Recycling of domestic wastewater by subsurface flow constructed wetland for construction purposes

C. Ramprasad* and Moly Kutty

Department of Civil Engineering,
BSA Crescent Engineering College,
Vandaloor, Chennai - 48,
Tamil Nadu, India
Email: ramprasad_88@yahoo.co.in
Email: cesbatch2009@gmail.com
*Corresponding author

Abstract: The problem of water scarcity is increasing drastically all over the world. The case is still worse in developing and under-developed countries, where few countries faces drought during their monsoon. There is considerable increase in the use of treated water as non-potable water. The objective is to assess if the domestic wastewater treated by subsurface flow constructed wetland can be successfully recycle in the constructions. The aim of the study is achieved by fabricating a small scale plastic crate (0.6 m × 0.4 m × 0.5 m), and was filled with sand and planted with *Phraghmities austarlis*. The domestic wastewater is fed as the inlet at one end of the crate and the treated water is collected from the other end. The quality of both raw and treated water were evaluated using wet chemistry experiments. The treated water is reused in making concrete cubes, after 28 days of curing time the cubes were checked for compressive strength. It was observed that the strength of cubes did not vary much from the one made with normal water and one made with treated water. Our findings will encourage the builders association to rethink on water reuse and reduce the load on freshwater resource.

Keywords: compressive strength; constructed wetland; organics; solids; water reclamation.

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Biographical notes: C. Ramprasad is currently a Research Scholar in the Indian Institute of Technology, Madras. He completed his Master of Engineering in Environmental Management and Bachelors in Civil Engineering. His areas of interest are solid waste management, sustainable water and wastewater treatment and impact assessment studies.

M.V. Moly Kutty is currently working as a Professor in BS Abdur Rahman University. She has more than 25 years of experience in the field of water and wastewater treatment, and her specialisation includes the design and construction of waste treatment plant in the campus. Her current research is focused on the interlinking of the geographical information system and coastal ecosystem.

1 Introduction

The construction sector is considered as one of the highly water consuming sector all over the world. The report suggests that the total amount of water consumed by one construction company in a year (2008–09) was estimated around 24, 67,035 cu. m (Waylen, Caviedes and Quesada, 1996). The above-said problem if persists for a longer run will lead to the availability of freshwater for drinking. The availability of fresh water is too worse in arid and semi-arid regions, where the availability of water resources is restricted. Subsequently, a better way to solve the problem is wastewater treatment and recycling (Asano and Levine, 1996). The treated wastewater can be recycled and reused for agricultural land irrigation, landscaping, toilet flushing, car washing, floor washing and artificial recharging of aquifer (Asano, Maeda and Takaki, 1996). It is feasible to recycle the treated water for various activities in the construction industry; thereby we can reduce the stress on freshwater source.

The water that has to be used in the construction industry should also be equally good as the drinking water, because of the presence of chlorides and sulphate ions which will affect the strength of the concrete. The chlorides and sulphates should be less than 500 for chlorides and 2000 for sulphates as per American society for testing and materials (ASTM) standards (Tsimas and Zervaki, 2011). There are few reports which demonstrated a promising result regarding the use of treated water for making different ratios of ready mix concrete (Borger, Carrasquillo and Fowler, 1994; Sandrolini and Franzoni, 2001; Su, Hsu and Chai, 2001; Chatveera, Lertwattanaruk and Makul, 2006, Chatveera and Lertwattanaruk, 2009). There are not many studies on the reuse of treated water for making concrete cubes.

The conventional wastewater treatment systems are not very effective in the treatment of wastewater and also require uninterrupted power supply and high capital cost. The constructed wetland (CW) is one such technology, which requires less operation and low maintenance cost and can treat the wastewater effectively (Knight et al., 2000; Toscano et al., 2009). The CW is an engineered purification system that includes a combination of biological and physio-chemical process (Sani, Scholz and Bouillon, 2013). There are not much studies carried out in treating wastewater in a constructed wetland and reusing the treated water for casting concrete cubes. Therefore, the objective of the study was:

1 to characterise the wastewater

2 to design and fabricate a constructed wetland system

3 to evaluate the compressive strength of cubes made with treated wastewater and with normal water.

2 Materials and methods

2.1 Constructed wetland set-up and operation

The horizontal flow constructed wetland is located in a highly ventilated area inside the university campus and also in the vicinity of the cube casting yard. The CW is operated continuously between 30 January, 2009 and 27 March, 2009. The schematic diagram of the experimental set-up was shown in Figure 1. The wetlands are constructed in a readily available plastic crate of dimension 0.65 m × 0.45 m × 0.5 m. The CW was planted with *Phragmities australis* and substrate media is sieved soil (<0.5 mm) in the reactor with one in 40 slopes. The wastewater is taken from the sewage treatment plant (STP) after the settling tank existing inside the campus. The treated water is collected and used for concrete cubes casting. The wetland received 40 L/day in the inlet zone and received 36 L/day in the outlet zone.

