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SHORT COMMUNICATION

Reverse osmosis plant maintenance and efficacy in chronic kidney disease endemic region in Sri Lanka

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Abstract

Objective Chronic Interstitial Nephritis in Agricultural Communities (CINAC) causes major morbidity and mortality for farmers in North-Central province (NCP) of Sri Lanka. To prevent the CINAC, reverse osmosis (RO) plants are established to purify the water and reduce the exposure to possible nephrotoxins through drinking water. We assessed RO plant maintenance and efficacy in NCP.

Methods We have interviewed 10 RO plant operators on plant establishment, maintenance, usage and funding. We also measured total dissolved solids (TDS in ppm) to assess the efficacy of the RO process.

Results Most RO plants were operated by community-based organizations. They provide clean and sustainable water source for many in the NCP for a nominal fee, which tends to be variable. The RO plant operators carry out RO plant maintenance. However, maintenance procedures and quality management practices tend to vary from an operator to another. RO process itself has the ability to lower the TDS of the water. On average, RO process reduces the TDS to 29 ppm.

Conclusions The RO process reduces the impurities in water available to many individuals within CINAC endemic regions. However, there variation in maintenance, quality management, and day-to-day care between operators can be a cause for concern. This variability can affect the quality of water produced by RO plant, its maintenance cost and lifespan. Thus, uniform regulation and training is needed to reduce cost of maintenance and increase the efficacy of RO plants.

Keywords Chronic kidney disease of unknown etiology · Reverse osmosis plant · North-Central Province · Pesticides · Sri Lanka

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Introduction

Chronic Interstitial Nephritis in Agricultural Communities (CINAC) is an epidemic affecting farmer community in rural Sri Lanka. This disease is also known as chronic kidney disease of unknown etiology (CKDu) and has become a major health issue in the dry zone of Sri Lanka [1].

Male farmers from North-Central province (NCP) who spray glyphosate-based herbicides, drink water from shallow wells and had history of drinking from an abandoned well (abandoned due to increasing foul taste), are at higher risk of developing CINAC [2]. Chronic low dose exposure to multiple heavy metals and agrochemicals is hypothesized as the etiological factor for CINAC [3]. Heat stress and chronic repeated dehydration also may be an aggravating factor in disease progression [4].

Paddy farmers after spraying their pesticides, wash their applicators in nearby streams. Many villagers use these streams for drinking, bathing, cooking and washing clothes. Heavy fertilizer and pesticide use pollutes public water sources and groundwater [5]. Only 31 % of people in the NCP are provided with pipe-borne water [6]. Access to clean water was a part of millennium development goal and now the sixth goal in sustainable development [7]. A possible major cause for the increased incidence of CINAC is due to water pollution that has been caused by the exposure to herbicides and other agrochemicals through polluted water sources [8].

The establishment of RO plants is a short-term measure implemented to combat the problem of agrochemical pollution and the lack of access to clean water sources, and a possible measure to reduce CINAC incidence [9]. Providing clean drinking water also reduces the possibility of chronic repeated dehydration among farmers. Although costly, RO process is an excellent, and a viable method of water purification in providing access to clean water [10]. The RO plant project, conducted in early 2015, served as an extension of the previous studies conducted on epidemic of CINAC by us (CJ, SG, SS). The aim was to investigate the efficacy and management of the RO plants that were established in these areas to combat the CINAC crisis. In this study, water purification plants in two selected areas in NCP, were investigated about the, maintenance, cost, effectiveness, and feasibility in providing sustainable access to clean water.

Materials and methods

Large- and medium-scale RO plants ($n = 10$) that act as water distribution centers that sell water for a nominal fee or those located at public institutions, such as at schools or hospitals were investigated. RO process and the plant maintenance protocol were observed with the trained RO plant operator working in the Faculty of Medicine, Rajarata University of Sri Lanka. A questionnaire was prepared for RO plant operators (those who regularly operate and maintain the RO plants) as well as consumers (who regularly consume the RO purified water). In the operator survey, the questions were on, maintenance procedure, time frame of maintenance, funding, waste management and waste disposal, whether the water is being sold and if so for how much. In the consumer Survey, the main focus was the attitude towards the plants, whether they find these plants and the purified water useful, tasty and with health benefits. Total dissolved solids (TDS) in parts per million (ppm) were measured using a TDS meter before and after the RO purification. Through this measure, RO plant efficacy in reducing the amount of dissolved solids to a range that is suitable for drinking was obtained.

The majority of the data was collected through the surveys given to the RO Plant operators. At each site, the GPS coordinates were taken, the site was photographed and the TDS of the water before and after the RO process was collected. The survey questions were asked in Sinhalese and the responses were recorded using an audio recording device with the verbal consent of the interviewee. The interviewee responses were transcribed into word and excel documents in English after translating. The GPS coordinates were taken using two different GIS Coordinate system applications.

