Concept Paper

Reframing Chronic Kidney Disease of Unknown Etiology (CKDu): A Hydrogeochemical and Technological Perspective on Water Extraction Practices

C.K. Gamini Piyadasa *

Posted Date: 6 February 2026

doi: 10.20944/preprints202602.0436.v1

Keywords: chronic kidney disease of unknown etiology (CKDu); groundwater extraction; drinking water quality; heavy metals; hard water; deep groundwater; technological transformation of water use; environmental exposure; mineral; mineral stratification

 doi:10.20944/preprints202602.0436.v1

Concept Paper

Reframing Chronic Kidney Disease of Unknown Etiology (CKDu): A Hydrogeochemical and Technological Perspective on Water Extraction Practices

C.K. Gamini Piyadasa

Ministry of Science and Technology, 3rd Floor, Sethsiripaya, Battaramulla, Sri Lanka; gaminickg@gmail.com; Tel.: +94 70 497 4368

Abstract

Chronic Kidney Disease of Unknown Etiology (CKDu) represents one of the most persistent unresolved epidemics in global environmental health, affecting rural agricultural communities in Sri Lanka and comparable tropical regions. Here, we propose a conceptual shift in CKDu research by linking the disease not only to chemical exposure but also to technological transformation in water extraction. Synthesizing epidemiological evidence, groundwater chemistry, and historical water-use practices, we show that the transition from surface and shallow sources to deep-well pumping has systematically increased long-term consumption of mineral-dense and trace metal–enriched groundwater. This altered exposure pathway provides a coherent explanation for the recent emergence of CKDu despite long-standing natural groundwater hardness. We further demonstrate that widely adopted reverse osmosis interventions may generate unintended risks by eliminating essential minerals alongside toxic contaminants. We therefore propose surface-layer water extraction as a low-cost, scalable, and culturally compatible alternative that preserves beneficial mineral content while reducing nephrotoxic exposure. This framework reframes CKDu as an unintended consequence of technological modernization and offers a testable pathway for integrating hydro geochemistry, public health, and water policy in addressing unexplained chronic disease.

Keywords: chronic kidney disease of unknown etiology (CKDu); groundwater extraction; drinking water quality; heavy metals; hard water; deep groundwater; technological transformation of water use; environmental exposure; mineral; mineral stratification

1. Background and Rationale

Chronic exposure to heavy metals in drinking water, including lead, arsenic, mercury, cadmium, and chromium, is widely recognized as a cause of severe long-term health effects such as neurotoxicity, carcinogenesis, cardiovascular disorders, and renal impairment. These contaminants accumulate in biological systems and disproportionately affect vulnerable populations, particularly children and rural communities.

Chronic Kidney Disease of Unknown Etiology (CKDu) has emerged as a progressive and often fatal disease affecting agricultural populations in tropical regions, most notably Sri Lanka and Central America. Unlike conventional chronic kidney disease, CKDu occurs in individuals without established risk factors such as diabetes, hypertension, or hereditary renal disorders. Over the past two decades, CKDu has evolved into a major public health crisis with profound socio-economic consequences.

In Sri Lanka, CKDu prevalence is particularly high in dry zone districts such as Anuradhapura, Polonnaruwa, Badulla, and Monaragala, with reported prevalence ranging from 15.1% to 22.9% and strong associations with farming livelihoods and environmental exposures (Rajapakse et al., 2016).

 doi:10.20944/preprints202602.0436.v1

Despite extensive scientific investigations, the etiology of CKDu remains unresolved, suggesting a multifactorial origin involving environmental, occupational, climatic, and water-related factors.

This concept paper proposes a novel integrative hypothesis: that CKDu may be partly an unintended consequence of technological transformations in water extraction practices, which have altered long-term exposure pathways to groundwater constituents.

2. Problem Statement

Existing hypotheses on CKDu have focused on agrochemicals, heavy metals, fluoride, hard water, heat stress, dehydration, and cyanobacterial toxins. However, none of these factors alone sufficiently explains the temporal emergence, geographic clustering, and demographic patterns of CKDu.

A critical unresolved question remains: if groundwater hardness and mineral content have existed for millennia, why has CKDu emerged predominantly in recent decades? The absence of historical evidence of widespread kidney disease in pre-modern Sri Lanka suggests that natural groundwater chemistry alone cannot explain the epidemic. This gap indicates the need to examine behavioral and technological changes in water use as potential determinants of disease emergence.

