Review Article

Efficacy of reverse osmosis in reducing chronic kidney disease of unknown etiology in Sri Lanka: A narrative review

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Abstract

There has been an epidemic of Chronic Kidney Disease of Unknown Etiology (CKDu) affecting the agricultural communities in Sri Lanka, spanning three decades. The main pathological finding has been chronic interstitial nephritis. This narrative review focuses on the efficacy of Reverse Osmosis (RO) technology in purifying water and its impact in reducing CKDu. PubMed, Cochrane and Google Scholar were used to search for peer-reviewed articles from 2000 to 2023. The themes that emerged from the literature review were validated through the opinions of key informants and subject matter experts.

There were anecdotal, as well as some research evidence to indicate that RO-treated water is efficacious in preventing and slowing down the progression of CKDu. This relationship needs further investigation with well-designed prospective studies. The literature review also revealed many social, technical and environmental issues related to the use of RO machines. Despite the potential benefits of RO machines, these issues must be resolved in order to prevent serious problems in the future.

In conclusion, this review underscores the need for further research, interventions and regulatory measures related to the use of RO machines to reshape the CKDu trajectory in Sri Lanka.

Keywords: Chronic kidney diseases of uncertain etiology (CKDu), Chronic interstitial nephritis in agricultural communities (CINAC), Reverse osmosis (RO)

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Introduction

In the 1990s North Central Province (NCP) of Sri Lanka experienced an epidemic of chronic kidney disease [1]. The term chronic kidney disease of unknown etiology (CKDu) was introduced because they lacked the usual causal factors like diabetes, hypertension and glomerulonephritis [2]. Due to its high prevalence among agricultural workers and due to its pathological characteristic of tubulointerstitial nephritis [2–4], the term "chronic interstitial nephritis in agricultural communities" (CINAC) was also introduced to describe this epidemic.

Over the last three decades the disease has progressed outside the NCP, affecting other parts of Sri Lanka involving almost 50,000 patients [2].

Work done by the World health organization (WHO) and others all point to multiple causes for this disease [5,6]. Some of the postulated risk factors include agricultural irrigation, drinking water sources, agrochemical usage, heavy metals such as Arsenic and Cadmium, hardness in water, fluoride levels and genetic predisposition [2,7,8].

There is a high concentration of CKDu in regions where the cascade irrigational systems are used to distribute water to paddy fields. Concentration of the agro-chemicals due to this system may be contributing to the pollution of the drinking water sources such as wells [3][9]. Clusters of CKDu cases were found below the level of the reservoirs/canals where the contaminated water accumulated [10].

Similar epidemics of CKDu have been identified in geographically unrelated, agricultural communities in several countries. They include Mesoamerican Nephropathy in El Salvador, Guatemala and Panama and Uddanam Nephropathy in the Indian states of Andra Pradesh, Odisha, Goa, Chhattisgarh and Maharashtra [11].

CKDu in Sri Lanka

The prevalence of CKDu in the north central province ranged from 6% to 15% [13]. Over 50% of chronic kidney disease (CKD) cases are attributed to CKDu in these areas [3]. CKDu is seen in both men and women. But age-standardized prevalence of disease is higher among women. However, advanced disease prevalence is higher among men [2]. The age groups affected ranged from 17 to 70 years. But most cases are concentrated in the working age of 30 to 60 years [14]. A recent study even observed early renal damage in children [15].

A large economic burden has been imposed on Sri Lanka to prevent and treat CKDu and to care for families and children who are orphaned by the loss of their breadwinners [16]. CKDu has become a “devil” both patients and their families fear and hate.

