Exploring the Use of Domestic Wastewater as an Alternative to Freshwater in Concrete Production to avoid future Disasters

Peche Rajesh T.* and Jamkar Sanjay S.
Department of Applied Mechanics, Government College of Engineering, Aurangabad, Maharashtra, INDIA
*peche.rajesh@gmail.com

Abstract
As per various codes, fresh water is the most preferable for use in construction industry. It is also said that water fit for drinking is fit for construction. Such perceptions are putting tremendous pressure on fresh water availability. This study explores the use of the fraction of domestic wastewater i.e. greywater in concrete production as a sustainable approach in addressing the high water demand in the construction industry and the growing issue of freshwater scarcity, particularly in regions like India. Greywater, which is low-contamination domestic wastewater, is abundant, perennial and ubiquitous. It can be an environmentally sustainable alternative to fresh water particularly in huge water demanding construction industry. The research focuses on the qualitative and quantitative characteristics of grey water. Screened grey water samples were collected from three distinct household sources and analyzed for mixing water parameters to compare with the limiting values given in various mixing water codes. These grey water samples are then used for concrete preparation. Potable water based concrete and grey water are compared for environmental sustainability and material performance to avoid future disasters.

The results indicate no significant differences in compressive strength between greywater-based and potable water-based concrete. In terms of compressive strength, greywater concrete performed similarly to or slightly better than its potable water counterpart. The presence of soaps, detergents and surfactants in the greywater may have contributed to these enhanced properties, demonstrating the potential of greywater as a sustainable solution for reducing freshwater consumption and advancing environmentally conscious practices in concrete production and overall construction industry.

Keywords: Domestic waste water, Grey Water, Potable water, Compressive strength.

Introduction
Water and concrete are the extensively used things by manhood: water first and concrete the next[4]. A world without concrete and concrete without water is hard to imagine. Concrete plays a key role in infrastructural development of any country at present and in future as well. With increasing demand for concrete, water demand of concrete industry is also huge. It is expressed that the total amount of water about 42 percent is therefore required for chemical reactions to occur and for filling of gel pores[9]. Average consumption of water in concrete making is around 9% by volume. Fresh or potable water is usually preferred, while making concrete. As India is already on the edge of being water stressed country[20], therefore there must be search for means of conservation of water along with recycle of the already used water.

Reutilization of non-potable water can decrease the stress on fresh water resources. Out of two category of household waste water, one is grey water. Domestic or household wastewater is discharged. Grey water is said to be relatively low in pollution and is regarded as weakly contaminated by pathogenic organisms and other potentially dangerous substances[26,30]. Moreover, grey water is a perennial, huge and ubiquitous source of non-potable water. Consequently, it has a lot of potential applications where presently potable is being used; one of them is the construction industry. This study intended to look into the quality of concrete produced by using grey water.

India has about 17% of the world's population but just 4% of its available fresh water. The imbalance between supply and demand is growing as a result of rapid economic growth and urbanization. India is already in danger of being added to the list of nations experiencing water crisis[20]. The majority of India's land is water stressed area and under scarcity of water. Per capita water availability in India in 2025 and 2050 is shown in fig. 1 as per Niti Ayog report in 2025. Fig. 1 is indicative enough to underline the fact that most of the Indian area is under scarcity of water. Water is required mainly for preparation of cement paste, mortar, mixing of cement concrete, for curing work, for cleaning constructional equipment, washing, sprinkling for onsite dust control, compaction of filler material etc. during construction work.

Quality Requirements of water for construction: Generally speaking, potable water is suitable for producing concrete and for all activities in construction like curing etc. When non-potable water sources are to be considered, they have to satisfy certain specifications. The suitability of water for making concrete can be ascertained by verifying the quality of mixing water and compressive strength of concrete as per IS 456. BS EN: 1008, ASTM C94, ASTM C

https://doi.org/10.25303/186da035041

1602 and AS 1379[5-12]. Assessment of suitability of water for mixing is elaborated by many codes of mixing water and concrete as in table 1. Abrams and Duff[1] expressed that the test for setting time is not appropriate guide for ascertaining the fitness of water for production of concrete. Cement Concrete and Aggregates Australia[13] briefly listed the effects of contaminants of mixing water on concrete properties as in table 2.

