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Recycling Reverse Osmosis Reject Water for Burnt Clay Brick Production

U.L.S. Yasarathne, T.W.L.R. Thalgaspitiya , T.A.B. Karunasinghe and B.C.L. Athapattu

Abstract: Chronic Kidney Disease of unknown etiology (CKDu) was identified in North Central Provincein 1990s. Then it started spreading over the next two decades in most of the farming areas not only in NCP but also,in other provinces. It has been widely accepted that the supply of potable water is one of the most important interventions to prevent the said disease. Therefore, strategies were implemented like installing Reverse Osmosis (RO) plants to supply potable water inCKDu affected areas. However, treated effluent of a plant varies from 30–50 %, so that a large amount of concentrate water releases to the environment without any beneficial use and it may create the environmental pollution in long-term practice. A project was carried out at Sangilikanadarawa RO plant, which is located in Medawachchiya DS division. The brick manufacturing process was implemented using two different water samples. One sample was from well water and other sample was from RO concentrate. Followed thefour steps; winning of clay, tempering, moulding, and drying, for brick manufacturing. 24 numbers of bricks were manufactured from each sample and carried out physical tests as soundness, hardness, and visual inspection. Laboratory tests were performed for dimension, compressive strength, water adsorption and efflorescence. All the Tests were carried out according to SLS 39:1978 standard. Results show that the compressive strength increases up to 9–52% using RO concentrate and water absorption and the efflorescence are within the standard limits. It can,therefore,be concluded that Reverse Osmosis concentrate can be used for industrial purposes such as brick manufacturing process in this area.

Keywords: Reverse Osmosis effluent, brick manufacturing, compressive strength, water absorption,efflorescence

1. Introduction

In 2008, the World Health Organization together with the Ministry of Healthcare and Nutrition launched anational research program for Chronic Kidney Disease of unknown etiology (CKDu) in Sri Lanka. But it was identified in the early 1990s and progressively increased to epidemic levels in rural farming communities, specifically in the North Central Province (NCP) of Sri Lanka [1, 2]. The greatest important source of employment of the majority of the NCP is considered as farmingspecially rice cultivation based on irrigation systems. The majority of NCP islow socio-economic farming families where more than 85% live in rural areas and have to use shallow/deep well water as a source of drinking and cooking purposes [3]. Medical statistics of the Anuradhapura General Hospital, which is the main hospital in the NCP indicated that there was a 227% increase in patients with end-stage CKDu, whereas the death rate increased by 354% during the year 1992–2006 [4]. The highest prevalence of CKDu occurs in the largest rice farming areas in Sri Lanka, and it is reported that approximately 99% of CKDu patients are farmers [5]. It was also found that the fluoride content of well water in all the areas with CKDu exceeded the WHO recommended level of 1 mg/L. The high fluoride in NCP can be explained by the fact that leaching of fluoride from soil in the wet zone and transporting it with groundwater towards dry-zone areas and the high concentration due to high evapotranspiration and slow rate of groundwater movement [6] and in the meantime WHO recommendation was to provide safe drinking water with low or no hardness to communities in CKDu endemic

Eng. (Dr.) B.C.L Athapattu, BSc. Eng (Moratuwa), MEng.(Osaka), PhD(Osaka) CEng. MIE(Sri Lanka), Senior Lecturer,, Department of Civil Engineering, The Open University of Sri Lanka.
Eng. T.W.L.R.Thalgaspitiya, BTech (OUSL), AMIE (Sri Lanka), Engineering Assistant, Planning & Design Section, NWSDB, Head Office, Ratmalana.
U.L.S.Yasarathne, BTech (OUSL), AMIE (Sri Lanka), Engineering Assistant, Planning & Design Section, NWSDB, Anuradhapura.
Dip.Eng,T.A.B.Karunasinghe, NDT (Civil Engineering), Engineering Assistant, Construction Section, NWSDB, Anuradhapura

areas by way of providing effective filters and/or delivering potable water with acceptable quality. Therefore, as an immediate solution, Reverse Osmosis (RO),which is a process used to remove a large majority of contaminants (dissolved inorganic solids) from solution (such as water) by pushing the water under pressure through a semi-permeable membrane, is introduced. The technology behind it can be used to remove particles, turbidity, cysts, bacteria, and even viruses depending upon the particle size [7] and this technology is promisingly used for desalinization of water in the Middle East and many other countries such as Singapore for wastewater treatment and reuse.