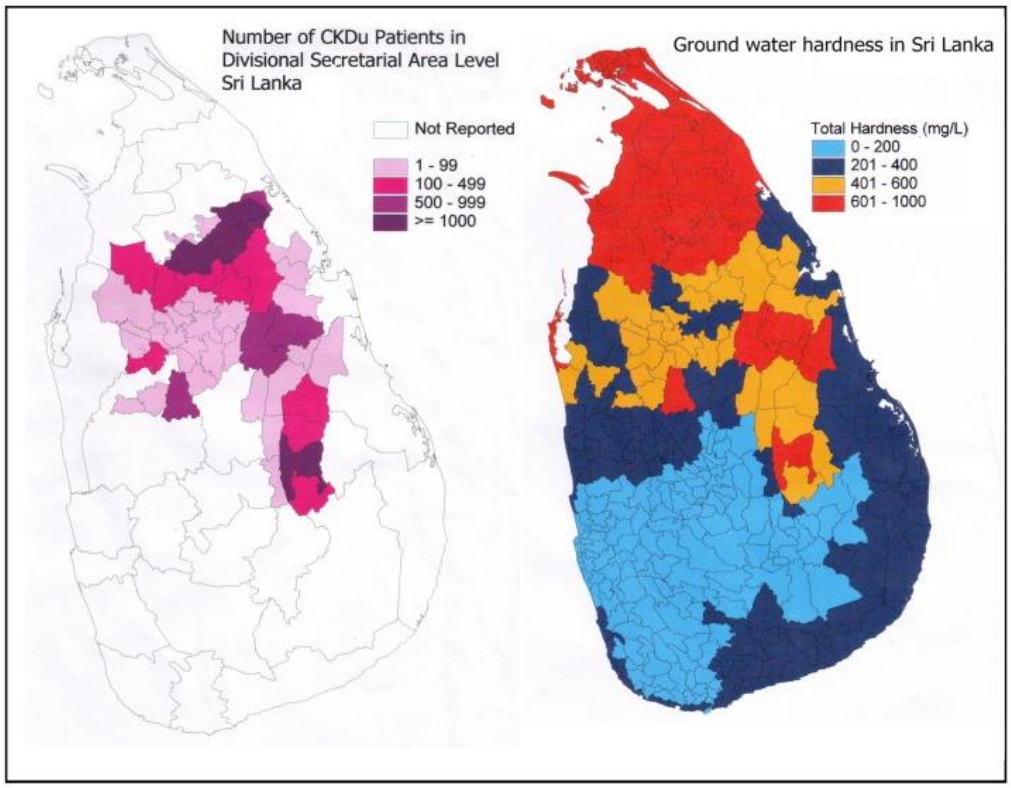

Figure 1 : Geographical distribution of patients with CKDu - Adopted without modification from the original publication which was published under Creative Commons License 3.0. [1]

