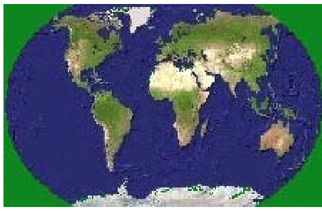
International Journal of Multidisciplinary Research and Development



International Journal of Multidisciplinary Research and Development

Volume: 2, Issue: 10, 104-110
Oct 2015
www.allsubjectjournal.com
e-ISSN: 2349-4182
p-ISSN: 2349-5979
Impact Factor: 5.742

Dr. Sachin Madhavrao Kanawade
Dr.Vasantraodada Patil Shetkari Shikshan Mandal's Padmabhooshan Vasantraodada Patil Institute of Technology, Budhgaon, Tal – Miraj, Dist – Sangali, Maharashtra– 416304, India.

Correspondence
Dr.Sachin Madhavrao Kanawade
Dr.Vasantraodada Patil Shetkari Shikshan Mandal's Padmabhooshan Vasantraodada Patil Institute of Technology, Budhgaon, Tal – Miraj, Dist – Sangali, Maharashtra– 416304, India.

Laundry Wastewater Reuse in Irrigation and its Effects on Soil

Dr. Sachin Madhavrao Kanawade

Abstract
In order to investigate the effects on soil hydrologic parameters for grey water irrigation, series of soil column (composed of several PVC rings) experiments was conducted using medium grain sand (d_{50}=0.52mm) under water-unsaturated condition for different grey water concentration. In each experiment, pH, EC and hydraulic conductivity were measured. At the end of each experiment, the column was dismantled and moisture content in each ring was measured gravimetrically and the soil suction in each ring was measured from the reference groundwater table. The breakthrough curves with EC value and the measured value of pH at the column outlet revealed that the grey water with higher concentration reach the column outlet faster because of increased hydraulic conductivity. Separate experiments were conducted for surface tension reduction for different grey water concentration and found that the surface tension becomes constant when it reaches 280mg/L. This value may be considered as the critical micelle concentration (CMC) for the laundry detergent used in this study. The pressure-saturation curves obtained for different experiments shows that the reduction of capillary rise stops when the grey water concentration reaches towards the CMC value.

Keywords: Grey water, Soil, Irrigation, Surfactant, Surface tension

1. Introduction

Water is the most precious resource, and arid and semi-arid regions may face enormous shortage of potable water in the coming decades because of the global climate change. In many countries, people are increasingly becoming aware of the need to preserve water because of the scarcity of potable water. Grey water reuse in irrigation may be one of the best options to save potable water. Grey water is a non-toilet component of household wastewater that is generated from bathtubs, showers, sinks, washing machines and dishwashers. Among these sources, laundry grey water may be considered as one of the best choices for reuse in irrigation because grey water originating from other sources (especially kitchen) may contain oil and grease [1]. A common misconception regarding the relative cleanliness of grey water for home garden irrigation has led to reuse it without sufficient treatment which has resulted in several environmental pollutions and health hazards [2]. Reuse of grey water is now becoming common in many arid and semi-arid regions in the world including Australia. In a typical household in Western Australia, total generation of grey water is 117 l/d per person [3]. Laundry and bathroom grey water contributes about 89% of this volume, which can be reused for the lawn/gardening watering. The domestic wastewater may generate effluents with reduced level of nitrogen, solids and organic matter, but often contain higher level of surfactants, oils, boron and salt [4-5]. These components of grey water may have harmful effects on soil, plants and underground water. Surfactants are the major components of detergents found in domestic wastewater which have hydrophilic head and hydrophobic tail [4-5]. Surfactant molecules in aqueous solution accumulate onto the different interfaces (such as, liquid/liquid; liquid/air or solid/liquid interfaces), increases the distance between the water molecules and therefore causes the reduction of surface tension [6]. Reduction of surface tension in surfactant-rich grey water may change the underlying soil structure and thus the soil-water environments, which are ignored in most of the cases. Interaction between laundry grey water and the saturated soil has been studied to quantify the soil hydraulic conductivity [7] in different soil samples. Shafaran *et al*. [4] suggested that accumulation of surfactants from grey water may lead to water repellent soil with significant impact on agricultural productivity and environmental sustainability. But still limited information is available regarding the effects of surfactants, commonly present in laundry and household detergents, on hydro-physical properties of soils in the aquifer [4-5]. There is still information gap regarding the potential environmental impacts due to unregulated use of grey water in irrigation [5]. In my previous study, OMO laundry grey water was irrigated and the changes on soil properties were observed [8]. The surface tension reductions were not studied. In this study, separate laundry detergent (DUO) is used for grey water irrigation and the possible changes of different soil hydrologic properties are investigated. The main aim of this study is to correlate the surface tension reduction with that of the changes of different soil hydrologic parameters especially capillary rise. The experiments are conducted in a special type of soil column designed to represent the real aquifer system [6].

