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Characterization of domestic grey water composition of Shivamogga urban municipal corporation, Karnataka, India

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Abstract
A study was conducted at Organic Farming Research Centre, Zonal Agricultural and Horticultural Research Station, UAHS, Shivamogga, from 2018 to 2019 to characterize the composition of municipal domestic grey water of Shivamogga city. Ten grey water samples were collected in plastic can by employing random sampling from each ward out of 35 wards 350 grey water samples were collected from Shivamogga municipal city corporation jurisdiction The pH of the domestic grey water was ranged from neutral to alkaline (6.58-8.91) and electrical conductivity was 0.2 – 2.16 dS m^{-1} with total dissolved solids are ranged from 68.32-1227.25 mg L^{-1}. BOD and COD values are within the permissible limit and ranged from 6 to 32.4 mg L^{-1}, 0.12 to 444 mg L^{-1}, respectively and BOD/COD (0.13 mg L^{-1}) ratio was well below the 2 mg L^{-1}. Among the cations, sodium (0.3-22.98 meq L^{-1}) and potassium (0-22.49 meq L^{-1}) concentrations range was observed and mean cationic concentration was in the order of Na (11.26 meq L^{-1}) > K (7.30 meq L^{-1}) > Ca (2.24 meq L^{-1}) > Mg (1.58 meq L^{-1}). In anions, bicarbonate (0.6-15.3 meq L^{-1}) and chloride (0.5-11.32 meq L^{-1}) concentration was higher in the grey water and carbonate (0-4.2 meq L^{-1}), phosphate (0.01-10.82 meq L^{-1}) and sulphate (0.02-22.0 meq L^{-1}). Among the nitrogen forms nitrate –N (1.12-427.84 mg L^{-1}) and ammonical –N (1.18-40.32 mg L^{-1}) was observed. The mean concentration of micronutrients in domestic grey water was zinc (0.12 ppm), iron (0.41 ppm), manganese (0.15 ppm) were within the permissible range except copper (0.27 ppm) and boron (1.33 ppm) which was above the permissible range and unsuitable for irrigation purpose. Grey water sodium adsorption ratio (SAR:0.13-19.77meq L^{-1}) and residual sodium carbonate (RSC:0.9-7.7 meq L^{-1}) indicated grey water can be used for irrigation purpose with management. Suspended solids (100-2000 ppm) in grey water were above the permissible limit and very hard in nature due to various dissolved salts. Heavy metals are below detectable limit and pathogen E. coli present in the range of 0-1× 10^3 CFU ml^{-1}.

Keywords: Carbonates, heavy metals, E.coli, irrigation, BOD,COD

Introduction
India is facing a water crisis and by 2025 it is estimated that India's population will be suffering from severe water scarcity. Although India occupies only 3.29 million square kilometres geographical areas which form 2.4 per cent of the worlds land area, it supports over 15 per cent of world's population with only 4 per cent of the world's water resources. With increased population growth and development, there is a need to critically look at alternative approaches to ensure water availability. These alternative resources include rainwater and bulk of water used in household will emerge as grey water and contain some minerals, organic waste materials dissolved and suspended in it. When this is allowed to flow out this will join the sewage and bacteriologically contaminated, resulting in a sewage stream. It is possible to intercept this grey water, at the household level, treat it so that it can be recycled for garden washing and flushing purposes.

Grey water is specifically wash water also spelled sullage. That is, sinks, showers, bath, dish washers and laundry water generated in households or restaurants and hotels from streams without fecal contamination that is excluding toilet wastes and free of garbage-grinder residues. As grey water contains fewer pathogens than domestic waste water (includes toilet stream), it is generally safer to handle and easier to treat and reuse, when properly managed. Treated grey water can be a valuable resource which horticultural and agricultural growers as well as home gardeners can benefit from. It can also be valuable to landscape planners,

builders, developers and contractors because of the design and landscaping advantages of on-site grey water treatment/management. It is, after all, the same phosphorous, potassium and nitrogen making grey water a source of pollution for lakes, rivers and ground water which are excellent nutrient sources for vegetation when this particular form of wastewater is made available for irrigation.

