International Research Symposium
Rajarata University of Sri Lanka

IRSyRUSl 2015

Can Concentrate Discharge of Reverse Osmosis Water Purification Plants Use for Irrigation?

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ABSTRACT

Reverse osmosis (RO) plants are the most effective drinking water treatment method, widely used in chronic kidney disease of unknown etiology (CKDu) affected areas in the North Central Province. The rejected water from the RO plant is known as the RO concentrate which is normally released to the environment without any beneficial use. An experiment was conducted in a farmer field adjacent to the RO plant installed in Thambalagollawa in Medawachchiya divisional secretariat division to study the possibility of using the RO concentrate as a source of irrigation water. Treatments were arranged in split plot design with three replicates. Irrigation treatments as RO concentrate and agro-well water were considered as the main plot and brinjal, chili and bare soil were considered as sub plots. Soil samples were taken before planting and during harvesting to study the pH and electrical conductivity (EC) changes of soil. Plant growth parameters were measured during the growing stage and 50% flowering stage. Water quality of both RO concentrate and agro-well water were measured. All data were analyzed using statistical analysis system using ANOVA procedure. Based on growth and yield parameters no significant difference ($p>0.05$) was observed between irrigation treatments. Soil analysis revealed that, RO concentrate has significantly enhanced ($p<0.05$) EC of soil compared to the agro-well water. According to the results, no heavy metals were detected in water. Salinity level based on EC, agro-well water and RO concentrate were slight to moderate restriction for use as an irrigation water. It can be concluded that, there is a potential of using the RO concentrate as an irrigation source for both brinjal and chili. However, remedial measures should be taken to control further development of soil salinity.

KEYWORDS: *Agro-well water, Growth parameters, Reverse osmosis, RO concentrate*

1 Introduction

Chronic kidney disease of unknown etiology (CKDu) is the most serious health problem faced by the people in North Central Province especially in *Medawachchiya, Kahatagasdigiliya* and *Horowpothana* areas. More than 90% of extensive agricultural communities are predominantly affected by CKDu(Wimalawansa, 2013). Farmers in these areas use excessive amounts of agrochemicals for their cultivation and some of them are accumulated in the soil and water. With time, these chemicals are percolated to the groundwater and as a result people drink chemically polluted water. Polluted water/foods, worse environmental conditions, irrigation methods and agricultural habits, chemical fertilizers and overuse of toxic agrochemicals play a major role in causing this disease (Weeraratna, 2012).

Currently, National Water Supply and Drainage Board (NWS&DB) has started a new project installing Reverse Osmosis (RO) plants in CKDu affected rural areas to provide safe drinking water for them (NWS&DB, 2010). RO systems remove heavy metals, such as cadmium, arsenic, lead, and copper, and volatile organic compounds, sodium, nitrates, phosphate, fluoride, total dissolved solids (TDS), and agrochemicals (Chian*et al.,* 1975). In RO system, raw water is delivered under pressure through the semi permeable membrane, where water permeates through the minute pores of the membrane and is delivered as purified water called permeate. Impurities in the water are concentrated in the reject stream and flushed to the drain is called concentrate (Garud*et al.,* 2011).Normally permeate taken for drinking and concentrate release to the environment without any beneficial use. Direct dispose of this RO concentrate to the environment for long time may cause the environmental pollution due to high concentrations of pollutants. There are some possible ways of discharging or reusing the RO concentrate such as disposal into surface water bodies, evaporation ponds, disposal through pipelines to municipal sewer systems, shrimp breading, hydroponic cultivation of salt tolerant plants (halophytic crops) and as irrigation source (Chian*et al.,* 1975).

In dry zone, water is the major constrain for agriculture and livelihood since limited availability and low quality (Kendaragama, 2000). If there is any potential to use RO concentrate as an irrigation source, it may be good solution for water scarcity while controlling the environmental hazards that might be generated due to unsafe disposal of RO concentrate.

Hence, this study was conducted to identify the potential use of RO concentrate as irrigation water and find out its effect on few soil properties and plant growth.

2 Materials And Methods

Field experiment was conducted in a farmer field adjacent to the reverse osmosis (RO) plant installed in *Thambalagollawa* village which is located in the *Medawachchiya*divisional secretariat in Anuradhapura district which belongs to DL_{1b} agro-ecological region of Sri Lanka.