The RO systems remove much smaller dissolved particles than ultra-filtration or any carbon filters do. The RO membrane removes impurities in water, such as cadmium, arsenic, lead, and copper, and volatile organic compounds, sodium, nitrates, phosphate, fluoride, cysts, total dissolved solids (TDS), agrochemical and petrochemical contaminants, and pharmaceutical contaminants in a one-step procedure and in addition, salinity and various microbial and biological contaminants and its average purification efficiency is more than 90% [2]. As distilled and low mineral content water (TDS < 50 mg/L) can have negative taste characteristics to which the consumer may adapt with time, this water is also reported to be less thirst satisfies [8]. The reject water from RO plants called RO reject or RO concentrate, which is highly concentrated as it removes most of the minerals and components from inlet water to about 90 to 95% with an average of 40 to 50% of inlet water. The high BOD, COD, TDS and other impurities in RO rejectdepend upon the intake water quality and can make it unacceptable for discharge into the environment because of contaminatingwater bodies directly and soils with the removed dissolved salts and therefore, it is needed to be treated. But still, in Sri Lanka, the RO concentrate is directly released to the environment for irrigation use or dumped on the soil even though in Sri Lanka has a particular Standards and regulations to discharge wastewater to theenvironment under the National Environmental (Protection & Quality) Gazette published in 2008. Anyhow, if this will continue further it will damage the inland waters, aquifers, and soils in the near future. We therefore, suggested bricks manufacturing from RO reject to delaying the re-adding time of RO reject to the environment in NCP. Hence, we postulated that the bricks from RO reject may have a potential to be used for brick manufacturing with the required standard properties to the SLS standard.

Most ancient Stupa in Sri Lanka is solid structures, built mostly of burnt clay bricks. Over the years, the structural form of the Sri Lankan Stupa has changed from the original Indian form to a form of its own [9]. Also, the most basic building material for construction of houses and some buildings is the conventional clay bricks in Sri Lanka so that the clay brickshavean undefeated demand in the construction industry. The recent challenges of traditional brick manufacturing areto find out many alternative options for its raw materials as clay cutting for the bricks becomesan unavoidable hazard to protect the environment, and lack of water for brick manufacturing during the drought season. Many researchers use alternatives such as water-related sludge for brick manufacturing. The water treatment sludge [10], wastewater treatment sludge [11] and the sewage treatment sludge [12] are successfully used for burnet clay manufacturing. But, there is no any research on brick manufacturing using RO reject.

Table 1 - Specific requirements of burnt clay bricks to SLS 39; 1978

Characteristic	Type I	Type II	
		Grade I	Grade II
Average Compressive Strength not less than N/mm^2 (Clause 7.2)	10	4.8	2.8
Water Absorption not more than (Clause 7.3)	18	28	28
Efflorescence – Highest permissible rating (Clause 7.4)	Slight	Moderate	Moderate
Nominal dimensions of bricks	For all types of and grades		
Length mm	220		
Width mm	105		
Height mm	65		

2 Materials and Methods

The CKDu prevalence areas were focused to obtain the total number of RO plants in NCP. Through the NWSDB at Anuradhapura, the past records of water quality analysis of all RO plants were investigated and site for the pilot project was carefully selected after considering several factors such as close proximity to the RO plant, relevant community based Organization (CBO), and land availability. 20 cubic meters per day (20,000 l/day) RO plant was selected for this study. This is the highest capacity RO plant situated at SangilikanadarawaGramaNiladhari Division (GND) in Medawachchiya District Secretariat (DS) which is recorded as the highest number of CKDu patients in NCP.

The water source of the plant is a shallow well with a diameter of 9 m and the depth of 8 m, which is a covered well. According to the historical data, the well provides water throughout the year including dry season. The number of current beneficiariesof the RO plant is about 2300 personnel, and it includes partly some surrounded GNDs. About 5100 L/day is being provided as the treated effluent, which is only for drinking and cooking purposes. Basically, there are two types of bricks as Type I and Type II, which aremachine-made wire-cut bricks and handmade bricks, respectively. According to the compressive strength, handmade bricks classified into two groups, as Grade I and Grade II (SLS39:1978). As the usual method used in Sangilikanadarawa village for manufacturing clay bricks is handmade method;it was,therefore, selected in this project too.

2.1 Testing of Bricks

Tests were carried out according to the Sri Lankan Standard 39:1978, Specification for common burnt clay building bricks. All four Parameters specified in the specification were tested in order to assess the quality of bricks such as dimensions, compressive strength, water absorption, and efflorescence. The permissiblevalues stipulated in theSLS standard areshown in Table 1.