Results

The survey was conducted in Padaviya and Mahawilachchia regions (Fig. 1). All 11 water purification plants were established to combat the epidemic of CINAC and 10 of them were RO plants. Nine plants were established at least a year prior to the study.

There are five school-based plants all maintained by the parent teachers associations. The government (central or local) installed four school-based plants (nos. 8, 9,10 and 11 in the Table 1) and the other was donated by a commercial organization (no. 7). Five plants are situated in the public places. Four of them are maintained by community-based organizations (CBOs) and the other purchased and maintained by the local government (no. 6). Two of four plants (nos. 1 and 3) were purchased also by the CBOs themselves and other two was donated by a commercial organization and expatriate Buddhist organization (nos. 4 and 5). There is a one privately owned and maintained plant situated in a private property (no. 2).

Many of the large-scale RO plants (Fig. 2, plant numbers 1 and 5 from the Table 1) serve as water distribution stations and are maintained through CBOs. In these water distribution stations, water is sold between Rs. 1 and 2 per liter, and is used to pay for the maintenance. Some of the medium scale RO plants (Fig. 3, plant numbers 4, 7 and 8 from the Table 1) is located in schools, and temples. The water from these plants is free. Parent-teachers association raises a monthly donation of Rs. 50 from parents for maintenance and repairs of No. 9, RO plant.

Water source, consumption, and TDS values of the water are shown in Table 1. The TDS values showed that the RO process is capable of significantly lowering the