2. Materials and Methods

2.1 Materials

A medium sand (d_{50}=0.52mm; ρb=1.37 g/cm^3; n=0.42 cm^3/cm^3; Ks=38.48 m/d) was selected as the porous matrix for this study. The soil medium was washed for several times using tap water and oven dried (at 105°C for 24 hrs) before sieve analyses (Method AS1289). The DUO 2X Ultra Concentrated Top Loader Aromatic Detergent Powder is selected as laundry detergent for grey water preparation based on the availability of required information in the literatures [9]. The concentrations of laundry grey water were calculated based on the full washing capacity of a washing machine and following the given instructions of DUO washing powder. Normal load wash and three cycles of wash and rinse were assumed and the grey water concentrations used in the experiments were, 0.316g/L, 0.368g/L, 0.442g/L. 0.6g/L and 0.736g/L.

2.2 Column Experiments

The experiments were conducted in a laboratory soil column composed of several PVC rings of 9 cm inner diameter and 3 cm length as shown in Fig. 1. The column was packed successively with the soil in small increments under water saturated condition and tapped at the bottom. This procedure ensured the elimination of any trapped air and layer formation during the packing process. The effective length of the soil column was 54cm. The column was kept saturated for 1 hour and the outlet tank was brought down and kept the water level of the outlet tank at the same level of the bottom of the soil column. This arrangement could maintain the water level at the bottom of the soil column referring to groundwater table. The column was kept in this position for 24 hours to equilibrate the system. After establishing equilibrium in the system, the grey water of known concentration was flushed through the column and pH and EC at column outlet were measured in every two minutes interval. Total pore volume of the column was calculated as 1443cm^3. Grey water irrigation continued until the EC of the column effluent became constant. To get constant EC at the column outlet, approximately 7 number of pore volume of grey water solution was flushed into the column for 120 minutes. The flow velocity of grey water flushing was on an average 3.11 cm/min. The column was again kept 24 hrs to establish equilibrium in the system and then the column was dismantled [6]. The moisture content in each ring was measured gravimetrically and the suction head corresponding to each ring was taken as the distance between the ring's mid-point and the bottom water level [6]. The same experiment was repeated for different grey water concentration and one experiment was done with tap water at the beginning to record the initial soil properties. The porosity of soil was taken as the saturated moisture content and the bulk density was calculated for each ring gravimetrically. Separate experiments were done with the same grey water concentration to calculate the soil hydraulic conductivity using constant head method. All the experiments were conducted at 22±1 ºC.

2.3 Measurement of Surface Tension

Surface tension of grey water with different concentration was measured by the Wilhelmy plate method [6], with the help of a surface tensiometer (Sigma 700). First, the platinum Wilhelmy plate was cleaned, burned on a Bunsen burner and 3/4 of the plate was wetted by the grey water solution. The plate was positioned hanging on a balance and the solution level was automatically increased until it touched the plate. The increase of the weight was recorded by the electronic balance and was converted to surface tension directly. The measurements were taken at the room temperature of 22±1 ºC for a range of grey water concentrations (0-500 mg/l).

3. Results and Discussion

3.1 Electrical conductivity of soil

Higher concentration of grey water contributes to higher Electrical Conductivity (EC). The EC of aqueous solution indicates the presence of salt and hence the salinity of the soil. Generally the tap water has EC of 420 µs/cm, but sometimes it may go up to 500 µs/cm plus. The salinity is an issue where laundry water is discharged over the soil in gardens and lawns. A salt is simply a compound that dissociates in water to form cations and anions. Salt in the washing powder is not the common salt that we use to cook. It's made up of cations such as, calcium, magnesium, and potassium and anions of sulphate, phosphate, nitrate, chloride and carbonate [4]. The breakthrough curves (BTC) of EC measurements are shown in Fig. 2. The BTCs indicate that the higher concentration grey water reach the column outlet faster. The normal electrical conductivity level for irrigation water is about 1ds/m while higher EC values are more likely to induce loss of plant production. The general plant health will be affected by increased salinity in irrigation water due to effects of increased salinity on the physiology of the plant and the effects of soil salts. The normal salinity level in laundry greywater is found between 800 µs/cm to 1050 µs/cm for normal load wash (one scoop of washing powder) and rinse water together. Most of cities discharge grey water into ocean without reuse it; therefore much attention was not paid on the effects of grey water on soil structures. Appropriate regulations are absent in most places to reuse laundry grey water. However, diluting laundry grey water before irrigation may be needed to maintain low levels of soil salinity.