2.1.1 Dimension

24 bricks were selected from set "R"&"W" and grouped. The overall dimensionsweremeasured by placing each set of 24 bricks in contact in a straight line upon a level surface using anappropriate arrangement and any blisters, small projections or loose particles of clay adhering to each brick were removed. The overall dimensions of each set weremeasured to the nearest millimeter, using steel tape.

2.1.2 Compressive Strength

Five bricks were selected foreach type. The overall dimension of each bed surface was

Table 2 - Methods of analysis for water and analytical data

Constituents	Method	Permissible levels	Analytical Data Well water	Analytical Data RO Reject	Unit
Total dissolved solids	Conductivity meter	500	563	1128 - 2200	mg/L
pH	pH electrode	6.5	8.5	7.51	
Iron	Atomic absorption	0.3	0.02	0.06	mg/L
Fluoride	Ion-selective electrode	1.0	0.97	0.95 – 1.65	mg/L
Ammonia N	Ion-selective electrode	0.06	0.02	0.03	mg/L
Nitrate	Cd reduction method	10	0.88	1.32	mg/L
Phosphate	Ascorbic acid method	2.0	0.68	1.13	mg/L
Hardness	Titrimetric method	250	306	580 - 1100	mg/L
Alkalinity	Titrimetric method	200	336	600 - 1015	mg/L
Cadmium	-do-	0.003	ND	ND	mg/L
Chromium	-do-	0.05	ND	ND	mg/L
Lead	-do-	0.01	ND	ND	mg/L
Arsenic	-do-	0.01	ND	ND	mg/L
Mercury	-do-	0.001	ND	ND	mg/L
Cyanide	CN analyzer	0.05	ND	ND	mg/L

measured and the area was calculated. Then the bricks were immersed in water for 72 hours at the ambienttemperature. After 72 hours immersion, bricks were removed and allowed to drain at ambienttemperature, and then wiped surplus moisture and subjected to the test. Bricks were placed between 2 plywood sheets and carefully centredbetween the plates. Then the load was applied axially to the direction of thickness of the brick until failure occurs. The maximum load at failure was noted. The compressive strength was calculated by dividing the maximum load at failure by the area of the face on which the load was applied.

2.1.3 Water Absorption

Five bricks of each mix were selected and dried to constant mass in a well-ventilated oven at 100°C to 115°C. Then they were cooled to approximately ambienttemperature and weighed. The dry bricks wereimmersed in water at room temperature for 24 hours as far as possible to each surface has free access to water. Then each brick wasremoved, and surface water wiped off with a damp cloth and weighed in a balance sensitive to about 0.1% of brick weight. The percentage of water absorption wascalculated by subtracting the dry weight from the mass of the brick after immersion and divided by mass of the dry brick into 100%.

2.1.4 Efflorescence

Bricks of each type were placed in a shallow flat bottom dish having an area of $0.1m^2$. Then distilled water was placed to the depth of 25mm. It was placed in a well-ventilated room until all the water in the dish evaporates. When the water had been absorbed and bricks appeared as dry similar quantity of water were placed in the dish and allowed to evaporate as early. Then bricks were examined for Efflorescence. Five bricks of each mix were selected and dried to constant mass in a well-ventilated oven at 100°C to 115°C. Then they were cooled to approximately to ambient temperature.

2.2 Sampling and analysis of soils for bricks

Random samples of soils used for brick manufacturing (native soil) were selected to identify the soil type using sieve analysis; effective size D10 is 0.076mm, D60 is 0.61mm and the Group symbol – SP (Sand, Poorly-graded), which is Coarse-grained, poorly graded gravel sand with little fines.

2.3 Sampling and analysis of RO rejected

Water samples were collected from intake well (raw water/well water) and from RO reject (RO concentrate) of the Sangilikanadarawa RO

