Comparison of Performance Data of EDR and Nanofiltration Technologies for Groundwater Treatment

K.M.L.D. Kulasekara, R. Weerasooriya, T.N. Premachandra

Abstract: Water is an essential need of living beings, and issues regarding its quality have become a crucial concern. Chronic Kidney Disease of Unknown Etiology (CKDu) is a common health problem in Sri Lanka. The literature explains how the quality of water bodies indirectly affects to CKDu. Water filtration technologies including electrolytic reversal (EDR) and nanofiltration (NF/RO) were established to facilitate safe drinking water in affected areas. NF/RO is a membrane filtration-based method that allows water to pass through nanometer-sized pores of a membrane. Whereas EDR is a water purification technology that separates unwanted ions electrochemically. Five NF/RO plants installed in the Wilgamuwa area; Abagahapallassa, Asamodagamyaya, Mahayaya, Udayagala, Dahamigama, and Kahatagasdigiliya and EDR plants located in the dry zone of Sri Lanka, were evaluated and tested for water quality parameters. Onsite measurements were obtained for electric conductivity (EC), pH, and turbidity while hardness, total dissolved solids (TDS), anion concentrations (F^-, Cl^-, Br^-, NO_3^-, SO_4^{2-}, PO_4^{3-}), and heavy metal concentrations (Mn, Li, Al, Fe, As) were measured in the laboratory. Anions were measured using Ion Chromatography and Total hardness was determined using titrimetric methods. Results obtained from EDR and NF/RO plants were compared and were countered parted with SLS (614,2013) and World Health Organization (WHO 4th edition, 2011) guidelines. Removal efficiencies of hardness, TDS, and EC of EDR plants were averaged at (15% – 68%), (8% – 48%) and (12% - 35%) respectively. The same parameters of NF/RO were averaged at (45% – 89%), (60% – 92%) and (79% - 89%) respectively. (25%-88%), (3%-51%) and (14%-50) were obtained as the average removal efficiencies of the anions, SO_4^{2-}, F^-, and Cl^- of EDR, and the same parameters of NF/RO gave values of (51%-98%), (80%-95%) and (75%-98%). The study reveals that the removal efficiency of hardness, TDS, EC, anions, and heavy metals is higher in NF/RO treatment plants compared to the EDR plant.

Keywords: EDR Technology; NF/RO; Water purification; Groundwater

1. Introduction

Water is a fundamental objective of living creatures, and issues concerning its water quality have ended up a considerable concern within the world. Effects on water quality are due to environmental pollution and also climate change. Drinking water must be safe for our health; this is defined in law by standards for a wide range of substances, organisms, and water belongings regulations. In terms of drinking water quality, there are worldwide agreements on health base

*Mr. **K.M.L.D.Kulasekara** B.Sc (Material and Nanoscience Tech (Hons) (WUSL), Trainee, JRDC*
Email: fot189068@kul.wyb.ac.lk
*Prof. **R. Weerasooriya** B.Sc (Hons), Ph.D. (Geology)(Peradeniya), Research Professor, NIFS*
Email: rohan.we@nifs.ac.lk
*Dr **T.N Premachandra** Bsc. (sp, Hons) (Peradeniya), Ph.D. (SL)/ Chemist, JRDC*
Email:thejaninisa@gmail.com
ORCID ID: https://orcid.org/0000-0002-7797-9259

standards by the World Health Organization (WHO) (Inspectorate, 2010). 30% of the Worldwide population doesn't have access to safe, clean, and reliable Drinking water. The world urgently needs development goals to eliminate water pollution and produce effective treatment and water management strategies for clean and safe drinking water. (Guo et al., 2022)

1.1 Chronic Kidney Disease of Unknown Etiology in Sri Lanka

CKDu is a public health problem in the Sri Lanka dry zone area. The literature explains how the quality of water bodies indirectly affects CKDu. It has ever more increased to wide-ranging stages in rural farming communities of Sri Lanka over the last 20 years. (Wanasinghe et al., 2018)(Rango et al., 2015)