3. Conceptual Framework

3.1. Epidemiological and Geographical Dimensions

Spatial analyses demonstrate a strong correlation between CKDu prevalence and irrigation-based agricultural regions with heavy reliance on groundwater for drinking and irrigation. Interdisciplinary studies across environmental science, toxicology, epidemiology, and public health have investigated water chemistry, agrochemical residues, occupational exposures, climatic stressors, and biological markers. Yet, causal relationships remain inconclusive, highlighting the complexity of CKDu pathogenesis.

3.2. Hydrogeochemical Stratification of Groundwater

From a geochemical perspective, dissolved minerals and heavy metals tend to accumulate in deeper groundwater layers due to gravitational settling and geochemical processes. Consequently, deep aquifers often exhibit higher concentrations of fluoride, calcium, magnesium, and trace toxic metals such as cadmium and arsenic. These constituents may exert synergistic nephrotoxic effects, particularly under conditions of chronic dehydration and heat stress.

3.3. Transformation of Water Extraction Practices

Historically, communities in Sri Lanka relied predominantly on surface and shallow water sources, including reservoirs, canals, shallow wells, streams, and rivers, which generally contained lower mineral concentrations than deep groundwater.

 doi:10.20944/preprints202602.0436.v1

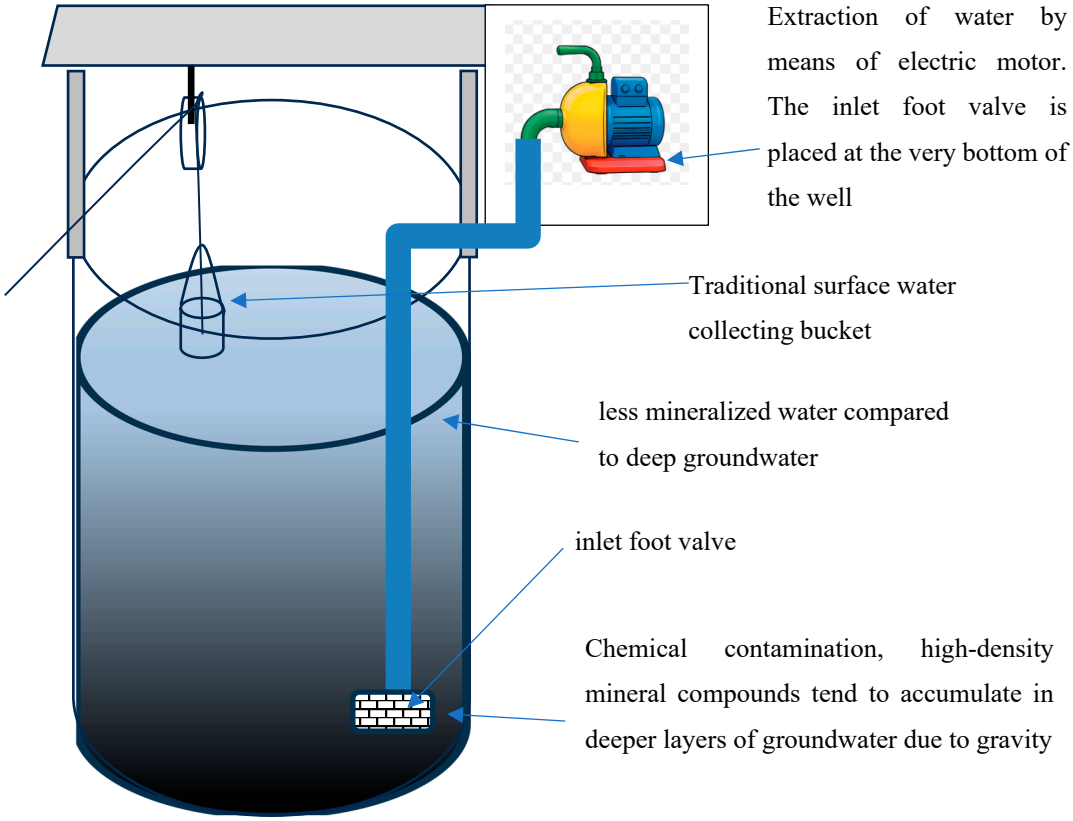

Figure 1. Gravity-driven vertical stratification of high-density minerals within a water well, illustrating differences between traditional and modern water extraction practices. In the traditional system, water is collected manually using a bucket, primarily from the upper layers of the well. In contrast, modern systems employ electric pumps with intake pipes equipped with foot valves positioned at the deepest point of the well, thereby extracting water predominantly from deeper layers where mineral and heavy metal concentrations are typically higher.

The mid-20th century marked a rapid expansion of deep groundwater extraction through electric pumps, tube wells, and mechanized systems. Modern pumping technologies typically draw water from the deepest layers of wells, thereby increasing long-term consumption of mineral-rich and potentially contaminated groundwater.