Characterization of Grey Water: Grey water is a type of household waste water; it consists of discharge excluding water form kitchen sink and toilet. The features of grey water are influenced by composition of the source water and house hold activities. It is expressed that grey water has lower concentrations of various potential pollutants than domestic or commercial wastewaters[21]. Presence of the pollutants like color, odour, high pH, sulphates, nitrates, chlorides, zink, MABS (soaps and detergents), solids, lead and phosphate are reported by various researchers. Detergents and soap water from bathroom and laundry share the major fraction of contaminants in grey water. Detergents and soaps are the key bases of anionic surfactants found in grey water. Researchers[16,18,19] have reported the anionic surfactants' presence in terms of methylene blue-active substances (MBAS) which confirm the existence of detergents in grey water.

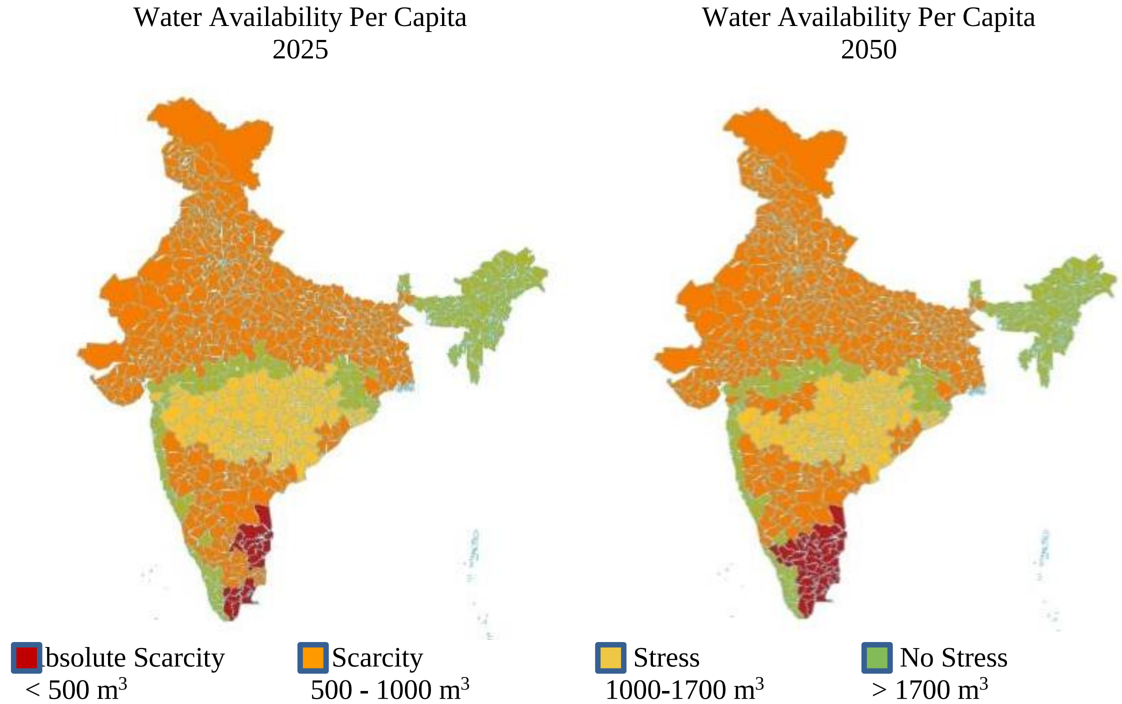

Figure 1: Per capita water availability in India in 2025 and 2050

Table 1
Strength and set time criteria given by various codes.