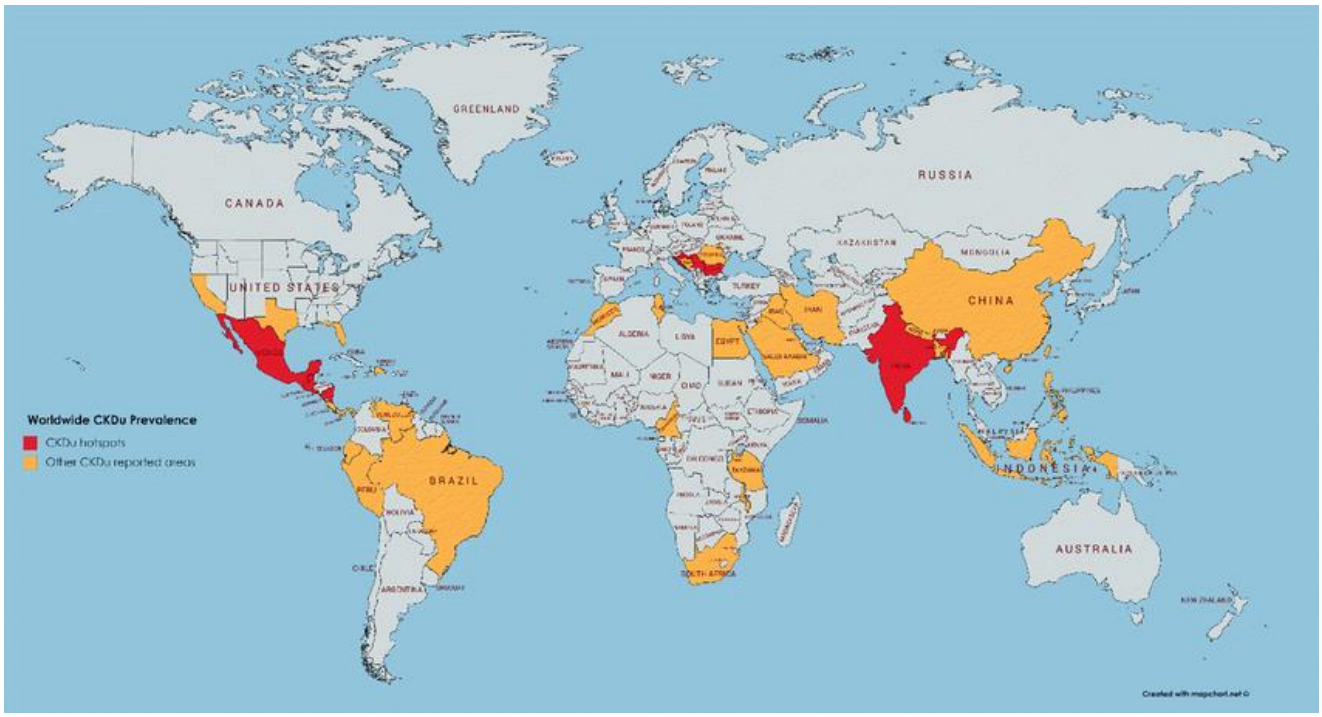

Figure 2 : Worldwide CKDu prevalence. Red colour for CKDu hot spots and orange colour for other CKDu reported countries. (Adopted without modification from the original publication which was published under creative Commons License 4.0. [12]**)**

Importance of early diagnosis and preventive measures

Patients with CKDu are usually diagnosed in the late stages of the disease. The prognosis depends on the degree of renal dysfunction at diagnosis [2,4]. Compared to traditional CKD, there is a relatively rapid progression to end stage renal disease in 4 to 10 years [4,17]. Renal replacement remains the only effective therapy for late disease. Therefore, prevention and early detection remains the best solution to decrease CKDu cases [4]. Unfortunately a lack of precise diagnostic criteria has complicated screening during the early asymptomatic stages [13].

Importance of safe water

Although the exact aetiology of CKDu remains unclear, contaminated water sources have been incriminated as one of the main culprits [1,18]. Groundwater is the main source of drinking water for nearly 90% of individuals in the NCP [19]. Therefore contamination of well water becomes a significant issue [14].

A study published in 2019 on Water Quality Indexing (WQI) in the NCP, found only a small fraction of 88 groundwater samples met the "excellent quality standards" [14]. In other studies, the water quality in these areas exceeded the maximum allowable levels (MALs) for alkalinity, hardness, Fluoride, Chloride and microbiological parameters [20,21].

Several studies have shown that individuals using uncontaminated water from natural springs demonstrated extremely low incidence of CKDu even if they were residing in areas considered to be hotspots [1,2,22]. In another study, providing bottled water to CKDu patients for 18 months resulted in a reduction of disease progression in comparison to the non-interventional group [23]. All this points to the importance of ensuring safe drinking water in this community.

Preventive measures taken in Sri Lanka

The WHO has stated safe drinking water is a basic human right [14]. This has led to multiple initiatives to provide safe drinking water in Sri Lanka [6,24].