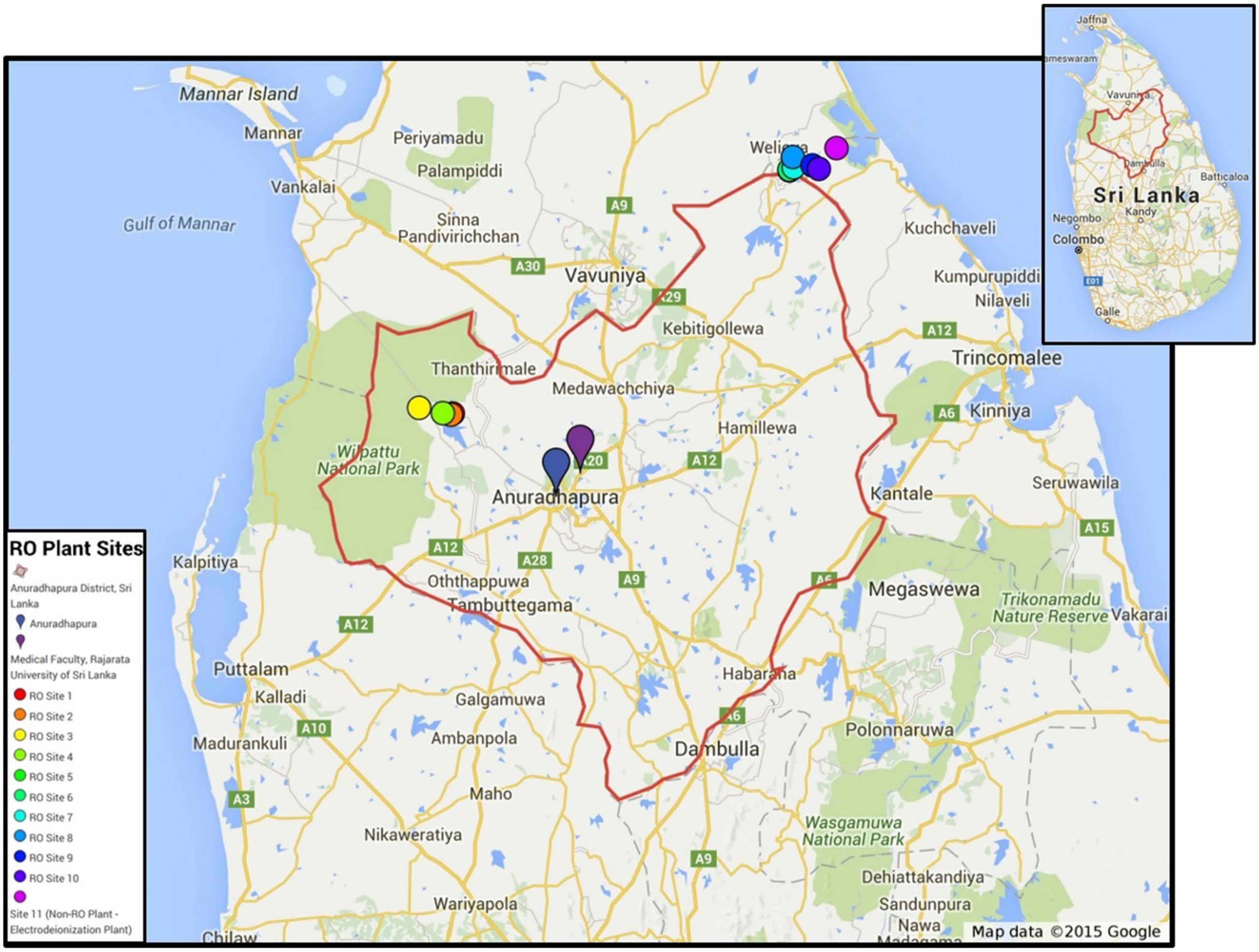

Fig. 1 RO plant sites map

total dissolved solids within a given sample of water. Average pre-RO water had TDS 498 ppm (range 228–907) and the post-RO processed water 29 ppm (range 9–65). Thus, the RO process is effective in purifying or reducing the amount of dissolved solids. Lastly, a non-RO purification process, electro deionization (ED) plant, was also observed and the operators were interviewed in the maintenance, use and efficacy of the plant. The ED process is an extensive and elaborate process of filtration that requires a lot more resources and space while not exactly efficacious in reducing the dissolved solids compared to the RO process. When measured, the TDS of the ED process yields 281 ppm compared to the TDS of the RO process that range 9–80 ppm. School-run RO plants maintained by organizations consisting of teachers, parents and students have better-quality water measured by TDS (14 ppm) when compared with RO plants maintained by other organizations (39 ppm). However, due to small number and other confounding variables, no firm conclusions can be made.

The maintenance of the RO plants is not protocol driven. Many of the CBOs assign operators and provide some form of formal training in how to service the plants. There are set times for cleaning and replacing of the RO filter. The operators do not perform any extensive repairs and only carry out day-to-day filter cleaning and measurement of TDS. The actual filter replacement and RO plant repairs are carried out within one to two days of being informed by agents who sells RO plants.

Four RO plant operators rely on TDS readings to clean or change the filters (Table 2). The operators utilized this as a quantitative measure to manage water quality. Six RO plants use the water taste of the consumers as a clue to change or clean the filters. The RO-processed water tastes better due to the removal of impurities. If the water that is being processed is not adequately clear and has noticeable solids, then operators carry out RO plant cleaning. One operator relies on the "transparency and clearness" of the water samples and two operators use the sound originating

Table 1 Details of RO plants

	Location	Location	Funding (maintenance)	Water source	Daily water consumption		Price per liter of water	TDS (ppm) source	TDS (ppm) after
					Rainy season	Dry season			
1	Dimutu Prajamula Sanvidana, Randuwa, Pemaduwa	Public space	CBO (CBO)	Shallow well	2000–3000 L	5000–6000 L	Rs. 2/=	655.7	19.7
2	Police station road, Pemaduwa	Private property	Privately funded (private)	Tube well	500 L	1000–2000 L	Rs. 2/=	906.7	48.0
3	Saubhagya Prajamula Sanvidana, 365 Mannar junction	Public space	CBO (CBO)	Shallow well	500 L	500 L	Rs. 2/=	494.0	9.0
4	Sri Bodhriukhkaramaya, tract 2, Pemaduwa	Buddhist temple	Commercial organization (CBO)	Shallow well	1000 L	1000 L	Free	871.0	65.3
5	Padavi, Pallugaswanguwa	Public space	Buddhist organisation (CBO)	Tube well	2500 L	2500 L	Rs. 1/=	386.3	38.0
6	Pradeshiya Sabha shopping complex, Padavi Sripura	Public space	Local government (same)	Tube well	800 L	1200 L	Rs. 1/=	386.3	52.0
7	Tricomalee North Padavi Pallugahawanguwa Maha Vidyalaya	School	Commercial organization and CBO-3 plants (school)	Tube well	500 L	500 L	Free for students	376.0	18.0
8	Tricomalee North Padavi Gamunupura primary college	School	Central government (school)	Tap water	600 L	700 L	Free for students and nearby families	293.0	12.0
9	Padavi tract 10 Tissa college, Padavi Sri Tissapura	School	Central government (school)	Shallow well	100 L	150–200 L	Free for students and nearby families	386.3	16.0
10	Padavi tract 11–12 Maha Vidyalaya. Sri Tissapura	School	Central government-3 plants (school)	Tap water	600–800 L	1000 L	Free for students	227.6	10.0
11	Sri Pavadavi 13 Vidyalaya, Sri Thissapura (non-RO electrodeionization plant)	School	Local government (school)	Shallow well	200 L	200 L	Free for students Rs. 1/= for consumers	374.0	281.0

from the RO plant as a clue for blocked or dysfunctional filter.