Parameters	IS 456[14]	EN 1008[10]	ASTMC94[8]/ASTM 1602[7]	AS 1379[9]
Setting time	Initial ≥ 30min and final ≤ 10 hrs	Initial ≥ 1 hr and final ≤ 12 h with both ± 25% from control.	From 1:00 early to 1:30 later than control	Initial 60 min early to 90 min ahead than control.
Compressive strength	min 90 % of control at 28 days	minimum 90% control at 7& 28 days	min 90 % of control at 7 days	min 90 % of control at 7& 28 days

Table 2
Effects of contaminants of mixing water on concrete properties

S.N.	Type of Impurity	Effect on Concrete
1	Oil, fat or detergents	Air entrainment
2	Calcium chloride and other calcium salts	Probability of acceleration of setting time
3	Salt of zinc, lead and a variety of other inorganic and organic materials	Probability of retardation of setting time
4	Chloride ions	Strong probability of corrosion of reinforced steel in RCC

Presence of microbial contamination is quite often in grey water. According to NEERI[22] and WHO[29], grey water is considered to be weakly contaminated by pathogenic organisms. Neither of the standards has commented on the existence of microorganisms. Since its high pH discourages acts that could harm it, concrete is typically resistant to microbial attack[2].

Availability of grey water: Lamine[18], Leal[19] and Finley[15] estimated that quantity of grey water is around 65 to 75% of household water use. It is estimated that 75% of total domestic waste water and roughly 50-60% of domestic water supply turn out to be grey water.

UNICEF report "Water in India: situation and prospects"[27] published a State wise list of supply of water in class-I, class-II and class-III cities. In this list, daily water supply per capita in the different cities is given. In the category of class-I cities Tamilnadu is at the bottom with 79.9 Lits/Capita/Day and Maharashtra is at the top with 310 Lits/Capita/Day. The national average is 179.02 Lits/Capita/Day. In the group of Class-II cities i.e. those with a population of 50,000 to 1,000,000, again Tamilnadu stands last and Punjab at the top with 70.93 and 177.31 Lits/Capita/Day. The national average of class-II cities is 120.79 Lits/Capita/Day[3].

Considering all the factors, it can be stated that grey water is a potential, perennial, omnipresent and weakly contaminated source of waste water that can be used for mixing to save mankind from disasters in future.

Estimation of quantity of grey water generation: Estimation of grey water generated in various cities of Maharashtra is calculated on the basis of

- Population as per 2011 census,
- Lower value from State and National average water supply lit/capita/day,
- Estimated quantity of grey water as 50% of domestic water supply.
- Water required per square meter construction = 2500 liters (as per detailed study conducted by author)

The estimated area of construction could be undertaken by using grey water as presented in table 3.

Material and Methods

The investigational work is arranged in following parts;

- Simple screening of raw grey water for collection of samples from different sources.
- Chemical analysis of grey water samples.
- Comparison of the respective parameters with the permissible limit set by different codes of mixing water.
- Confirmative test for usability of grey water samples by comparing 28th day compressive strength of grey water and potable water based concrete.

Collection of grey water: Samples of grey water are collected after screening in order to remove floating and suspended matter. The schematic of grey water collection system is shown in fig. 3. It consists of three 200 litre barrels connected to each other. The first barrel is provided with two screens to remove floating materials. The screened water is passed through from top of a second barrel containing 20 to 10mm coarse aggregates. Then the water is flown upward through the third barrel containing 10 to 4.75mm coarse aggregates and coarse sand for more screening and subsequently collected in a bigger tank for equalization. Sludge valves are supplied for the recurring backwashing in each barrel. Designation of Grey water samples is shown in table 4.

Chemical analysis of grey water: The chemical analysis of grey water for 14 relevant parameters of mixing water was carried out. The test procedures given in respective codes like various parts of IS 3025, IS13428, IS573 are adopted. The average results of the chemical analysis of GW1, GW2 and GW3 are presented in table 5.