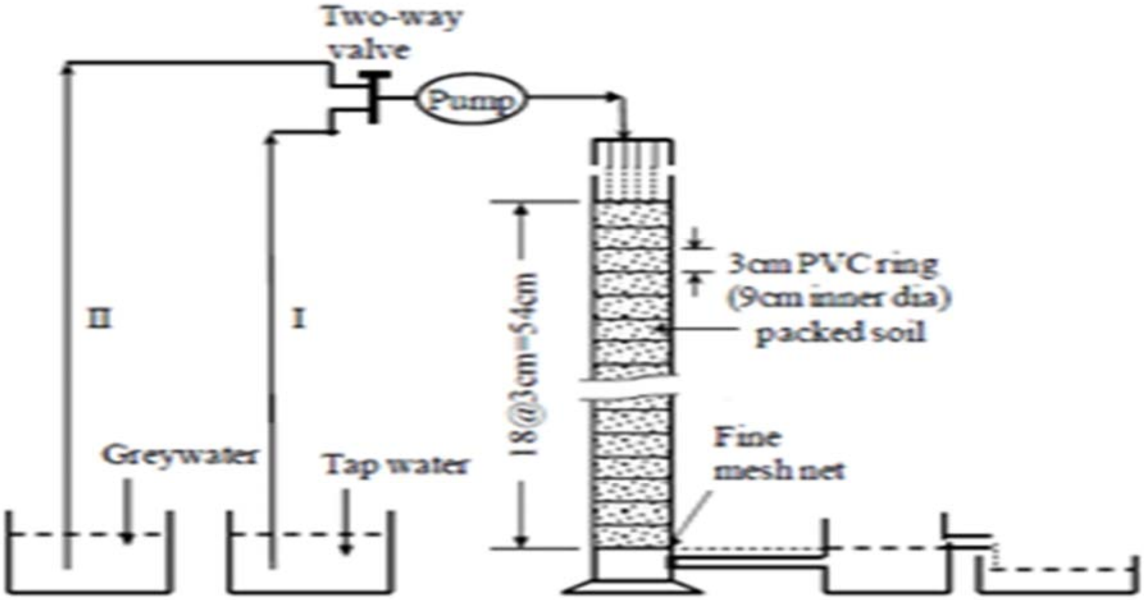


Fig. 1 Experimental setup

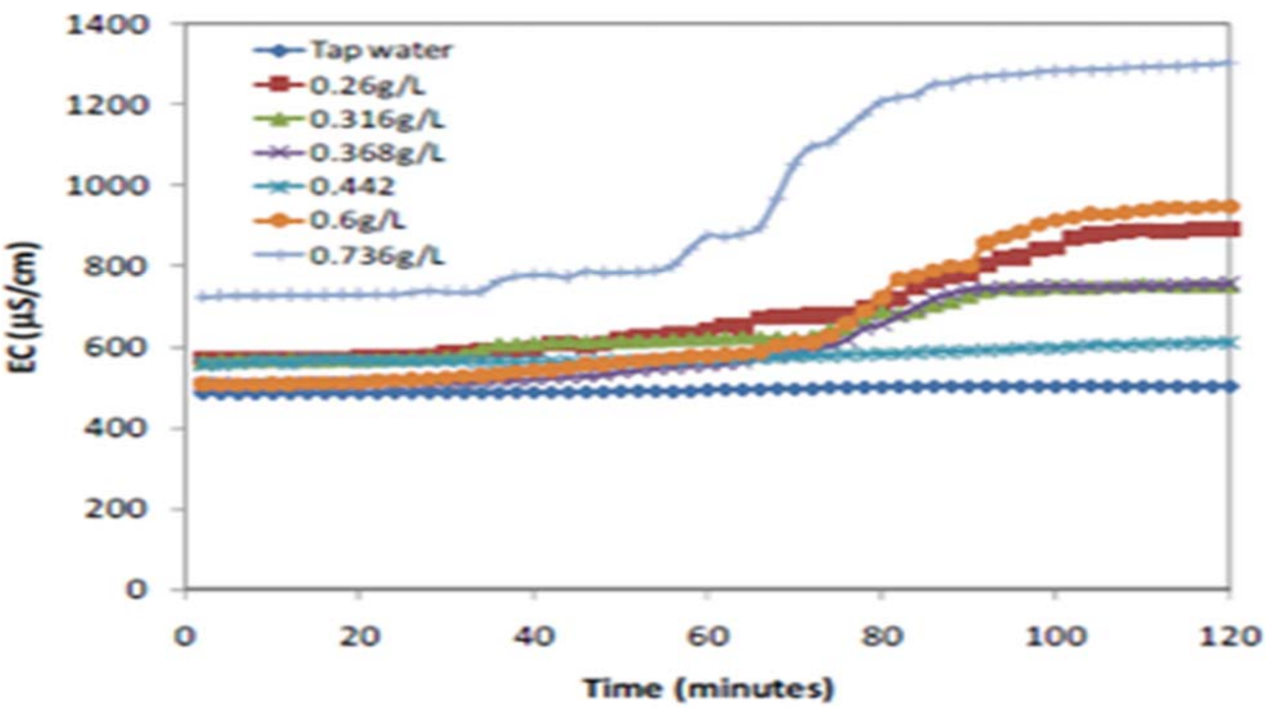


Fig. 2 Breakthrough curves with soil EC

3.2 pH of soil

The pH of column effluent was measured in every two minutes interval for each experiment and shown in Fig. 3. Results revealed that the pH value of column effluent starts to increase after 30 minutes for the lower range of grey water concentration (0-368mg/L) but it was obtained much faster in the higher concentration. This was because of the rapid changes of soil hydraulic properties. Higher grey water concentration with high pH value has the ability to dissolve organic matter, such as sweat, blood, food and also has adverse effect on skin [4]. The pH value was observed increasing with time which indicates that the grey water has the effect on soil environment to make it more alkaline. Therefore, one should be careful when handling the wash water where pH value is above 10. The pH value is related with soil structure and health of the plants. High pH value could lead to the dissolution of organic material and induces dispersion in the soil. This is because the detergent in the washing powder supposes to remove soils from clothes. Therefore high pH liquids act as dispersing agents, causing the soil particles to separate and lead to soil structure decline. The normal pH range for biological activity is between 5 and

9. If pH value reached more than 9, biological activity won't be happened in normal way and dissolved organic material can be leached out of soil [4]. The dissolved organic materials degrade in time to become plant nutrients, so a loss of organic material may be detrimental to plant health [5]. Therefore it is recommended to dilute the grey water to reduce pH before using for irrigation.

3.3 Hydraulic conductivity

Soil hydraulic conductivity depends on the type of soil, porosity and the pore size distribution. Saturated hydraulic conductivity with tap water and different grey water concentration were measured using constant head method and presented in Fig. 4. Hydraulic conductivity increases steadily with grey water concentration. This is because of washing the very fine particles and due to the reduction of surface tension. Increasing hydraulic conductivity also indicates that the soil may convert to be water-repellent due to the reuse of grey water in irrigation. As a result, overall water transmitting capacity increases and the water retention capacity decrease. Hydraulic conductivity is a very important soil property when determining the potential risks for widespread groundwater contamination by a contaminating source. Soil with high hydraulic conductivities and large pores for transmit water are likely candidates for far reaching contamination. This means increasing of hydraulic conductivity due to grey water irrigation may enhance the groundwater contamination.