CKDu is a highly destructive disease with an unknown responsible cause and it is most common in men (Proportion of male: Female is 3:1) aged around 40 - 60 years, most of whom are farmers and agriculture workers. The only medical solution for this disease is dialysis or a kidney transplant. The cost of dialysis for CKDu patients has become a serious problem for the government health authorities. 95 % CKDu persons live in Rural areas in Sri Lanka. (Wanigasuriya, 2012)

Many factors affect CKDu within the dry zone area. In the past 10 years, several risk factors have been proposed to be hypothesized to cause CKDu. These include aluminum utensils, drugs, alcohol, smoking, chemical contamination, use of contaminated water and food, lack of safety measures in the use of agrochemicals and toxic and

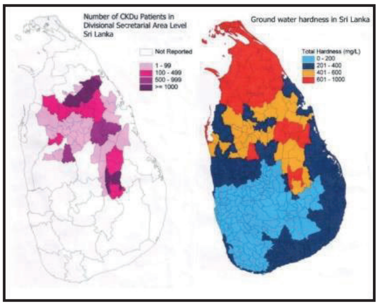

Figure 01: Prevalence of CKDu patients in Dry zone areas (Jayasumana et al., 2014)

harmful agricultural practices, and consumption of contaminated water from paddy fields and other agricultural activities. Drinking well water due to groundwater contamination has led to the development of the disease (Wanasinghe et al., 2018) (Wanigasuriya, 2012) (Gunatilake et al., 2015)

1.2 Groundwater quality in CKDu areas

Sri Lanka has a total land area of 65000 km^2 where 20 million people live. The climate varies widely from arid to semi-arid except in its uplands and southwest quadrant. Annual rainfall in the dry zone is less than 1500 mm in the temperature range of 25-30 °C, but in the humid zone, it exceeds 2500 mm annually (Chandrajith *et* al., 2012). The majority of Sri Lanka's population depends on groundwater sources for consumption. People in the rural dry zone suffer a lot from water shortages and also raw groundwater has been the main source of drinking water for farmers in the dry zone for several years(Indika et al., 2021). Many areas of the dry zone suffer from health problems associated with high fluoride concentrations in drinking water (Kurisu et al., 2016). Groundwater is the main source of drinking water in

Wilgamuwa, an area where chronic kidney disease of unknown etiology (CKDu) is prevalent (Galketiyahewage et al., 2021). In most parts of the dry zone, people use dug wells or tube wells as drinking water sources. Conventional water treatment technology used in Sri Lanka is not capable of removing excess dissolved minerals and nephrotoxins from groundwater in the dry zone(Cooray et al., 2019)

1.3 Nanofiltration Technology in Drinking water

Nanofiltration (NF/RO) is a membrane-base separation technique that is a process between reverse Osmosis (RO) and Ultrafiltration (UF). NF/RO membranes have moderately loose structures that allow speedy water production and low energy requirements. NF/RO membranes can be designed and used in a more flexible way to maximize the efficiency of safe drinking water production according to different applications. These membrane technologies have improved and improved separation performance has been achieved by tuning their material compositions and structural properties. There are many advantages as lower energy consumption, smoother operation and maintenance than other methods, and, the high-pressure NF/RO membrane process which is accomplished by generating large volumes of high-quality water. This technology is widely used for many types of water treatment. That is drinking water, domestic wastewater, chemical industry water, and pharmaceutical industry water. NF/RO membrane technology is capable of removing dissolved organic molecules and viruses. Most importantly, it can partially treat a significant number of dissolved salts. As an alternative to RO, this property of NF/RO can be used to retain filtration natural water signatures. (Guo et al., 2022)(Cooray et al., 2019)(Mohammad et al., 2015)

1.4 Electrodialysis Reversal technology in drinking water

EDR is a water treatment technology that uses a variation of the electrodialysis process. This technology was introduced to avoid organic fouling on membranes. In a short time, it has become the go-to technology for the desalination process due to its economical nature and reliability for reusing water. In Sri Lanka, it is used to purify contaminated drinking water. The EDR uses direct current (DC) to transfer ions from the source stream to a concentrated stream. The ions travel through the cathode to an anode. This produces a more dilute stream of the source water stream. It uses electrode polarity reversal to automatically clean the membrane surface. The EDR membrane stack in between a cell pair composes the basic structure of an EDR unit.(Valero & Arbós, 2010)(Schorr, 2011) The stack in between the cell pair consists of membranes and spacers namely: Anion permeable membrane,