Table 3
Grey water generation and estimated area of construction

City	Class of city	Population as per 2011 census in Lakhs	State Avg. Water supply Lits/Capita/ Day[29]	National avg. of water supply Lits/Capita/ Day[29]	Estimated Quantity of Grey water per year lits/year = col 3*col 5 * 0.5 * 365 days	Estimated Area can be constructed m^2 (2500 lits/M^2) = (col 6)/2500
01	02	03	04	05	06	07
Pune	Class-I	31.15	310	179.02	1017,77,06,32,250	4,07,08,253
Aurangabad	Class-I	11.71	310	179.02	38,25,79,16,650	1,53,03,167
Nagpur	Class-I	24.05	310	179.02	7857,41,15,750	3,14,29,646
Nashik	Class-I	14.86	310	179.02	4854,93,28,900	1,94,19,732
Nanded	Class-I	5.50	310	179.02	1796,91,32,500	71,87,653
Chandrapur	Class-I	3.20	310	179.02	1045,47,68,000	41,81,907

The data presented above indicate that the huge area of construction can be undertaken U\using grey water generated. The grey water is perennial and available everywhere, therefore it can provide an alternative source for making of concrete.

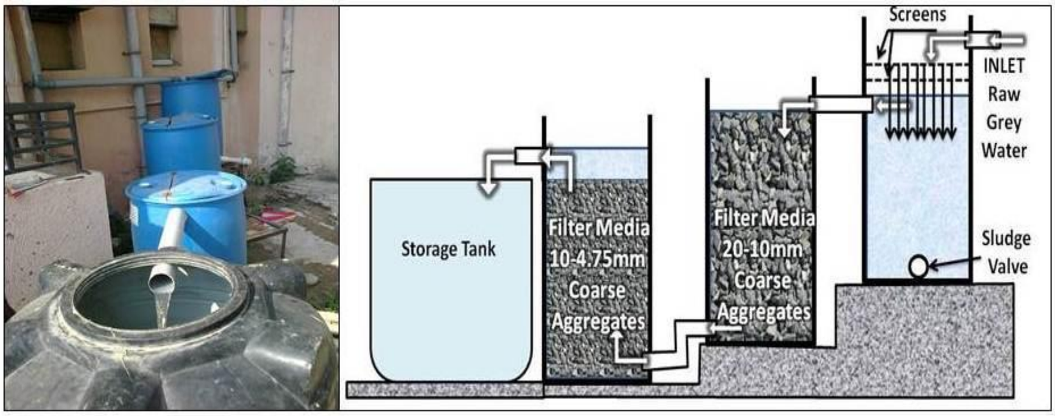

Fig. 3: Schematic diagram of system for collecting grey water

Table 4
Designation of Grey water samples collected from three different sources

Type of mixing water	**Designations of mixing water**
Tap Water from Municipal council supply	TW
Grey water from Government Engineering College Boy's Hostel	GW1
Grey water from Government employees residential apartment	GW2
Grey water from Private residential apartment	GW3