This concept paper posits that CKDu may not solely depend on the chemical composition of water but also on the depth and origin of extracted water. Thus, the disease may reflect a structural shift in exposure pathways rather than the emergence of entirely new contaminants.

4. Limitations of Current Mitigation Strategies

Reverse osmosis (RO) technology has been widely deployed in CKDu-affected regions to remove toxic contaminants from drinking water. While effective in reducing heavy metals and other pollutants, RO systems also remove essential minerals such as calcium and magnesium. Long-term consumption of demineralized water has been associated with adverse health outcomes, including reduced bone mineral density, dental problems, and potential cardiovascular effects. The World

 doi:10.20944/preprints202602.0436.v1

Health Organization emphasizes that drinking water should contain adequate mineral content for optimal health (WHO, 2009).

Therefore, reliance on RO systems without remineralization may inadvertently introduce new public health risks, underscoring the need for alternative, context-sensitive interventions.

5. Proposed Conceptual Solution

This concept paper proposes a simple, low-cost, and potentially transformative intervention: prioritizing the extraction of drinking water from the upper layers of wells rather than deep groundwater.

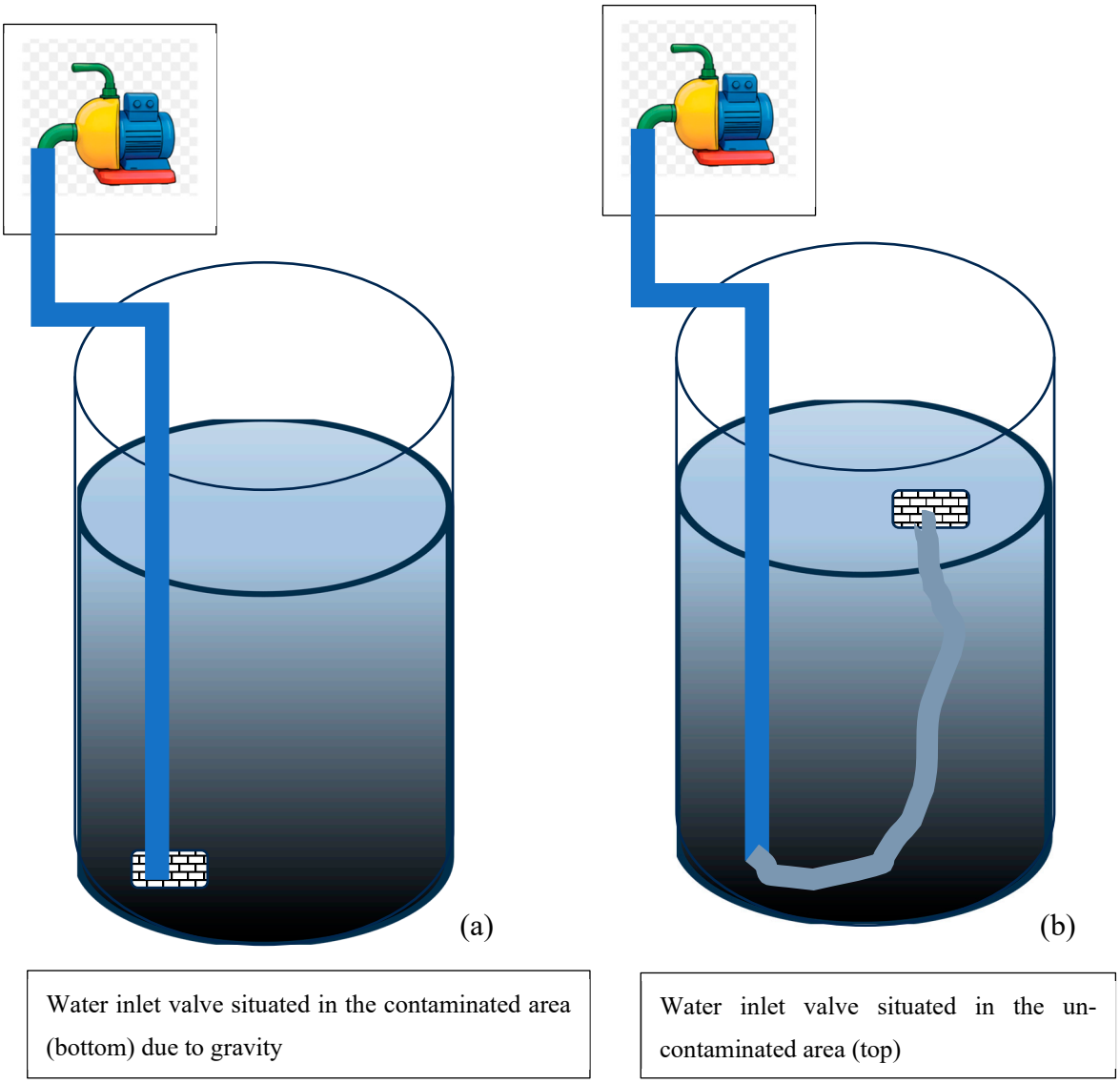

Figure 2. Method of Water Extraction from a Well (a) Conventional method: In the traditional system, the inlet foot valve is positioned at the deepest point of the well. This configuration draws water primarily from the bottom layer, which often contains higher concentrations of dissolved minerals and heavy metals. As a result, the extracted water may include pollutants and dense mineral compounds accumulated in the lower strata of the well. (b) Proposed method: The suggested approach introduces a floating intake valve positioned at the surface layer of the well water. This floating valve is connected to the conventional inlet system via a flexible tube that adjusts automatically with fluctuations in water level. By drawing water from the upper layers, this method preferentially extracts water with potentially lower concentrations of heavy metals and dense mineral constituents, thereby reducing exposure to contaminated deep groundwater.

 doi:10.20944/preprints202602.0436.v1

The rationale is threefold: (i) upper water layers are likely to contain lower concentrations of heavy metals and dense mineral compounds; (ii) surface-layer extraction aligns with traditional water-use practices; and (iii) the approach preserves essential minerals while reducing exposure to toxic constituents without requiring expensive treatment technologies.

Technically, this can be implemented through modifications such as floating intake valves connected to conventional pumping systems, enabling dynamic adjustment to water levels while selectively drawing water from surface layers.

6. Objectives and Research Directions

The overarching objective of this concept is to test whether depth-specific groundwater exposure contributes significantly to CKDu risk. Key research directions include:

- Comparative hydrochemical analysis of surface versus deep groundwater in CKDu-endemic regions.
- Longitudinal epidemiological studies correlating water extraction depth with CKDu prevalence.
- Experimental toxicological studies on combined mineral and metal exposures.
- Pilot interventions implementing surface-layer extraction systems in affected communities.

7. Expected Outcomes and Policy Implications

If empirically validated, this conceptual framework could reshape CKDu research and prevention strategies by integrating hydrogeochemistry, technology, and behavioral factors. Reforming water extraction practices may offer a scalable, culturally compatible, and cost-effective approach to reducing CKDu risk, complementing existing water purification initiatives.

Beyond Sri Lanka, the proposed framework may provide insights into unexplained CKD epidemics in other regions, contributing to global environmental health and sustainable water management policies.

8. Conclusion

This concept paper reframes CKDu as a complex socio-technical and hydrogeochemical phenomenon rather than a purely chemical or biomedical problem. By highlighting the overlooked role of technological transformation in groundwater extraction, it offers a novel and testable hypothesis with significant implications for public health, water policy, and sustainable development.

Although rigorous scientific validation is required, prioritizing surface-layer water extraction represents a promising pathway for mitigating CKDu while preserving essential mineral intake. Ultimately, this integrative perspective has the potential to transform CKDu prevention strategies and inform global approaches to unexplained chronic kidney disease.

Author Contributions: Conceptual framework developed by C.K.G.P.

Funding: This research received no external funding.

Institutional Review Board Statement: The Institutional Review Board Statement and approval number is not relevant to this study and did not require ethical approval.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest

Abbreviations

The following abbreviation is used in this manuscript:

 doi:10.20944/preprints202602.0436.v1

CKDu Chronic Kidney Disease of Unknown Etiology

References

1. Rajapakse, S., Shivanthan, M. C., & Selvarajah, M. (2016). Chronic kidney disease of unknown etiology in Sri Lanka. *International Journal of Occupational and Environmental Health*, 22(3), 259–264. doi:10.1080/10773525.2016.1203097
2. World Health Organization (WHO). (2009). *Calcium and Magnesium in Drinking-water: Public Health Significance*. WHO Press, Geneva.
3. Jayasumana, C., Gunatilake, S., & Senanayake, P. (2014). Glyphosate, hard water and nephrotoxic metals: Are they the culprits behind the epidemic of chronic kidney disease of unknown etiology in Sri Lanka? *International Journal of Environmental Research and Public Health*, 11(2), 2125–2147.
4. Wimalawansa, S. J. (2016). Escalating chronic kidney diseases of multi-factorial origin in Sri Lanka: causes, solutions, and recommendations. *Environmental Health and Preventive Medicine*, 21, 375–394.
5. WHO & Sri Lanka Ministry of Health. (2013). *Investigation and evaluation of chronic kidney disease of uncertain etiology in Sri Lanka*.