1. Winning of clay

2. Tempering for different water samples

3. Moulding

4. Drying

5. Firing of bricks

Figure 1 - Brick casting process

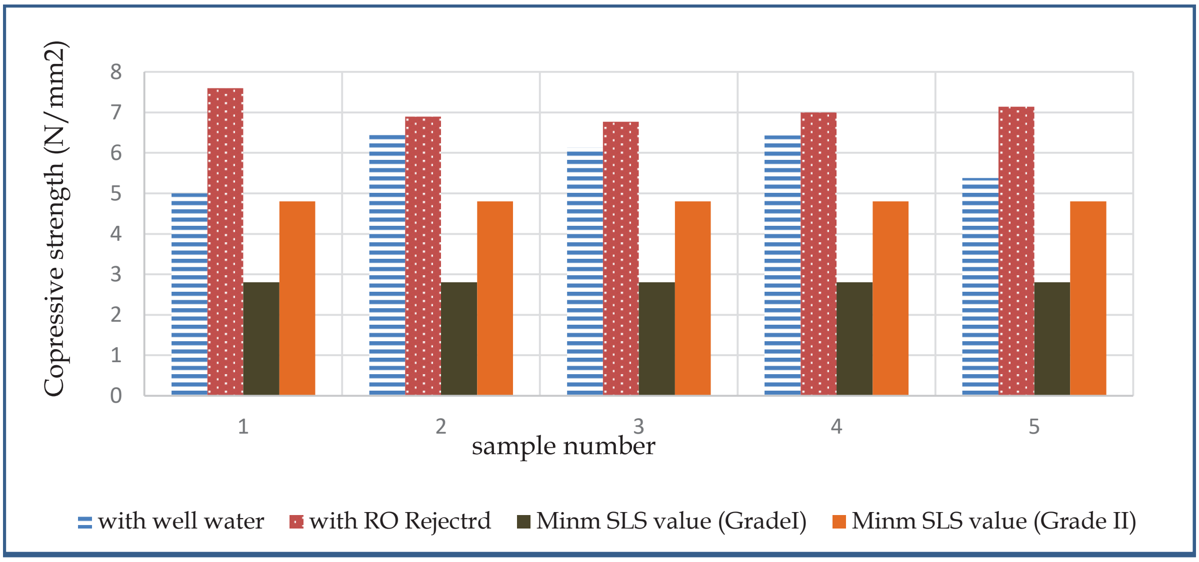

Figure 2 - Compressive strength

(Table 2). According to the analytical data of RO reject water, water quality parameters such as Total Dissolved Solid (TDS), Total Hardness, Total Alkalinity, and Fluoride indicated noted the higher values and those increased in drought season. The measured equal quantities of reject water and well water were collected to plastic cans and transport to the site after marking "R" and "W" on it separately for brick manufacturing.

2.4 Brick manufacturing

The main five steps of brick casting process (Winning of clay, Tempering for different water samples, Moulding, Drying and Firing of bricks) were performed. In the first two steps the soil is excavated, then laid on the levelled ground and then the soil is cleaned of impurities such as vegetation, stones or pebbles. After removing impurities, it is exposed to open airfor a considerable period, and tempering was then done by thoroughly breakingup, kneadingand wateringfor different samples. In next step, it was moulded by hands.

The tempered clay was forced into the mould to fill all the corners of the mould having dimensions of 215x102x65mm, which is the common size in the brick casting. Extra clay was removed either by a wooden strike.

Mould is then lifted up, and raw brick is left on the ground. In the drying process, the raw bricks were placed in sheds with open sides to ensure free circulation of air and protection from bad weather and rains. The bricks were allowed to dry for 14 days. Finally, all were placed with other bricks in the clamp and burned with firewood. All steps are shown in Fig. 1.

3 Results and Discussion

As per the test results all quality parameters are compared according to the SLS 39; 1978 Machine-made bricks are recommended for use on load bearing walls of multistorey building and for two-story building and for single floor structures respectively. The testing under this experiment was done for randomly selected bricks cast with well water and RO reject.

3.1 Compressive Strength

In this experiment the compressive strength test results with the RO reject, the average of all five samples value (6.68 N/mm^2) exceeded the required minimum values for both Grade I and II (2.8 and 4.8 N/mm^2 respectively) of the standard value as shown in Table 3 and that is a 12.46% increment compared to the well water. The graphical representation is shown in Figure 2.

Table 3 - Test results and tabulated data of compressive strength of experimented bricks

Sample No	Minimum Compressive strength to SLS 39; 1978	Compressive Strength N/mm2 for Well Water	Compressive Strength N/mm2 for RO Rejected
R1	2.8 or 4.8	5.00	7.60
R2	2.8 or 4.8	6.90	6.45
R3	2.8 or 4.8	6.77	6.13
R4	2.8 or 4.8	6.43	7.00
R5	2.8 or 4.8	5.38	7.14
Average	**2.8** or 4.8	**6.10**	**6.86**

3.3 Water Absorption

Water asorption indicated that the ability withstan any environmental condition in humidity. The more absorption may the less durability. For Grade I & II bricks, the water absorption should be less than 28% as per the standard. In this test with the randomly selected samples, the average absorption is 13.9% which is lower to the maximum value but it seems the absorption which is made with RO rejected, is little higher than the Well water about 1.1%. The comparison is demonstrated in the Table 5and Figure 3.