Concentrate spacer, Cation permeable membrane, Dilute stream spacer Water quality parameters of samples collected from EDR and NF/RO plants were compared with each other and with WHO guidelines and SLS standards with the intention of determining the best technology for the country and ensuring the quality of the treated water from both technologies

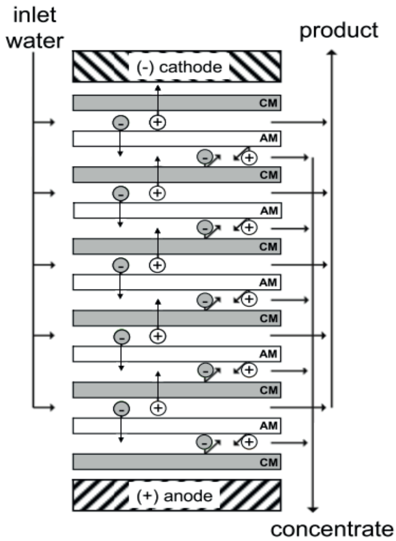

Figure 02: EDR Process Diagram

2. Material and methods

2.1 Study areas and sample collection

The groundwater quality in these areas is suspected to be the cause of this issue. Water filtration technologies including electrolytic reversal (EDR) and nanofiltration (NF/RO) were established to facilitate safe drinking water in affected areas. Five NF/RO plants were installed in Wilgamuwa – Hasalaka area; Abagahapalassa, Asamodagamyaya, Mahayaya, Udayagala, Dahamigam, and Kahatagasdigiliya EDR plants located in the dry zone of Sri Lanka.

The 05 NF/RO water plants were examined and water samples (Feed, Treated, and Concentrate) were collected for water quality analysis to evaluate the performance of each NF/RO system. The sociological information of each NF/RO Plant was collected through a questionnaire filled out by the villagers. The Questionnaire was focused on the NF/RO system basic information, quality of groundwater and Treated water, opinions on NF/RO technology, challenges, recommendations, and the number of CKDu patients in this area. The Existing data of the EDR System was analyzed and a comparison of the Technologies.

2.2 Water Quality analysis

All the NF/RO water samples were analyzed In the Joint research and demonstration Centre for water technology (JRDC), Ministry of Water Supply, Kandy, Sri Lanka. Onsite measurements were obtained for electric conductivity (EC), pH, and Turbidity while hardness, total dissolved solids (TDS), anion concentrations (F^-, Cl^-, Br^-, NO_3^-, SO_4^{2-}, PO_4^{3-}), and heavy metal concentrations (Mn, Li, Al, Fe, As, Cr, Zn, Pt, Cu) were measured in the laboratory. Anions were measured using an Ion Chromatography instrument (Eco IC, Metrohm, made in Switzerland; Shine, Made in China). Elements were measured using Inductive Coupled Plasma Mass Spectroscopy (ICAP RQ, Thermo scientific) in the JRDC.

The Total Dissolved Solids (TDS) were measured in the laboratory. The Total Hardness was determined by the Titration method and Ca^{2+} and Mg^{2+} concentrations in the water samples were determined using the following equation:

$$\text{Hardness (EDTA)} = \frac{(A \times B \times 1000)}{\text{mL Sample}}$$

Where: A=mL titration for sample,
B= mg $CaCO_3$ equivalent to 1.00 mL EDTA titrant

(Standard Method for the examination of water and wastewater, 23rd Edition)

2.3 Data analysis

On-site parameters (EC, Turbidity), mineral salts (hardness and anion) rejections, permeate recovery, and ion permeability was used as key performance criteria in EDR and NF/RO technologies. Results obtained from EDR and NF/RO plants were compared and were countered parted with SLS (614,2013) and World Health Organization (WHO 4th edition, 2011) guidelines. Microsoft office professional plus 2016 (64-bit, build 15427.20210), and Google Earth Pro (Keyhole, Inc, Google, 64-bit) software were used to analyze water quality and other data. Equations used for calculations of rejection are given below.