Discussion

Through the surveying of ten RO plants as well as one ED plant, there has been significant insight about the efficacy of RO plants to provide a clean and sustainable drinking water to regions that show high incidence of CINAC. When compared to the ED system, the RO process significantly reduces TDS in the water. Post-processed water in ED system contains 281 ppm of TDS (pre-processed water of 374 ppm), but the RO processed water contains 29 ppm of TDS (pre-RO processed average 498 ppm) for the ten sites. Thus, the RO process significantly lowers the total impurities in the water when compared to ED system. Thus, the RO plants are effective in providing water with fewer impurities compared to those that are available to them.

Although, the TDS is an adequate measure of water quality or the amount of impurities in water, it is not a holistic measure of the quality of the water. Most RO plants only utilize TDS and, taste as a measure of water quality. Pesticide residues, heavy metals (arsenic, cadmium, etc.) biological contamination, silica (silt density index) are not tested. The RO process is not a foolproof mechanism to reduce heavy metals [11–13]. The presence

Fig. 2 A large-scale Ro plant

Fig. 3 A medium-scale RO plant

of impurities is not checked by a regulating authority and due to the lack of oversight and regulations, this can be alarming when consumers are paying out of pocket to have access to "purified" water.

At any case, RO process does great service in providing the populous with access to a clean water source, even if it might cost many people a nominal fee. Some may not be able to afford even this nominal fee but there are many community centers providing free access to clean water. RO plants that are located in Schools tend to better quality water with low TDS than other RO plants. In comparison, the CBO-owned and -operated RO plants tend to register higher TDS and show poor maintenance of the plants. Most of the CBO-maintained RO plants have not been active for a long period of time and are fairly new, and so have not required any significant repairs or any mandatory filter replacements. Thus, it is quite difficult to exactly assess the management quality of the operators working in these RO plants by a single survey/investigation process. RO plants do not have a set protocol that many operators follow to maintain the plants. The operators who manage the plants are not formally trained and in some occasions do not service the plants on a daily basis. These differences in maintenance protocol give the plants a fluctuating TDS measures. This was observed at a RO plant operated by hospital staff, where the RO plant condition was not in the utmost quality and the TDS measures were higher.

In all of the sites that were surveyed in this particular study, the RO process shows significant reduction in the TDS levels and vast improvement in water quality. However, there are differences in water quality when comparing different RO plants. These differences come into play due to the lack of adequate maintenance and management protocol that is given to the operators. Because many of the plants are operated by different organizations, no two RO plants necessarily follow the same protocol in the plant quality management and efficacy. Thus, there are variations in the TDS and the overall quality of the water that is being distributed or sold to the consumers. During the rainy season, people use rainwater; hence, water requirement from larger RO plants may show a significant decline. With that there is decreased production of water and the frequency of filter change (Plant no. 1).

Proper oversight and regulation enacted by a central authority would be conducive to the betterment of the RO plant efficacy, water quality and the accessibility of the consumers to healthy and sustainable water source. Even with distribution centers being available to consumers, not every individual will have access or means to obtain water. Thus, better means of distribution should be established through community centers that allow individuals to access purified water sources. Mechanism to monitor pre- and post-RO water, based on TDS is needed to prevent sickness and promote health of people in endemic region. The destiny of RO effluent in the environment also needs monitoring.

There should be better education that should be offered to individuals within these regions regarding the purified water consumption and mainly about CINAC. Health Ministry of Sri Lanka, should take a lead role in the regulation, oversight and education not only in water

Table 2 Details of maintenance of RO plants

	Duration of the plant	Clue to change or clean the filter	Frequency of cleaning filters	Frequency of changing filters
1	1 year	Complaints about water taste	Daily	Dry season 3 months, wet season 5 months
2	2 years	High TDS, owner keeps it around 40	Clean filter if TDS is over 40 ppm	Every 2 years
3	4 months	TDS weekly	Daily	Not been replaced yet
4	1.5 years	TDS monthly, taste	Every other day	Every 6 months
5	1.5 months	Holding water tube into sunlight to check for impurities	Every other day	Every 6 months
6	2 months	TDS	Every other day	Not been replaced yet
7	~1 year, 6 months	Taste	Every 2–3 months	Not been replaced yet
8	1 year, 8 months	Taste	Fortnightly	Not been replaced yet
9	~2 years	Taste of water and sound originating from the plant	Fortnightly	Ever 6 months
10	~2 years	When there is a humming sound coming from RO plant	Weekly	Annually
11	~1 year, 6 months	Taste	Daily	Not applicable

consumption, RO plant establishment, and maintenance but also in the utilization of agrochemicals and the reduction in environmental pollution that can effectively combat the CINAC epidemic.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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