Ministry of water supply and drainage, together with other organizations have developed short and long term strategies to provide safe drinking water to affected communities. It is estimated that 3 decades are needed to establish long term permanent water supply schemes. The short-term plan is to use Reverse Osmosis (RO) plants, supply water from bowsers and promote rainwater harvesting [20].

Introduction to reverse osmosis (RO)

Reverse Osmosis is a filtering process to remove minerals, heavy metals and other particles that are dissolved in water [24]. In order to extract pure water, high pressure ranging from 2 to 10 Mega Pascals is used to overcome the natural osmotic pressure and reverse the flow of water [20]. There are 3 main types of RO plants used in Sri Lanka. They are low pressure, ultra-low pressure, and extremely low-pressure plants [21].

Objectives of the review article

The purpose of the review is to understand the efficacy and identify the main problems associated with RO plants in reducing CKDu incidence in Sri Lanka. We hope to identify gaps in knowledge that would require further research and hope to educate agricultural communities in Sri Lanka and in other countries.

Methods

Search strategy, selection and eligibility criteria

All peer reviewed relevant articles regardless of research type from 1st of January 2000 to 31st of July 2023 were chosen.

Initially Lit Maps was used to understand the current data and the themes. Pub Med (33), Cochrane (32) and Google Scholar (286) were used to find relevant articles. (total 352) The key words used for this included "Chronic Kidney Diseases of Uncertain/Unknown Etiology" (CKDu), "Reverse Osmosis", "Chronic Interstitial Nephritis in Agricultural Communities" (CINAC), "Treatment", "Prevention" and "Sri Lanka".