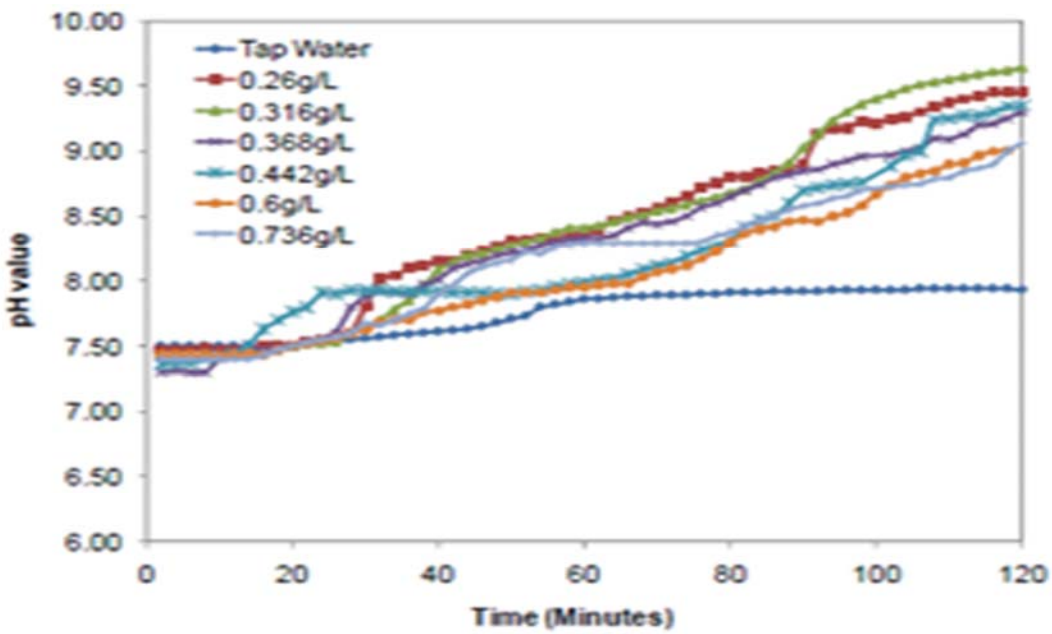


Fig. 3 Change of soil pH during greywater irrigation

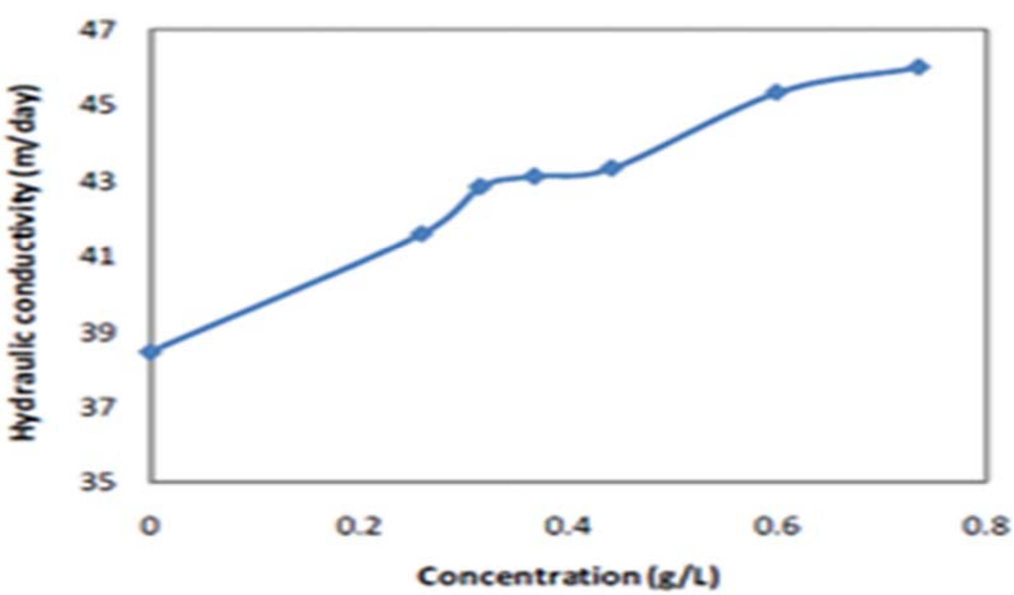


Fig. 4 Effect of greywater irrigation on soil hydraulic conductivity

3.4 Surface tension reduction and capillary rise

Accumulation of surfactant molecules onto different interfaces reduces the interfacial tension. As Grey water contains substantial amount of surfactant, it also reduces the surface tension. In this study, surfactant present in laundry detergent is unknown. For this reason, surface tension of grey water (as a whole) was measured for different concentration and presented in Fig 5. The concentration was converted to logarithmic value in order to fit the Gibbs adsorption equation [6]. When all the interfaces are saturated with surfactant molecules, there is no reduction of surface tension and hence the concentration refers to critical micelle concentration (CMC). The CMC value for the grey water used in this study was found as 280 mg/L. Usually CMC is determined for a specific surfactant but the surfactant in the detergent is unknown in this study. During each column experiments, the moisture contents in each ring were measured gravimetrically and the capillary rise was taken as the distance between the groundwater table and the mid-point of each ring. The pressure-saturation curves for each experiment are plotted in Fig. 6. Capillary rise is a phenomenon that can have both beneficial and detrimental effects on the soil. It is a main mechanism by which plants can draw water from below the root zone, but it is also a mechanism contributing to the accumulation of salts in the soil. The reduction of capillary rise with increasing grey water concentration is mainly because of the surface tension reduction as described by the capillary theory. Figure 5 revealed that the surface tension reduction continues until the grey water concentration reaches its CMC value. The reduction of surface tension consequently changes the migration pattern in the soil pores. Figure 6 revealed that the capillary pressure decreases sharply at the lower concentration of grey water but have a little effect at the higher concentration. This is because the surfactant monomers form micelles when the entire interfaces are saturated with monomers and the concentration reaches its critical value. Though the specific surfactant in DUO detergent is unknown in this study but several studies show that anionic and non-ionic surfactants are present in detergents. [4-5]. Shafran *et al*. [4] reported that it is only the surfactant in laundry detergent has the influence on the reduction of surface tension, not any other ingredients present in it. Another explanation for decrease in capillary pressure is embedded in the mechanism of surfactant adsorption onto the soil surfaces. Shafran *et al* [4] performed experiments with the pure surfactants normally present in laundry detergent such as linear alkylbenzene sulfonate (LAS) and found that the electrostatic bonds of negatively charged sulfonate groups interact with the positively charged sand surfaces causing the adsorption of hydrophobic tails of LAS monomers and protruding into the aqueous phase. These actions of surfactants enhance the soil to be water-repellent. A water-repellent soil (or hydrophobic soil) does not wet up spontaneously when a drop of water is placed upon the surface and thus it becomes a problem for future irrigation and enhanced environmental pollution. However, the information about water-repellent soil is inadequate in the literatures and it needs further investigation.