Treatments were arranged in split plot design with three replicates. Irrigation sources as RO concentrate and agro-well water were considered as main plots and brinjal (Var. *Padagoda*), chili (Var. KA-2) and bare soil were considered as the sub plots.An area of 216 m^2 was prepared into three blocks. Each block was divided into six plots with the size of a single plot is 3 m x 4 m. There was a 1.5 m allay area between irrigation treatments to control the effect of seepage. Drip irrigation was practiced to irrigate sub plots according to their crop water requirement. Total crop water requirement of the chili and brinjal were calculated separately using the equation 01. Average amount of chili and brinjal water requirements was applied to the bare soil using drip irrigation.

Irrigation efficiency was assumed as 90%.

$$ET_{crop} = K_c \times ET_0 \qquad \text{Equation 01}$$

Where,

ET_{crop}=water requirement of a given crop in mm/day

K_c = crop coefficient

ET_o= Reference crop evapotranspiration in mm/day

Three types of data were collected as selected soil chemical parameters, physicochemical parameters of water and plant growth parameters. Soil samples were analyzed to estimate pH and electrical conductivity (EC) before planting and during the harvesting to study the changes due to the RO concentrate and agro-well water.

Plant growth and yield parameters were measured using both destructive and non-destructive methods. Plant height, number of branches and number of leaves were measured in randomly selected five plants from each plot and these measurements were commenced from two weeks after transplanting and continued up to 50% flowering stage in two weeks interval. At the 50% flowering stage, number of flower buds were counted in randomly selected five plants from each plot. Leaf area, root length and total bio mass of crops were also measured in this stage. At the harvesting stage, yield per plot was estimated.

Water samples of the RO concentrate and agro-well water were collected in two weeks interval during the cropping period. Water samples were analyzed to assess the physicochemical parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), calcium (Ca^{+2}), magnesium (Mg^{+2}), carbonate (CO_3^{-2}), bicarbonate (HCO_3^-), sodium (Na^+) and potassium (K^+) using standard methods and procedures (Table 01). Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC) and Sodium percentage (Na %) were calculated for both RO concentrate and agro-well water using the measured parameters.

Following equations were used to calculate the SAR, RSC and Na %.

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \qquad \text{Equation 02}$$

$$Na\% = \frac{Na^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100 \qquad \text{Equation 03}$$

$$RSC = (CO_3^{2-} + HCO_3^- - (Ca^{2+} + Mg^{2+}) \qquad \text{Equation 04}$$

All ion concentrations in above equations were expressed in the unit of meq/l.

Table 1: Instruments and methods used for water quality analysis

Water quality parameter	Instrument/Method
pH	Multi parameter analyzer (HATCH, Sension 156)
Electrical Conductivity (EC)	Multi parameter analyzer (HATCH, Sension 156)
Total dissolved solids (TDS)	Multi parameter analyzer (HATCH, Sension 156)
Sodium (Na^+)	Flame photometer(Sherwood, Model 360)
Potassium (K^+)	Flame photometer (Sherwood, Model 360)
Calcium (Ca^{2+})	Atomic absorption spectrophotometer (BUCK Scientific)
Magnesium (Mg^{2+})	Atomic absorption spectrophotometer (BUCK Scientific)
Carbonate(CO_3^{-2})	Titration method
Bicarbonate (HCO_3^-)	Titration method

All the collected data were analyzed using analysis of variance (ANOVA) and means were separated following the Duncan's multiple range procedure.

3 Results and Discussion

Soil chemical properties

Soil pH and EC play a significant role in plants' nutrient absorbance. Therefore analysis of Soil pH and EC is vital in understanding plant nutrient availability of soil. Results of pre planting soil analysis revealed that, all plots are homogeneous ($p>0.05$) in terms of pH and EC of soil. With compared to the initial conditions, both irrigation treatments were significantly increased ($p<0.05$) the soil EC and pH levels during the harvesting period. Further, soil EC level has significantly enhanced ($p<0.05$) by RO concentrate compared to the agro-well water. These results agreed with previous studies conduct with soil application of the RO waste water to the pasture land by Mohannad (2013). There were no any significant variations were observed among the sub plots, confirmed that there was no effect on chili and brinjal in changing the pH and EC of soil in experimental field.

Water quality

Ca^{+2}, Mg^{+2}, Na^+ and K^+ concentrations

Quality and yield of a crop depends on irrigation water quality. Further water quality is vital in maintaining the land productivity and environment protection. Irrigation water quality can be determined by the physicochemical analysis of water. Certain water quality parameters such asCa^{+2}, Mg^{+2}, Na^+ and K^+ concentrations were determined and results revealed that those cation concentrations were within the acceptable range in both RO concentrate and agro-well water (Table 02).