Table 5
Results of chemical analysis of grey water

Parameters	**Test Procedure**	**Average (Avg) results and range of per source six samples of Grey Water**						**Max. Permissible limit of chemicals in mixing water as per EN 1008[10], AS 1379[9], IS 456[14]**
		GW 1		**GW2**		**GW 3**		
		Avg.	**Range**	**Avg.**	**Range**	**Avg.**	**Range**	
Turbidity	IS3025-10	14	18-10	12	8.0-14.0	9	5.0-12.0	Limit not specified in any code.
pH	IS3025-11	7.9	7.8-8.0	7.8	7.6-7.9	7.9	7.7-8.1	IS456 : >6
Total Solids	IS3025-16	170	130-223	166	155-187	244	190-314	IS456 : ≤2000
Oil and grease	IS3025-3	5.3	2.8-6.9	14.4	8.2-21.8	9.0	5.0-11.0	EN 1008:No more than visible traces, AS 1379: < 50
Chlorides (as Cl)	IS3025-32	26	19-35	34	18-50	19	14-25	EN 1008:≤500, IS456 : ≤500
Nitrates	IS3025-34	0.071	0.4-1.2	1.85	1.1-3	1.37	0.7-2.1	EN 1008:≤500
Sulphate	IS3025-22	1.4	0.9-2	2.8	1.5-4.1	2.2	1.2-4.0	EN 1008:≤2000, AS 1379: < 500, IS456 : < 400
Total Alkalinity	IS3025-23	104	80-124	100	64-122	119	109-135	EN 1008:<1500
Phosphates	IS573	0.21	0.14-0.35	0.17	0.1-0.3	0.33	0.11-0.65	EN 1008:100
Lead	IS3025-47	0.9	0.7-1.2	1.2	0.6-2.1	1.7	0.5-2.4	EN 1008:100
Zink	IS3025-49	0.06	0.08-0.07	0.08	0.04-0.15	.09	0.06-0.12	EN 1008:100
Anionic surfactant	IS13428	16.2	13.7-17.5	34.7	21.3-54.9	22.8	14.5-30.6	Limit not specified in any code.
B.O.D5	IS3025-44	47	28.0-12.0	45	31-65	23	13-31	Limit not specified in any code.
C.O.D.	IS3025-58	89	19-39	71	58-92	48	37-56	Limit not specified in any code.

(Unit for Turbidity is NTU and for all other mg/lit)

Results and Discussion

Soaps and detergents are integral part of grey water. Amount of anionic surfactant is assessed as 16.2, 34.7 and 22.8 confirming the occurrence of soaps and detergent (anionic surfactants) in grey water. Permissible limit of anionic surfactants (detergents) is not given in any code. All types of oils, detergents, soaps, hair dyes, cosmetic chemicals and other items are frequently found in grey water. However, soaps and detergents are more common than others[30]. Fat or oil, sodium carbonate, sodium alkyl sulphate, glycerol (a non-ionic detergent), sodium alkyl benzene sulfonate, sodium tetra borate, carboxylic acid groups, synthetic detergents, potassium hydroxide, sodium hydroxide etc. are typically found in detergents and soaps[17,29].

The commonly used water repelling agents include soaps or other fatty acids compounds such as calcium, ammonium, aluminium, or sodium steroids or oleats and petroleum oils or waxes. Some of these chemicals may be responsible for air entraining, workability, permeability reduction, damp proofing, set time retardation etc. These actions may lead to strength and durability increase.

Limit of BOD and COD is also not specified in any code. It may not be directly related with strength and properties of concrete. But a reliable measure of biodegradability is the COD/BOD ratio of waste water and will help to select method of treatment if needed. The ratios of C.O.D. to B.O.D. are 1.89, 1.61 and 1.58 respectively. Wastewater that is considered easily degradable has a COD/BOD ratio of less than 2 to 2.5. Grey water comes under the degradable category[21].

Above analysis results of total 18 grey water samples i.e. six per source are positive in terms of its use as mixing water. All chemicals not good to concrete are found well within the permissible limits of mixing water set by all related codes.

Neville[23] claimed that due of its high pH, which discourages microbial attacks, concrete is typically immune to them. As grey water does not contain faeces, it is normally regarded as rather harmless. The risk of infection is the function of the faecal contamination of the water. Presence of fecal coliform indicates that grey water could create a health risk if it comes into contact with humans.

Confirmative test for usability of grey water: Confirmative test for usability of grey water samples was carried out by comparing compressive strength of grey water and potable water based concrete at 7th and 28th day. Concrete having compressive strength covering the variety of ordinary to high strength as per IS 456-2000[14] is considered for the study. Accordingly, water cement (w/c ratio) is varied from 0.30 to 0.50. OPC 53 grade cement, coarse aggregate of nominal maximum size of 20 mm, river sand, water and super plasticizer are used. Basic water content 180 kg/m^3, 25% water reduction and 0.5% super plasticizer are the constant parameters adopted. As per IS 10262-2009, w/c ratio portion of fine and coarse aggregate are calculated. Grey water from three different sources is used as mixing water for comparison of properties and potable water is used for producing control concrete.

