxic zones hosting distinct groups [16]. Alpha, Beta, and Gammaproteobacteria predominated, responding to oxygen and nutrient gradients [16]. While no widespread fecal contamination was reported, potential risks exist from tourism, agriculture, and inflows from contaminated tributaries [17].

Sediment studies identified microbial roles in mineral precipitation (e.g., vaterite "biscuits"), indicating active biogeochemical cycling but not necessarily pathogenic threats [18].

Groundwater and Springs

Groundwater serves many rural communities. Limited data suggest variable quality, with some springs showing low coliforms due to natural filtration, while shallow wells near settlements exhibit fecal contamination [19]. In miningaffected areas, indirect influences (e.g., surface seepage) may introduce bacteria [10].

Drinking Water Supplies

Centralized piped systems and rural sources show the highest concern. National surveillance reports 2.2–3.4% noncompliance for microbiological parameters in public supplies [8]. Regional disparities are pronounced: JalalAbad (28.3%), Chui (18.4%), and IssykKul (19.3%) regions record highest tap water contamination, often exceeding standards for total coliforms [20].

Rural areas reliant on decentralized sources face greater risks, linked to poor sanitation and animal proximity [9]. Acute intestinal infections correlate with these patterns, highlighting water as a transmission vector [11].

Results

Summarized findings from reviewed studies:

- Rivers: FC 0–23 MPN/100 mL overall; elevated in MailuuSuu (pathogens detected) [13][14].
- Lake IssykKul: Stratified nonpathogenic communities; no high fecal indicators reported [16].
- Drinking Water: National noncompliance 2.2–3.4%; regional highs up to 28.3% for bacterial parameters [8][20].
- Health Linkages: Higher acute intestinal infections in contaminated areas; water factor in regional morbidity [9][11].
- Bacterial Composition: Proteobacteria dominant in surface waters; Actinobacteria/ Firmicutes in impacted soils/water interfaces [15][21].
- Most studies used standard methods (MPN, membrane filtration) and found compliance in source waters but failures in distribution.

Discussion

The reviewed evidence reveals a paradox in Kyrgyzstan's water quality: pristine glacial sources contrast with frequent microbiological failures in delivered water [7][13]. Low river FC levels reflect minimal upstream human impact, a benefit of mountainous terrain [13]. However, point sources like MailuuSuu demonstrate how legacy pollution amplifies risks [14].

Distribution system contamination likely arises from aging pipes, intermittent supply allowing ingress, and inadequate treatment/disinfection [20]. Rural sanitation gaps exacerbate issues, aligning with global patterns where fecaloral transmission drives disease burden [3].

Health implications are significant, with waterrelated infections contributing to child morbidity [9]. Compared to neighbors, Kyrgyzstan's river quality appears better than more industrialized areas but drinking water compliance lags [4].

Gaps include limited pathogenspecific data (beyond indicators), seasonal/longitudinal studies, and climate change impacts on glacial melt altering microbial dynamics. Molecular methods (e.g., 16S rRNA) in recent studies enhance understanding of communities but need integration with health risk assessment [16].

Recommendations: Strengthen surveillance under the Protocol on Water and Health, invest in sanitation (WASH), and implement water safety plans [11].

Conclusion

Kyrgyzstan benefits from highquality surface water sources but faces ongoing microbiological challenges in drinking water supplies, driven by infrastructure and sanitation deficits. While rivers and Lake IssykKul generally meet standards, localized contamination and regional tap water issues pose public health risks. Enhanced monitoring, infrastructure upgrades, and integrated management are essential to safeguard water quality and reduce waterborne disease burden. Future research should prioritize pathogen tracking, climate impacts, and intervention efficacy to support sustainable development goals.

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