The composition of grey water varies greatly with its origin (i.e., bathroom, laundry or kitchen grey water) and is influenced by the water quality of the locality. A variety of contaminants including acidic and alkaline substances, suspended and dissolved solids, fats, oil and grease, heavy metals, synthetic chemicals and pathogenic organisms are likely to be present in grey water (Rakesh *et al.*, 2004; Eriksson and Donner, 2009) [9]. Roeleveld and Zeeman (2006) [22] reported that the organic fractions in grey water are around 30 per cent, while the nutrient fraction constitutes 9 – 20 per cent.

Materials and methods

The Shivamogga urban is semi densely populated municipal corporation located in central parts of Karnataka divided with 35 municipal wards. Ten grey water samples were collected in plastic can by employing random sampling from 10 house of a 35each wards of Shivamogga municipal city corporation jurisdiction. Water sample collected from showers, bathtubs, sinks, kitchen, dishwashers, laundry tubs and washing machines together called grey water. Collected grey water samples were brought to the laboratory and were refrigerated at 4 ^{o}C immediately and analyzed subsequently. The dissolved solids in the samples were determined by gravimetric method and suspended solids by filtration method. The biological oxygen demand (BOD) of water samples was determined by Wrinkler's method and the chemical oxygen demand (COD) by Open reflux method. Micronutrients and heavy metals (Fe, Zn, Cu, Mn, Pb, Hg, Cd and Cr) in the water samples were measured by using ICPOES. The filtered water samples were acidified with 1 ml of conc. HNO_3 and the samples were fed to the ICP-OES. The bacteria, fungi, actinomycetes and E.coli count in grey waters were determined by using serial dilution and standard plate count technique. The other estimations for the characterization of grey water were carried out by applying standard procedures.

Results

Chemical Characteristics of Shivamogga city domestic grey water

The results of grey water samples were interpreted like the 85% pH of the domestic grey water was alkaline (>7.5) can be used with treatment and ranged from 6.5 to 8.91.Electrical conductivity 43% (0.8 – 1.6 dS m^{-1}) grey water samples can be used with moderate leaching and 26% (1.6 – 2.5 dS m^{-1}) were high in EC cannot be used for irrigation, but 63% (450 – 2000 ppm) samples were medium in total dissolved solids and shows moderate restrictions in irrigation use. Grey water samples with 100% BOD (<1000 ppm) and >70% COD (<250ppm) values were within the permissible limit and ranged, respectively and 92% samples BOD/COD ratio was well below the 2 mg L^{-1}, which indicates biodegradable effluents are readily decomposable.

Among the cations, sodium (63%) and potassium (66%) concentrations was above the permissible level for irrigation and cationic concentration was in the order of Na (11.26 meq L^{-1}) > K (7.30 meq L^{-1}) > Ca (2.24 meq L^{-1}) > Mg (1.58 meq L^{-1}). In anions, bicarbonate (83%) and chloride (83%) concentration was moderate and higher in the grey water, respectively which suggesting moderate restriction for irrigation and carbonate (96%), phosphate (90%) and sulphate (97%) which was usual range for irrigation water. Among the nitrogen forms nitrate –N (85%) and ammonical –N (62%) moderate restriction to high for irrigation use. Concentration of micronutrients zinc (0.12 ppm), iron (0.41 ppm), manganese (0.15 ppm) were within the permissible range except copper (0.27 ppm) and boron (1.33 ppm) which was above the permissible range and unsuitable for irrigation purpose. Grey water sodium adsorption ratio with 94% samples were suggest that no hazard and it was within the permissible range for irrigation, but 80% grey water samples can be used for irrigation purpose with management of residual sodium carbonate. Suspended solids (658.20 ppm) in grey water were above the permissible limit and 94% samples were very hard in nature due to various dissolved salts. The concentration of heavy metals like Cd, Co, Cr, Ni, As and Hg were below detectable level in the Shivamogga domestic grey water. The heavy metal Pb and Se detected from the range of 0.001-0.016 mg $L^{-1}$and 0.001-0.003 mg L^{-1}, respectively.