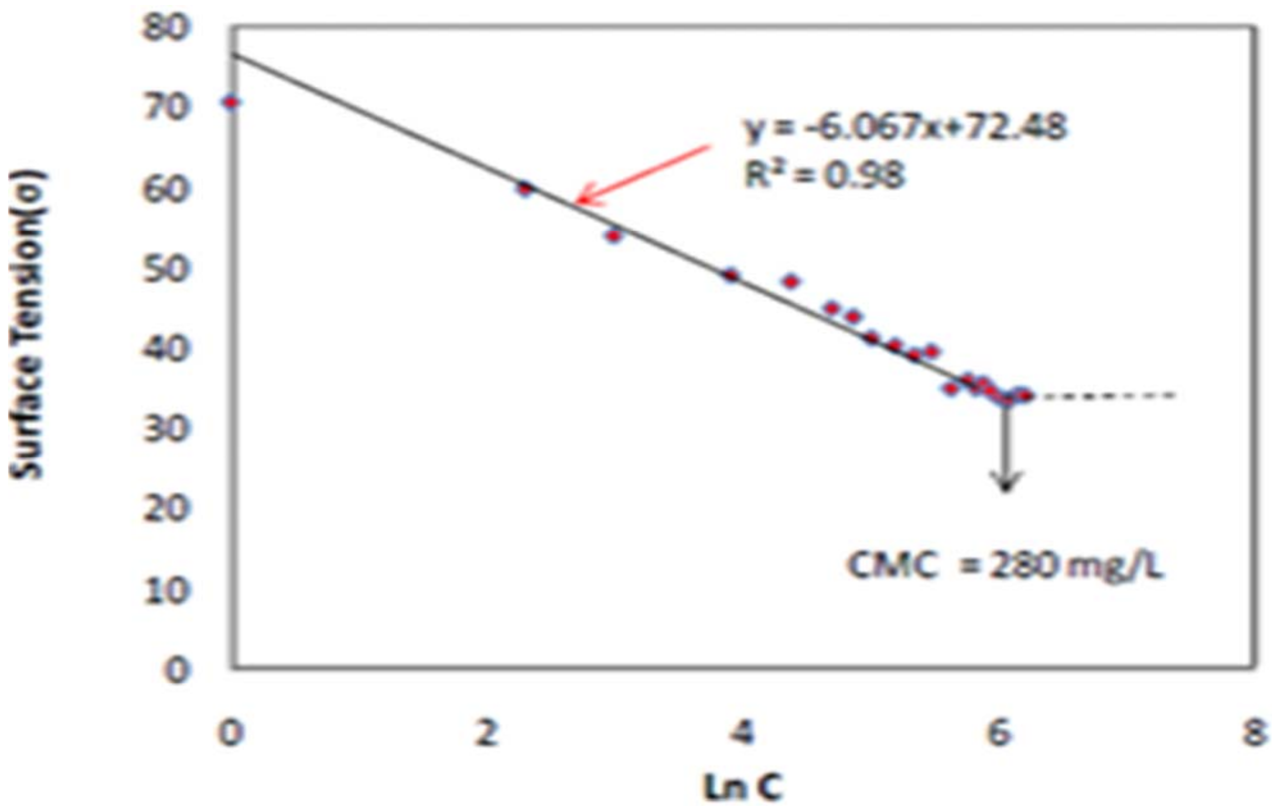


Fig. 5 Surface tension reduction of greywater

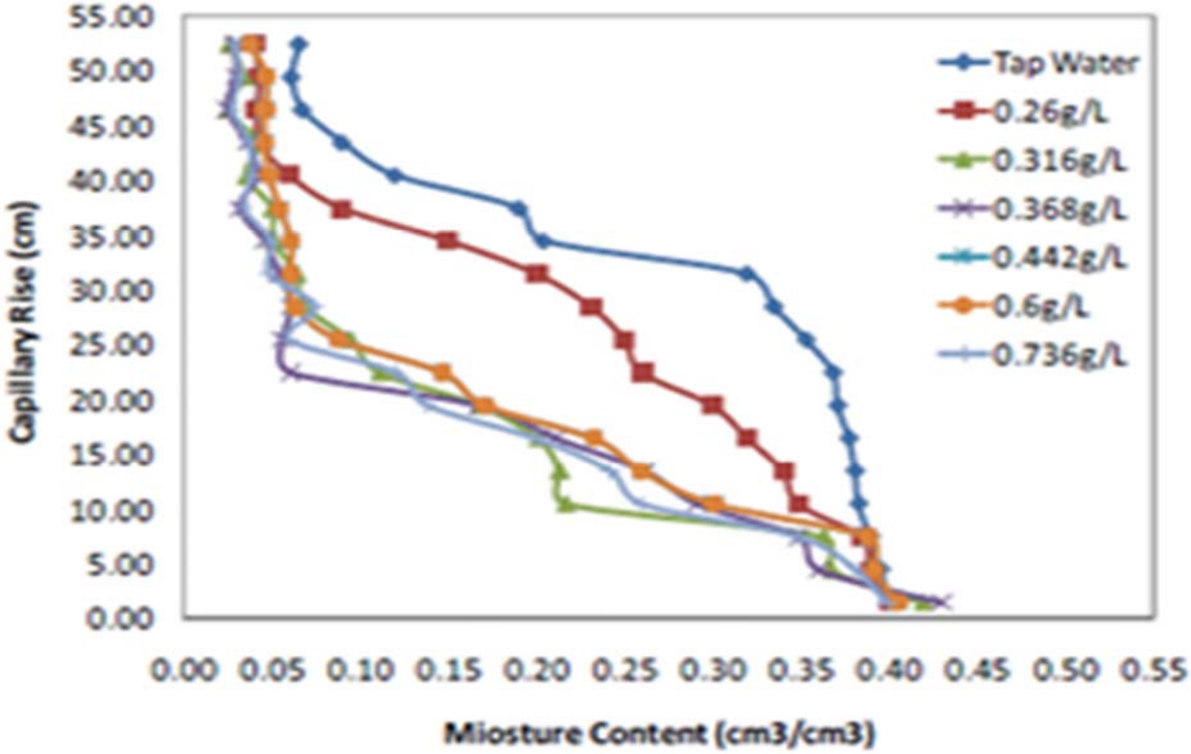


Fig. 6 Pressure-saturation relationship for greywater irrigation

4. Conclusion

The changes of different soil hydrologic parameters during grey water irrigation were investigated. A series of column experiments was conducted using a medium-grain sand for different grey water irrigation. The results of EC and pH revealed that the grey water reaches faster at the column outlet with increasing concentration. Soil hydraulic conductivity was observed increasing steadily with grey water concentration. Surface tension of grey water was observed decreasing steadily with increasing concentration and found constant at 280 mg/L which may be referred to the critical micelle concentration (CMC) of grey water. Usually CMC is measured for specific surfactant. But the surfactant in the laundry detergent was unknown in this study and the measured CMC stands for whole laundry grey water. Capillary rise in the column decreases sharply with grey water concentration but remain constant after CMC. The long-term irrigation of laundry grey water may lead to water-repellent soil and enhance future environmental pollution. The current knowledge on the causes of water-repellent soil is insufficient and further study is needed to understand the accumulation of surfactant in soil due to the reuse of laundry grey water in irrigation.