$$\text{Percentage(\%) of Rejection} = \frac{(Cf-Cp)}{Cf} \times 100\%$$

Where:

Cf - influent concentration of a specific component mg/L

Cp – Permeate concentration of a specific component mg/L

3. Results and Discussion

NF/RO systems use groundwater as the primary feed water source. A significant number of samples showed to had elevated and unacceptable levels of some parameters such as anions in the feed water (Groundwater). This groundwater exceeds the guidelines given by WHO and SLS. These NF/RO and EDR techniques showed significantly increased removal rates of dissolved constituents in groundwater (Tables 1 and 2). This NF/RO and EDR technology can increase the removal rate of hardness and other anionic constituents in groundwater. Furthermore, the removal efficiency of the NF/RO unit and EDR unit (Min, Average, Max) was compared.

4. Conclusion

Chronic Kidney Disease of Unknown Etiology is one terrible and major issue found among people living in the dry zone areas of Sri Lanka. It has come to light that drinking water may have a significant effect on CKDu. Hence, to reduce the levels of unwanted ions in drinking water, the EDR and NF/RO units have been introduced. This study focused on comparing the efficiency of NF/RO plants and EDR plant for removal efficiencies of unwanted ions from water. The water recovery and removal efficiency of the NF/RO plant was higher than that of EDR. However, parameters such as initial cost for plant installation, maintenance cost, durability, ability to use on a large scale, etc. should be considered to determine the best over the other

Table 01 - Summarization of Removal efficiency from EDR unit

EDR Filtration System - Kahatagasdigiliya				
Parameters	Units	Removal Efficiency (%)		
		Min	Average	Max
Turbidity	NTU	7	36	88
Electric Conductivity (EC)	µS/cm	12	24	35
Total Dissolved Solids (TDS)	mg/L	8	28	48
Hardness	mg/L	15	41	68
Sulfate	mg/L	25	56	88
Fluoride	mg/L	3	23	51
Chloride	mg/L	14	33	50

Table 02 - Summarization of Removal efficiency from NF/RO Unit

NF/RO Plants Hasalaka- Wilgamuwa area				
Parameters	Units	Removal Efficiency (%)		
		Min	Average	Max
Turbidity	NTU	15	68	98
Electric Conductivity (EC)	µS/cm	74	84	89
Total Dissolved Solids (TDS)	mg/L	58	81	91
Hardness	mg/L	45	76	89
Sulfate	mg/L	83	95	98
Fluoride	mg/L	80	93	96
Chloride	mg/L	76	92	97

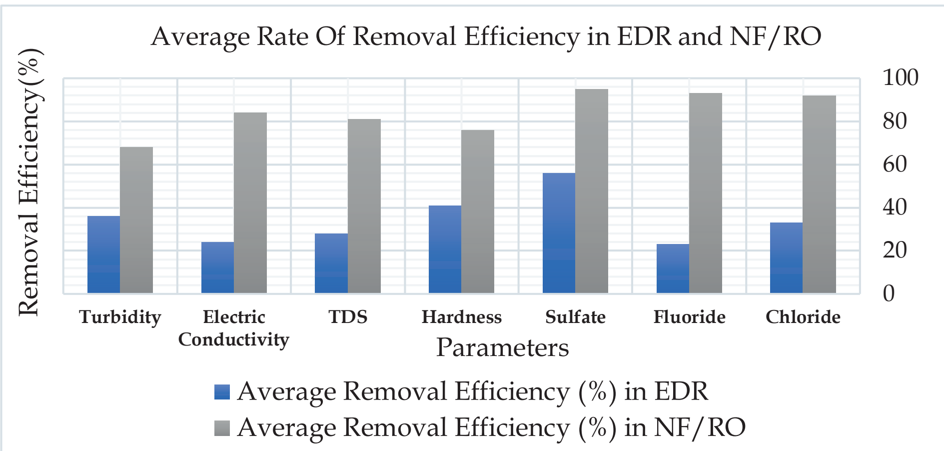

Figure 03 – Comparison of Average removal efficiency of EDR and NF/RO unit

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