Microbial load in domestic grey water

Grey water recorded large counts of microorganisms, in the order of abundance being bacteria (177 CFU × 10^5 ml^{-1}) > actinomycetes (67 CFU × 10^3 ml^{-1}) > fungi (5 CFU × 10^4 ml^{-1}). The organic material in the grey water provides the needed carbon materials for the growth of these microorganisms. The average of bacteria, fungi and actinomycetes count ranged from 58-632 CFU × 10^5 ml^{-1}, 1-11 CFU × 10^4 ml^{-1} and 21-109 CFU × 10^3 ml^{-1}, respectively. E.coli was present in the range of 0- 2 CFU × 10^3 ml^{-1} in grey water suggesting contamination by fecal matter.

Discussion

The pH in grey water is directly related to certain chemicals such as fabric softeners, bleaching agents and disinfectants (Eriksson *et al.*, 2002) [10]. Braga and Varesche (2014) [5] reported acidic pH (5.6) in grey water, but Friedler (2004) [11] reported extreme alkaline pH (10) in grey waters of Israel. In general, wide variation in pH, ranging from 6.4 to 8.1 was reported in grey water by many researchers (Parjane and Sane, 2011) [20]. Grey water with most of its sources originating from the laundry will generally exhibit high pH due to the presence of alkaline materials used in detergents. The major chemical constituents found in grey water which is generated as a result of cleaning or washing activities are surfactant. These surfactants serve as the main active agent in most cleaning products. They can be either cationic or anionic in nature with a majority of cleaning and laundry products being anionic (Jakobi and Lohr 1987) [14]. Cationic surfactants are generally salt based, and they constitute a source of ammonium in the grey water. Other constituents found in grey water also include nitrates and phosphate which are reportedly from ammonium and cationic surfactants and laundry disinfectants respectively (Eriksson *et al.*, 2002) [10]. Sodium which is also from cooking and preservation activities in the kitchen can also be found in appreciable levels. Sodium-based soaps also contribute significant quantity of sodium into grey water. Nutrients such as N and P are associated with kitchen and laundry activities. Grey water sources with high nutrients concentrations are mostly made up of a high fraction of kitchen and laundry sources (Boyjoo *et al.*, 2013) [4].

Bodnar *et al.* (2014) reported conductivity values ranging from 0.52 – 1.27 d Sm^{-1} in grey water. Higher values of upto 4.7 d Sm^{-1} was obtained by Jamrah and Ayyash (2008) [15]. These variations would have been due to differential discharge of laundry, kitchen and floor washings at differential times. The detergents contain phosphates, sodium and potassium in their raw materials leads to the enrichment of the dissolved solids in the detergents leads to increase in

the electrical conductivity. The ranges recorded for electrical conductivity in grey water is between 14 and 3000 µS/cm (Ciabatti *et al*., 2009) [6]. Groundwater sources and water scarce areas are mostly associated with high electrical conductivity due to dissolved materials. Poor or old plumbing materials also contribute to the increase in electrical conductivity due to leaching into grey water sources.