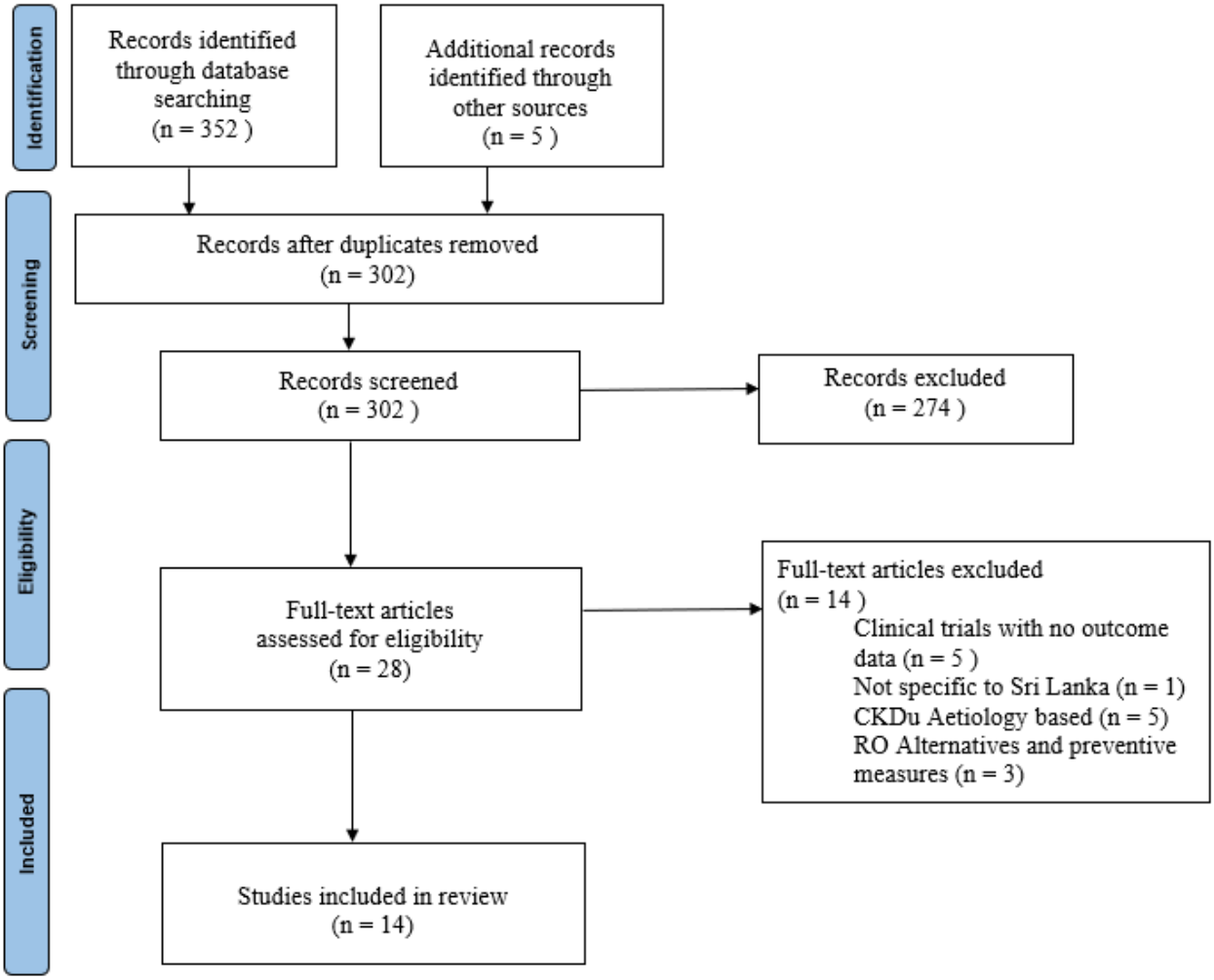

Figure 3 : PRISMA flow diagram depicting the screening process

Data extraction and Results

After reviewing the final 14 of articles [14,18,20,21,23–32] , 10 themes were recognized. These themes were confirmed after multiple discussions with experts in the field of CKDu and RO techniques in Sri Lanka, individuals in charge of maintaining RO machines and consumers of RO water.

The ensuing sections will elaborate the results under the following themes: Usage, acceptability, efficacy, adequacy, operational and maintenance issues, disposal of contaminated filters, toxins and heavy metals and the need for future research and regulations.

RO machine use in Sri Lanka

More than 2000 RO plants have been installed [21]. Majority were built between 2010 to 2016 [25]. Approximately 1/3rd was initiated by the Sri Lanka Navy and National Water Supply and Drainage Board (NWSDB). The remaining plants were built by Community based Organizations (CBO) and businesses [18,20,24]. According to the current data, 7.5 to 15m^3 of RO treated water is supplied in a day to the high-risk populations [21].

Water quality and efficacy

Compared to other membrane technologies of water purification such as nanofiltration, ultrafiltration and microfiltration, RO techniques use non-porous membranes which results in a higher removal rate of dissolved chemicals [20,21]. In one study the Total Dissolved Solvents (TDS) were reduced to 29 parts per million (ppm) from 498ppm. Compared to Electro Deionization (ED) plants, the RO plants were found to be more efficacious, occupied less space and used less resources [26].

Technological drawback

Fouling

Fouling means the accumulation of deposits in the membrane. The types of foulants depend on the characteristics of the feed water source. These foulants include inorganic matter, organic matter and microorganisms [14,20,21,27].

Pretreatment measures are used to reduce fouling. These include disinfection, coagulation, granular filtration, membrane filtration and scale inhibition. Periodic chemical cleaning of filters is also suggested [20].

In a research study done among 100 RO plants, only 36% removed the foulants. Even in these plants, when anti-scalants were used, the operators had little knowledge about the technique and misunderstood this process as a “chemical introducing process”[21].

Low percentage of water extraction

The average output of purified water from RO plants is approximately 46% of the feed water. [20,21]. Theoretically freshwater should give a higher rate of extraction compared to sea water or brackish water. It is postulated that this could be due to the design, inadequate cleaning of the membranes, insufficient numbers of RO elements and suboptimal water pressure [20,21].

Heavy metal removal and demineralization

RO techniques are less efficient in eliminating heavy metals [26].