The most significant of concrete's various qualities is its compressive strength, which has long been regarded as a measure of the material's general quality. The compressive strength of concrete seems to have a general relationship with many other engineering parameters[9]. For each w/c ratio and type of water, concrete specimens are casted and as per IS 516[11], compressive strength test was carried out at 7th and 28th day.

Table 6
Designations of specimens of concrete used in this study.

Type of mixing water	Designations of mixing water and concrete specimen	
Tap Water from Municipal council supply	TW	TWCC
Grey water from Government Engineering College Boy’s Hostel	GW1	GWCC 1
Grey water from Government employees residential apartment	GW2	GWCC 2
Grey water from Private residential apartment	GW3	GWCC 3

Table 7
Comparison of compressive strength of grey and tap water concrete

W/C ratio	Age of concrete in days	Compressive strength (average of three)				Relative Compressive strength in %			
		TWCC	GWCC1	GWCC2	GWCC3	TWCC	GWCC1	GWCC2	GWCC3
0.30	7	48.66	53.61	52.80	54.17	100	110.17	108.51	111.32
	28	56.24	59.38	57.18	57.53	100	105.58	101.67	102.29
0.40	7	40.83	41.23	38.56	41.25	100	100.98	94.44	101.03
	28	48.70	51.07	50.85	47.36	100	104.87	104.41	97.25
0.50	7	33.32	34.19	28.15	34.55	100	102.61	84.48	103.69
	28	40.30	42.13	44.93	45.23	100	104.54	111.49	112.23

Out of 18 compressive strength results of grey water concrete, 15 results are above 100% i.e. above strength of control results and 2 results are between 90 to 100%. As per IS 456, ASTM C94/ASTM C1602, EN 1008 and AS 1379 when sources other than potable water are to be considered, they have to satisfy the specifications given in table 1 i.e. 90% strength of potable water concrete. 17 of 18 results are satisfying these criteria. As differences in the test results are very minor, results of TWCC and GWCC are almost inseparable.

Carboxylic acids are employed as water reducers in admixtures and are frequently present in soaps and detergents, which are essential components of grey water. Effects of water reducers and super plasticizers are almost same i.e. increased flow ability with retarded set and reduced water–cement ratio. These effects may lead to improvement in strength of concrete[14,25,30].

Conclusion

Grey water is a large, perennial and ubiquitous source of waste water in urban areas. Grey water is shown to be less contaminated than other types of waste water. Soaps, detergents and surfactants are all components of grey water. Chemical examination of grey water reveals that the pollutants discovered are within the allowed limits for mixing concrete. There is no obvious difference in compressive strength between potable and grey water-based concrete. A little edge was detected for grey water concrete. The findings are consistent with the requirements outlined in the various codes. The presence of soaps, detergents and surfactants in grey water is small; it is possible that the increased qualities of concrete are due to them. Untreated but screened grey water can be used for construction purposes.

Existing literature reveals various unique strategies to address the growing scarcity of fresh water. Grey water, which is plentiful from household wastewater, is one such potential strategy that can be used for a variety of purposes. This study proposes utilizing residential wastewater in concrete production as a long-term approach for environmental sustainability. By utilizing grey water, we may lessen our reliance on freshwater resources which are becoming increasingly depleted owing to overuse and climate change. This not only helps to conserve scarce water, but it also promotes water recycling within urban ecosystems, which contributes to the circular economy. Furthermore, employing grey water in concrete manufacturing helps to lower the environmental imprint of the building industry, which is one of the most significant consumers of fresh water.