Table 2: Water quality parameters of RO concentrate and agro-well water

Quality parameter	Concentrate (mg/l)	Agro-well water (mg/l)	Accepted level for irrigation (mg/l)*
Calcium (Ca^{2+})	433	263	0 - 800
Magnesium (Mg^{2+})	104	65	0 - 120
Sodium (Na^{+})	37	24	0 - 900
Potassium (K^{+})	3.8	2.2	-

* (Ayers and Wescot, 1985)

HCO_3^- and CO_3^{-2} concentrations

Alkaline compounds in water such as bicarbonates (HCO_3^-), carbonates (CO_3^{-2}) and hydroxides (OH^-) lower the acidity of the water by combining with H^+ ions to make new compounds. Concentrations of the HCO_3^- ions were higher in the RO concentrate than the agro-well water. Acceptable range of HCO_3^- in irrigation water is 0 to 610 mg/l (Ayers and Wescot, 1985). Agro-well water was within this range while RO concentrate exceed the acceptable range of HCO_3^- in irrigation water.

Electrical conductivity (EC)

Electrical conductivity of the water is due to the presence of dissolved salts in the water. Irrigation water can be classified as no restriction (<0.7 dS/m), slight to moderate restriction (0.7-3.0 dS/m) and severe restriction (>3.0 dS/m) based on EC of water (Ayers and Wescot, 1985). Average EC values of RO concentrate and agro-well water were 2.15 dS/m and 1.23 dS/m respectively. According to the above classification, both waters can be categorized as slight to moderate restriction for irrigation.

pH

The average pH levels of RO concentrate and agro-well water were 7.44 and 7.35 respectively. Results revealed that, there was no significant difference of water pH among the RO concentrate and agro-well water. Both waters were within the acceptable level of pH (6.5 -8.4) for irrigation (Ayers and Wescot, 1985).

Total dissolved solids

The RO concentrate showed significantly higher TDS content (1378 mg/l)compared to agro-well water (789 mg/l). Significantly higher TDS content is resulted by the over 99% of rejection of TDS by RO filter membrane(Wimalawansa, 2013).

Sodium Hazard

Sodium Percentage (Na %)

Average Na % of RO concentrate and agro-well water were 5.0% and 5.3% respectively. Irrigation water can be classified as excellent (<20 %), good (20-40 %), permissible (40-60%), doubtful (60-80%) and unsuitable (>80 %) based on sodium percentage(Ayers and Wescot, 1985). According to the results, both waters can be classified as excellent water for irrigation in terms of Na%

Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio relates the concentration of Na to the concentration of Ca and Mg. The higher Na concentration compared to Ca and Mg concentrations leads to higher SAR values and cause to poor water infiltration. Results revealed that, SAR values of RO concentrate and agro-well water were 0.4 and 0.3respectively.

Bicarbonate hazards

Bicarbonate hazard is usually expressed in terms of RSC (Residual Sodium Carbonate).RSC value of the RO concentrate and agro-well water were -13.5 meq/l and -6.0meq/l respectively. Negative values of RSC are caused by the higher concentration of the Ca^{+2} and Mg^{+2} ions compared to CO_3^{2-} and HCO_3^- ions. Generally water with RSC value of 1.25 or lower is safe for irrigation; water with RSC between 1.25 and 2.5 is marginal and more than 2.5 is probably not suitable for irrigation (Ayers and Wescot, 1985). According to that classification, RO concentrate and agro-well water can be classified as suitable for irrigation.

Plant growth parameters and yield

There were no significant differences($p>0.05$)in all measured plant growth parameters (plant height, number of leaves per plant, number of flower buds per plant, average leaf area, root length and total bio mass) and yield. These results indicated that chili and brinjal crops performed equally with both RO concentrate and agro-well water despite their water quality differences.

4 Conclusions

Based on pH, SAR, Na% and RSC, both RO concentrate and agro-well water can be classified as safe water for irrigation. TDS and EC values showed that, both RO concentrate and agro-well water are in slight to moderate restriction level for irrigation. Plant growth and yield parameters showed that, RO concentrate can be successfully used to irrigate chili and brinjal crops without any penalty on plant growth and yield. However, RO concentrate significantly enhanced the soil salinity with compared to the agro-well water. Therefore it can be concluded that RO concentrate has good potential to use as irrigation water source with proper application of remedial measures to control salinity development. Since agro-well water are also showed slight to moderate restriction to use as irrigation water, remedial measures to control salinity development are also required in using agro-well water for irrigation.

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