Apart from the palatability issues, RO water can cause mineral deficiencies leading to tooth decay. Unfortunately, remedial methods of re-mineralization are performed only in 7.9% of plants. This has caused some individuals to refuse switching to RO water [21].

Remineralization is not done by some RO technicians as they consider it a chemical introducing method [21]. Using loose pore/ low rejection RO membranes instead of tight pore membranes [20], passage through a calcite bed or mixing with pre-treated sediments are some of the methods suggested in the literature to overcome this problem. Raising awareness and educating the consumers to increase their fruit and vegetable intake as a replacement for the mineral deficiency is an easier alternative [21].

Concentrate disposal

The reject water left after the RO treatment, also known as the concentrate, imposes a huge challenge. Majority of the Community Based Organization (CBO) run RO plants had no proper disposal method for their concentrate. (80% in one study). Some RO plants have used the concentrate as fertilizer for gardening, with some complaining that it reduced their crop yields [21].

This raises the concerns that improper disposal of concentrate, in these CKDu-endemic regions could lead to substantial environmental pollution and many public health issues in the future [20,26].

One solution to this problem is to use a special filter to remove toxic substances. These filters are made of locally available soil, Calicut tile, biochar, Vetiver grass, Scirpusgrossus, water lettuce and water hyacinth. As a result, total dissolved solids, hardness, total alkalinity and fluoride were reduced considerably (20–85%) and most met desirable levels of stipulated ambient standards [28]. However, this method does not address the issue of environmental contamination.

Disinfection

The two common methods of disinfection used are chlorination and UV disinfection [20]. The current disinfection practices were insufficient to ensure microbial safety of the product water. In addition, the distribution pipes were not well maintained [20] and the UV disinfection units were not uniform (39.6% in this study) [21].

Cost of RO treated water

There is a marked difference in the price of RO treated water. The Navy offers the water for free while others charge 1 to 3 LKR per liter [20] . Currently there are no rules governing the price.

The reason given for charging money is to cover the cost of operating and maintaining these plants. According to some studies, the funds collected were sufficient to cover the costs [20]. One way to reduce this cost is by running these plants at full capacity [21]. Several countries are investigating techniques to reduce the cost by coupling renewable energy sources to the RO plants (PV-RO systems) [20,29]. This could be utilized in Sri Lanka too.

Lack of regulations

There is a lack of regulations governing the operation of these plants. This has led to differences in the performance, efficiency, quality and a lack of training of the maintenance teams [21]. Even the pressures that the RO plants operated were not regulated [21]. Most concerning was a lack of regulation of the quality of the water [26].

Distribution of RO treated water

The distribution of RO treated water from the plant had many practical drawbacks [30]. The “last mile” problem is a term used to explain this [29]. Some individuals had to carry heavy containers and spend 2 hrs to collect water [31]. In some settings, distribution was done via trucks [20] .

During the rainy season, the demand for RO water goes down. This leads to a decrease in water production and a lesser frequency of maintenance during the rainy season [14,20,26].

Attitude and knowledge of the community regarding RO plants

Overall, the perception of RO water is positive among all the affected communities [20] . This can be considered a positive factor.

One study found that most villagers believed CKDu to be related to the use of agrochemical contaminated well water and that it posed a risk to all villagers. That the RO water is clean and is the safest for consumption [24].

Individuals from high-risk areas have a high tendency to use RO water for drinking. But use natural water sources for cooking and food preparation [24]. This highlights the need to educate these individuals of the importance of using safe water for all types of consumption.

Overall, the attitude and knowledge of a community depended on several factors. These included access to good health information, psycho-social beliefs and social media influences [24].

Reverse osmosis and reduction of CKDu in Sri Lanka

There is a paucity of data to show an absolute reduction of CKDu after the use of RO water [20]. However, several studies have shown promising outcomes. Additional research is needed to evaluate this matter.