5. Acknowledgements

I am gratefully acknowledgements to my family & friends for their guidance and help in completion of this paper.

6. References

1. Travis, M.J., Weisbrod, N. and Gross, A., Accumulation of oil and grease in soils irrigated with greywater and their potential role in soil water repellency, Sci. Total Environ., 2008, 394 (1):68-74.
2. Gross, A., Azulai, N., Oron, G., Ronen, Z., Arnold, M. and Nejidat, A., Environmental impact and health risks associated with greywater irrigation: a case study,Water Sci. & Technol., 2005, 52(8):161–169.
3. DHWA (Deaprtement of Health Western Australia), Code of Practice for the reuse of greywater in Western Australia, 2005.
4. Shafran, A.W., Gross, A., Ronen, Z., Weisbrod, N. and Adar, E., Effects of surfactants originating from reuse of greywater on capillary rise in the soil, Water Sci. & Technol., 2005, 52(10-11):157-166.
5. Shafran, A.W., Ronen, Z., Weisbrod, N., Adar, E. and Gross, A., Potential changes in soil properties following irrigation with surfactant-rich greywater, Ecol. Eng., 2006, 26(4):348–354.
6. Anwar, A.H.M.F., Bettahar, M. and Matsubayashi, U., A method for determining air-water interfacial area in variably saturated porous media. J. of Contam. Hydrol., 2000, 43(2):129-146.
7. Misra, R.K. and Sivongxay, A., Reuse of laundry greywater as affected by its interaction with saturated soil, J. of Hydrol, 2009, 366(1-4):55–61.
8. Anwar, A.H.M.F., Effect of laundry greywater irrigation on soil properties, Journal of Environmental Research and Development, 2011, 5(4):863-870.
9. Lanfax Lab, http://www.lanfaxlabs.com.au/ (accessed August 15, 2010)

Author's Biography:

Dr. Sachin Madhavrao Kanawade was born in 11 March 1978 at Nashik, Maharashtra, India. His native place is Nimgaonpaga, Tal-Sangamneer, Dist-A'Nagar, Maharashtra, India. He received his Bachelor's Degree in Chemical Engineering from Pravara Rural Education Society's Pravara Rural Engineering College, Pravaranagar (Loni) which is affiliated to Pune University in India in Nov.2001.Then he worked as a Production Officer in different Multinational Chemical Industries in India (2001 to 2008) like M/S Watson Pharma Ltd, Ambernath, MIDC, Mumbai, MS, M/S Glenmark Pharmaceuticals Ltd, Mohol, Dist. Solapur, MS, M/S Sun Pharmaceutical Industries Ltd, A. Nagar, MIDC,MS for 7 years.

Then he changes his field. He joined K. K. Wagh College, Nasik, MS, India in 2008 & worked as Lecturer for 2 years. At the same time he received his Master of Engineering in Environmental Engineering from Pravara Rural Education Society's Pravara Rural Engineering College, Loni in Dec.2010.Then he joined Pravara Rural Education Society's Sir Visvesvaraya Institute of Technology, Chincholi, Tal-Sinnar, Dist-Nasik, M.S. India in 2010 & worked as Assistant Professor in Chemical Engineering Department for 5 years. In the same period he completed his PhD Degree in Chemical Engineering in session 2011 – 2014 from Kumar Bhaskar Varma Sanskrit and Ancient Studies University Nalbari, Assam, India.

Presently he is Associate Professor at Dr. Vasantraodada Patil Shetkari Shikshan Mandal's Padmabhooshan Vasantraodada Patil Institute of Technology, Budhgaon, Tal – Miraj, Dist–Sangali, Maharashtra, India in Chemical Engineering Department.

Presently he is Reviewer / Editorial Board Member / Advisory Board Member of 64 different International Journals of different fields. He having 21 International Professional Membership of different Organizations

He published 47 Technical Research Papers in different International Journals like International Journal of Wastewater Treatment & Green Chemistry, International Journal of Chemical Engineering, International Journal of Environmental Pollution Control & Management, International Journal of Multidisciplinary Approach & Studies, International Journal of Chemical Engineering & Applications, International Journal of Chemistry & Material Science & International Journal of Engineering Studies and Technical Approach etc.

His research topic includes & interested in Chemical Engineering, Environmental Engineering, Wastewater Treatment by Adsorption, Advanced Separation Process, Chemical Engineering Design, Mass Transfer, Chemical Process Synthesis, Chemical Engineering Thermodynamics etc.