Figure 1 Schematic diagram of constructed wetland (see online version for colours)

2.2 Water quality analysis

Wastewater contains a variety of inorganic and organic substances from domestic sources. The wastewater parameters namely BOD, COD, TDS, TSS, chlorides, sulphates and pH were analysed both for the raw and treated wastewater. The procedure followed was the standard method as prescribed in the American public health association (APHA, 2005). The Equations (1) to (6) are the ones that govern the water quality analysis and are as follows:

For BOD, it is mostly

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O \quad (1)$$

$$NH_3 + 2O_2 \rightarrow NO_3^- + H_2O + H^+ \quad (2)$$

For COD analysis the governing equation is,

$$\begin{aligned} &2KC_8H_5O_4 + 10K_2Cr_2O_7 + 41H_2SO_4 \\ &\quad \rightarrow 16CO_2 + 46H_2O + 10Cr_2(SO_4)_3 + 11K_2SO_4 \end{aligned} \quad (3)$$

For chloride analysis the governing equation is,

$$Ag^+ + Cl^- \rightarrow AgCl \quad (4)$$

$$2Ag^+ + CrO_4^{2-} \rightarrow Ag_2CrO_4 \quad (5)$$

For sulphates analysis the equation that governs the analysis is

$$Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4 \quad (6)$$

2.3 Concrete cubes casting

The treated water is collected in a container and mixed with the concrete and the cubes are made using the mould. Two cubes are made in a day with a similar proportion of cement, sand and gravel; the only difference is the quantity of water mixed. One cube is made with the normal water and the other with the treated water. After 28 days of curing time the concrete cubes were tested for the compressive strength using 3000 KN digital compression testing machine.

4 Results and discussion

4.1 Water quality analysis

The characteristics of raw wastewater and treated water are shown in Table 1. The wastewater collected from the STP was relatively similar during the period of study for the organics and solids. Highly fluctuating results were obtained for chlorides (Cl^-) and sulphates (SO_4^{2-}) during 10 February, 2009 to 12 March, 2009, the reason for higher chlorides and sulphate levels are due to discharge of laboratory chemicals that contains chlorides and sulphates ions in wastewater streams. Additionally, it was observed from Table 1 that, during 12 March, 2009 the pollutant concentration was comparatively less compared to the other days, the reason is due to heavy downpour during the day. The percentage reductions of the pollutant are shown in Figure 2.

4.2 Cube compressive strength comparison

Two cubes are made with M30 grade concrete; one with normal water (NW) and the other with treated water (TW). The cubes are moulded in a similar pattern the only change is the water used as the mixing material. Cubes are kept for curing; after the curing period (28 days) is over they are taken out and checked for their compressive strength. The results are shown in Table 2; it was observed that, there was not much difference in the results. Both the cubes showed a superior result of strength as provided in ASTM guidelines and IS: 456–2000. The compressive strength obtained by the cube made with treated water was relatively lesser than the cube made with normal water. The reason for lesser strength for the cube made with treated water is due to the presence of competing ions like sulphates and chlorides (Mishra and Mathur, 2007; Haque and Al-Khaiat, 1999). This means that, the treated water even though has significantly reduced pollutant concentration, the concrete workability remains unchanged.

Table 1 Wastewater characteristics

Parameter	*Date (C1) 31.01.09**		*Date (C2) 10.02.09**		*Date (C3) 22.02.09**		*Date (C4) 12.03.09**		*Date (C5) 27.03.09**	
	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
pH	8.90	7.27	8.24	7.35	8.86	7.15	8.89	7.22	8.09	7.44
TSS (mg/L)	534	28	560	10	468	10	162	12	498	14
TDS (mg/L)	972	180	734	150	820	140	835	100	760	105
BOD (mg/L)	530	5.2	396	4	619	4	340	4	534	3.8
COD (mg/L)	792	24	894	16	1240	24	416	24	736	24
Cl^- (mg/L)	750	220	1280	140	880	156	1060	180	740	128
SO_4^{2-} (mg/L)	680	212	960	120	620	108	580	122	580	136

Figure 2 Percentage reduction of pollutant in constructed wetland (see online version for colours)

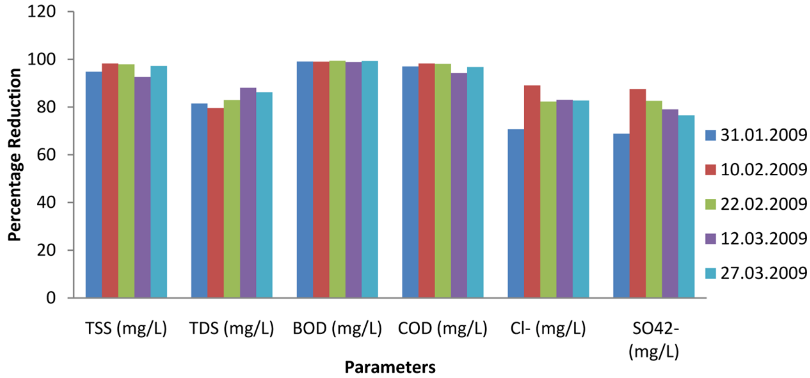

Table 2 Compressive strength of cubes made with NW and TW

	Compressive strength (N/mm^2)	
Cube ID – Date	*Normal water*	*Treated water*
C1 – 31.01.2009	49.3	47.9
C2 – 10.02.2009	47.1	45.4
C3 – 22.02.2009	46.2	44.3
C4 – 12.03.2009	48.8	47.9
C5 – 27.03.2009	46.9	46.3

4.3 Brief cost benefit analysis

The cost for purchase of one litre water from the Chennai Corporation or TWAD board is around INR eight. It is not economical to purchase water from the board every time. A rough calculation, for the purchase of 2467 ML (million litres) per year will cost around 197 crores. The installation of CW (is a onetime investment) it costs around INR 1,350; and the plant can function without much maintenance for almost 10–15 years. The only maintenance issue to be looked for was cutting the grown plants; it can be performed once in every 6th or 8th month. The nominal cost for a labour for a day to cut down grown plants is INR 200 per day. So, the maintenance cost for a ten year period was calculated around INR 1,000. Therefore, the total cost for obtaining the treated water is around INR 2,350. This means that using the treated water in construction activities will significantly benefit the builders or industries.

5 Conclusion

It was found in this study that use of treated water in the concrete specimen's did not deteriorate the workability of concrete. There is also a significant saving in terms of purchase of fresh water. Therefore, it is recommended to use constructed wetland for the treatment of wastewater and reuse the treated water for various construction activities.

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