In 2019, a prospective study did suggest RO water did decrease disease progression in CKDu patients [18]. After the installation of RO plants in many regions, Health Ministry CKD unit database did show a reduction in overall CKDu cases [32].

In one study, switching to RO water and adapting to other behavior changes, caused a mean reduction of the serum creatinine from 2.62 to 1.94 mg/dL among 23 CKDu patients out of 30 (76%) [31]. This is a promising finding. In another study, community feedback did mention a reduction of the incidence of newly reported CKDu patients [21].

Another study demonstrated that RO water can be used as a method of secondary prevention [25]. In this study, disease progression was reduced when RO water was used. Later the progression increased when they returned to their original source of water [23].

All these points to the need for further research.

Discussion and recommendations

The aetiology of CKDu in Sri Lanka is most likely multifactorial and not comprehensively understood.

The cascade irrigation system may have a significant role to play in conveying concentrated amounts of agrochemicals and fertilizer downstream to the low-lying areas where most of the hot pockets of CKDu cases are seen.

Almost all the literature reviewed indicates that shallow wells used as the primary drinking source of water were contaminated with agrochemicals.

Due to the high prevalence and fast progression of CKDu, safe drinking water as a preventive measure is extremely important.

There is anecdotal and some research evidence to indicate that RO water can prevent or slow the progression of CKDu. This relationship needs further investigation.

There is a high level of acceptance and a favourable attitude towards RO water among most villagers.

There has been a steady growth in the use of RO machines as the primary source of drinking water.

There is a host of issues related to the lack of maintenance and the shortage of trained personnel.

The lack of methods to properly dispose of used filters and the residual contaminated concentrates of water have resulted in the return of the same pollutants to the living environment of CKDu patients.

Due to monetary and transportation issues, most consumers use the available RO water for drinking purposes only. The non-availability of an adequate supply of safe water for cooking is a major concern.

The availability of safe water for drinking, cooking and other essential uses is a universal right. RO machines provide only a small fraction of this need. Therefore, there is a need to ensure the implementation of broader policies to meet the entire need for safe water with RO machines and other alternative systems.

Nanofiltration (NF) is one alternative to RO water. This method is suitable for areas with hard water. Advantages of NF include higher water recovery, better wastewater handling and fewer problems with changes in pressure levels [33].

Large-scale rainwater harvesting is another alternative. In 1995 a World Bank-funded project was started in Sri Lanka. The advantages of this method are the low cost of maintenance and ease of distribution of water. Disadvantages are the high initial cost, high microbial contamination and high iron and calcium levels [30].

Mining wastewater is another alternative which is less costly, easy to operate and can be used in rural farming communities. This is effective in removing fluoride to meet WHO safety levels. A sand filter and charcoal are used to remove organic matter, followed by the use of Natural Red Earth Waste (NRE). This is a locally sourced waste product left over from lime extraction [34].

In Central America, improving hydration to overcome heat stress with water and electrolytes have been utilized [35,36]. This could help Sri Lankans too. Purchasing bottled drinking water is another option [24].

Early detection by Screening, increasing awareness through social media and reducing the stigma associated with CKDu was suggested by an International WHO expert on CKDu [6].

Conclusion

CKDu, an interstitial nephritis, is a newly discovered pandemic in several agricultural communities all over the world. The cause of this pandemic is multifactorial. Safe water from RO machines is a viable intervention to prevent and slow down CKDu. Additional research, interventions and regulatory measures are urgently needed to reshape the CKDu trajectory in Sri Lanka.

Limitations

Despite anecdotal evidence to support the efficacy of RO plants, there is a lack of well-designed prospective studies, a lack of longitudinal data or a clear cause-and-effect relationship to suggest the reduction of CKDu cases from RO plants. This is especially due to the complexity of CKDu and its multifactorial nature. This underscores the eminent need of future in-depth research.

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