The solid content of grey water in generally low, indicating that a large portion of the contaminants in dissolved form (Jayyousi, 2003) [16]. Suspended solid content varying from 15 mg L^{-1} (Smith and Melhem, 2012) [27] to 800 mg L^{-1} (Braga and Varesche, 2014) [5] were reported in Brazil. The source of suspended solids is body care products, toothpaste, shaving waste, skin, hair, body fats and food particles and fibers from various textiles (Ghaitidak and Yadav, 2013) [13]. Dissolved solids constitute an important fraction of grey water. Abinaya and Loganath (2015) [1] have reported TDS values of 712 mg L^{-1} to 990 mg L^{-1} in grey water collected from Chennai. Shegokar *et al.,* (2015) [26] reported 688.5 mg L^{-1} dissolved solids in Nagpur. Much higher values of 6888 mg L^{-1} was also reported in India (Sharma and Chhippa, 2014) [25]. Higher concentration of dissolved divalent ions such as calcium and magnesium in grey water imparts hardness to grey water (Lucy *et al.,* 2010) [17]. Extremely high hardness of 7028 mg L^{-1} was reported in Jaipur by Sharma and Chhipa (2014) [25]. The high temperatures may favor microbiological growth which is undesirable and may also cause precipitation of certain carbonates such as $CaCO_3$ and other inorganic salts which become less soluble at high temperatures. The concentration of total suspended solids in grey water can range within 190–537 mg L^{-1} as has been reported (Edwin *et al.* 2014; Oteng-Peprah *et al.,* 2018) [8, 19]. Grey water with much of the water originating from the kitchen and laundry accounts for the relatively high values of total suspended solids (TSS), and this may be due to washing of clothes, shoes, vegetables, fruits, tubers and many others which may contain sand, clay and other materials that could increase TSS.

Biological Oxygen Demand (BOD) refers to the oxygen requirement in the grey water for microbial breakdown of organic compounds at a constant temperature. Smith and Melhem (2012) [27] reported that the BOD in the grey water has very wider variations (5 mg L^{-1} to 431 mg L^{-1}). In Chennai, Abinaya and Loganath (2015) [1], who reported BOD range of 120 mg L^{-1} to 350 mg L^{-1}. In Malaysia, identical result was recorded by Mohamed *et al.* (2012) [18] with BOD ranging from 155 mg L^{-1} to 213 mg L^{-1} in raw grey water. The BOD values of 41.2 mg L^{-1} in Amman, Jordan (Jamrah *et al.*, 2006) and 31.0 mg L^{-1} to 40.0 mg L^{-1} in Senegal (Sall and Takashi, 2006) [24] were also reported. The main contributor to BOD in grey water is the dissolved organics and suspended food particles. Braga and Varesche (2014) [5] reported COD values of 4800 mg L^{-1} in Brazil of commercial laundry grey water. In contrast to this, Smith and Melhem (2012) [27] reported lower COD values of 38 mg L^{-1} to 1843 mg L^{-1} in grey water. Jefferson *et al*. (2004) reported that grey water tends to contain fewer solids, as its contaminants are dissolved, which would keep the COD:BOD ratio around 4:1 in grey water. Variations in COD observed in the findings of Tilve (2014) reported COD variations between 383.57 mg L^{-1} and 434 mg L^{-1} in Nagpur. Similarly, in Chennai also, Abinaya and Loganath (2015) [1] reported COD values ranging from 254 mg L^{-1} to 618 mg L^{-1} in grey water.

The coliforms represent the fecal contamination in the water. Winward *et al.* (2008) [29] reported that the fecal contamination of grey water is a common occurrence, creating the risk of a range of fecally transmitted pathogens. Coliform populations of 3×10^3 to 2.4×10^7 CFU per 100 ml was reported by Eriksson *et al.* (2002) [10]. Rose *et al.* (1991) [23] reported that families with children had high coliform count (3.2×10^5 and 1.5×10^3 CFU per 100 ml) in grey water as compared families without children (6×10^5 and 80×10^3 CFU per 100 ml). In a study carried out in London, Birks *et al.* (2004) [2] observed that fecal Enterococci were found in at least 70% of grey water tested. Occurrence of other pathogenic bacteria, was also reported in grey water. Friedler *et al.* (2011) [12] found skin pathogen (*Pseudomonas aeruginosa*), respiratory pathogen (*Legionella pneumophila*) and enteric pathogen (*Escherichia coli*) in grey water. Not only bacterial pathogens, but the pathogenic protozoan, Cryptosporidium sp. was also reported (Birks *et al.,* 2004) [2]. Enteric pathogenic bacteria, such as Salmonella and Campylobacter, can be introduced by food handling in the kitchen (Cogan *et al.,* 1999) in addition to that from the fecally derived matter.