References

1. Abrams and Duff A., Tests of Impure Waters for Mixing Concrete, Bulletin 12, Structural Materials Research Laboratory, Lewis Institute, Chicago, http://www.portcement.org/pdf_files/LS012.pdf **(1924)**

2. Al-Jayyousi Odeh, Grey water reuse: knowledge management for sustainability, *Desalination*, **167**, 27–37 **(2004)**

3. Amerasinghe Priyanie et al, Cities as Sources of Irrigation Water: An Indian Scenario, International Water Management Institute (IWMI), Colombo, Water policy research highlights, IWMI-TATA Water Policy Programme 27/29 Ronni Wolf et al, Soaps, Shampoos and Detergents, Clinics in Dermatology, Elsevier Science Inc., **19**, 393–397 **(2001)**

4. Assayed Almoayied K. et al, Onsite Grey water Treatment Using Septic Tank Followed by Intermittent Sand Filter- A Case Study of Abu Al Farth Village in Jordan, *International Journal of Chemical and Environmental Engineering*, **1(1)**, 67-71 **(2010)**

5. ASTM International, C94 – 05, Specification for Ready Mixed Concrete, USA

6. ASTM International, C1602-06, Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete, USA

7. Australian Standard, AS 1379—2007, Specification and supply of concrete

8. British Standard, BS EN 1008. Mixing water for concrete - Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete **(2002)**

9. Bureau of Indian Standards, Handbook on Concrete Mixes, SP **(1982)**

10. Bureau of Indian Standards, IS: 10262, Indian Standard concrete mix proportioning guidelines **(2019)**

11. Bureau of Indian Standards, IS: 516, Indian standard methods of tests for strength of concrete **(1959)**

12. Bureau of Indian Standards, IS: 456, Indian Standard, Plain and Reinforced Concrete Code of Practice **(2000)**

13. Cement Concrete and Aggregates Australia, Use of Recycled Water in Concrete Production, August **(2007)**

14. Dara S.S., A textbook of Engineering Chemistry, S. Chand Publications, Third Edition **(2007)**

15. Finley Sara, Reuse of Domestic Grey water for the Irrigation of Food Crops, *Water Air Soil Pollut*, **199**, 235 – 245 **(2009)**

16. Gross A. et al, Environmental impact and health risks associated with grey water irrigation: a case study, *Water science & Technology*, **52(8)**, 161–169 **(2005)**

17. Katz David A., The Science of Soaps and Detergents **(2000)**

18. Lamine M., Biological treatment of grey water using sequencing batch reactor, *Desalination*, **215**, 127–132 **(2007)**

19. Leal Hernández, Characterization and anaerobic biodegradability of grey water, Desalination, Elsevier, December **(2010)**

20. Ministry of Water Resources, Govt. of India, India Water Week 2012, 8-12 April, Vigyan Bhavan, Delhi **(2012)**

21. Morel Antoine and Diener Stefan, Greywater Management in Low and Middle-Income Countries, Sandec: Department of Water and Sanitation in Developing Countries, September **(2006)**

22. National Environmental Engineering Research Institute and United Nations Children's Fund UNICEF, India, Grey water Reuse In Rural Schools, Wise Water Management, Guidance manual, January **(2007)**

23. Neville Adam, Water and Concrete: A Love-Hate Relationship, *Concrete International*, **22(12)**, 34-38 **(2000)**

24. Neville A.M., Properties of Concrete, Fourth Edition, Pearson Education **(2005)**

25. Portland Cement Asso., Admixtures for Concrete, Design and Control of Concrete Mixtures, EB001, http:// www.ce.memphis.edu/1101/notes/concrete/PCA_manual/Chap06 .pdf **(2002)**

26. Steinour H.H., Concrete mix water—how impure can it be?, *J. PCA Res. Dev. Lab*., **3(3)**, 32–50 **(1960)**

27. UNICEF, FAO and SaciWATERs, Water in India: Situation and Prospects **(2013)**

28. Wolf Ronni et al, Soaps, Shampoos and Detergents, *Clinics in Dermatology*, **19**, 393–397 **(2001)**

29. World Health Organization, Excreta and grey water use in agriculture, Guidelines for the safe use of wastewater, excreta and grey water, Volume IV **(2006)**

30. Yangxin Y.U., Development of Surfactants and Builders in Detergent Formulations, *Chinese Journal of Chemical Engineering*, **16(4)**, 517 -527 **(2008)**.

(Received 13th February 2025, accepted 15th March 2025)