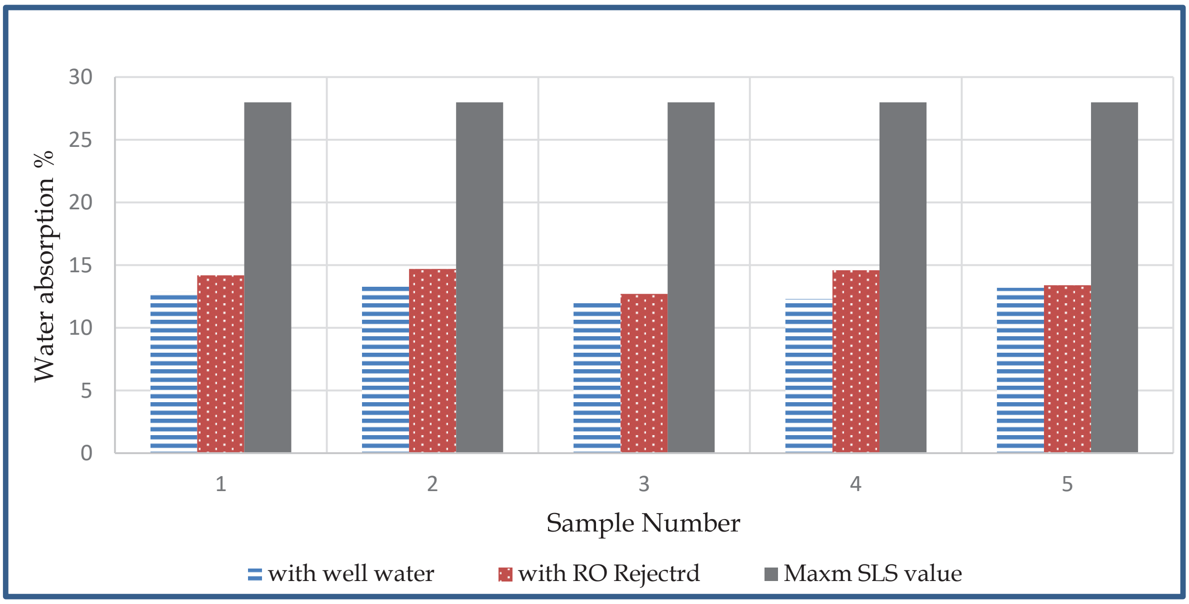

Figure 3 - Water Absorption

3.2 Efflorescence

Efflorescence can be varying among Nil, Slight, Moderate, Heavy or Serious options. With these samples of both Well water and RO reject, all efflorescence identified was slight.

Table 4 -Test results of efflorescence of experimented bricks

Sample No	For well water	For RO Rejected
1	Slight	Slight
2	Slight	Slight
3	Slight	Slight

Table 5 - Test results and tabulated data of water absorption of experimented bricks

Sample No	Maximum Absorption % to SLS 39; 1978	Water Absorption % for well water	Water Absorption % for RO Rejected
1	28.0	12.9	14.2
2	28.0	13.3	14.7
3	28.0	12.1	12.7
4	28.0	12.3	14.6
5	28.0	13.2	13.4
Average	**28.0**	**12.8**	**13.9**

3.4 Dimension

All dimension parameters are not satisfied with the Well water and only the length is not satisfied with the RO reject according to the standard as shown in Table 6. This may due to the common practice of locally available brick mould as theyare not using the standard dimensions for their mould for profitable brick casting.

Table 6 - Test results of dimensions of experimented bricks.

Parameter of samples	Specimen Dimension for 24 no of bricks	Standard $Dim^n$to the standard	Results for well water	Results for RO Rejected
Length	5070 mm	5280 +/- 75	Not Satisfy	Not Satisfy
Width	2445 mm	2520 +/- 40	Not Satisfy	Satisfied
Height	1565 mm	1560 +/- 40	Satisfied	Satisfied

Moreover, it was proved that the effect of the height of the specimen has the most significant effect on the compressive strength through a linear relationship which was found between the normalized mean compressive strength and the Young's modulus of the brick in each direction [14]. That may be the possible reason when though the results shows the high strength parameters compared to SLS 39; 1978 requirement using the moulded brick dimensions which was slightly smaller to the standard size.

4 Conclusion

Based on the results, it can be recommended that the RO reject can be used for industrial purpose as clay brick manufacturing for an alternative no cost source specially in drought season while water becomes a huge problem in that period in Sangilikanadarawa area. This gives a firm solution as this avoids recharging the inland waters and soils with a high concentrated water, which helps saveenvironment for the future generation.

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