Table 1: Chemical composition of Shivamogga city municipal corporation domestic grey water

S. No.	Parameters	Mean	Range	Interpretation
1	pH	7.86	6.58-8.91	> 85% samples were alkaline (>7.5 pH) and can be used after treatment with ammendments
2	EC (mmhos/cm)	1.15	0.2-2.16	> 69% samples were High in Electrical conductivity(>0.75 mmhos/cm) cannot be used for irrigation
3	TDS (ppm)	512.14	68.32-1227.25	>63% samples were medium in range (450-2000 ppm) and moderate restriction for irrigation use
4	CO_3(meq/l)	0.60	0-4.2	>96% samples were within the range (0-1 meq/l) can be used for irrigation
5	HCO_3(meq/l)	4.42	0.6-15.3	>83% samples were medium in range (1.5-8.5 meq/l) and Moderate restriction in irrigation use
6	Ca(meq/l)	2.24	0.62-21.4	>94% samples were within the range (1-20 meq/l)
7	Mg(meq/l)	1.58	0.43-6.3	>82% samples were within the range (0-5 meq/l)
8	Na(mg/l)	11.26	0.3-22.98	>63% samples were above the range (>9 mg/l) and severe restriction for irrigation use
9	RSC (meq/l)	2.10	0.9-7.7	>80% samples were low to medium range (1.25-2.25meq/l) and can be used with management
10	SAR	8.64	0.13-19.77	>94% samples were low to medium (10-18) and can be used with management
11	COD (mg/l)	147.82	0.12-444	> 70% samples were within the permissible limit (<250 mg/l)
12	PO_4(meq/l)	2.10	0.01-10.82	>90% samples were medium to high in range (0-2 meq/l)
13	SO_4(meq/l)	2.12	0.02-22	>97% samples were moderate in the range (0-20 meq/l)
14	K(meq/l)	7.30	0-22.49	>66% samples were above the range (>2 meq/l)
15	Fe(ppm)	0.41	0.12-0.76	Within the permissible range
16	Cu(ppm)	0.27	0.17-0.57	above the permissible range
17	Mn(ppm)	0.15	0.001-0.63	Within the permissible range
18	Zn(ppm)	0.12	0.03-0.23	Within the permissible range
19	Bo(ppm)	1.33	0.08-8.51	>91% samples were medium in range (0-2 ppm) and moderate restriction in irrigation use
20	Total N(ppm)	71.08	3.36-432.32	-
21	NH_3-N(ppm)	15.23	1.18-40.32	>62% samples were above the range (>5 ppm)

22	NO_3-N(ppm)	55.76	1.12-427.84	>85% samples were above the range (>10 ppm)
23	Cl (meq/l)	2.65	0.5-11.32	>83% samples were low in range (4 meq/l)
24	Suspended solids(ppm)	658.20	100-2000	>90% samples were above the permissible limit
25	Hardness(ppm)	427.59	122-1870	>94% samples were very hard in nature (>181 ppm)
26	BOD (ppm)	19.08	6-32.4	100% samples were within the permissible range

Table 2: Heavy metal composition of Shivamogga city Municipal Corporation domestic grey water

Sl. no	Heavy metals (mg L^{-1})	Range	Mean
1	Cd	BDL	BDL
2	Co	BDL	BDL
3	Cr	BDL	BDL
4	Ni	BDL	BDL
5	Pb	0.001-0.016	0.006
6	Se	0.001-0.003	0.001
7	As	BDL	BDL
8	Hg	BDL	BDL

BDL: Below Detectable Limit

Table 3: Microbial load in Shivamogga city Municipal Corporation domestic grey water

Sl. no	Microbial load	Range	Mean
1	Bacteria (CFU × 10^5 ml^{-1})	58-632	177
2	Fungi (CFU × 10^4 ml^{-1})	1-11	5
3	Actinomycetes (CFU × 10^3 ml^{-1})	21-109	67
4	E.coli (CFU × 10^3 ml^{-1})	0-2	1

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