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Qualitative characterization for suitability assessment of residential grey water in terms of water quality index

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Abstract
Grey water has attracted global attention as an alternative water source over the last few decades. In India, considering the projected decline in fresh water availability for agriculture to around 70 per cent by 2025, the major challenge before the nation is to increase the country's capacity to achieve expected food security. Under this water crisis scenario, grey water - an alternate source to supplement the overall water use is the need of hour. To exploit the potential resource of grey water, Water Quality Index based characterization with special reference to key water quality parameters bear immense importance to assess overall suitability of this resource for further reutilization. With 14 key water quality parameters *viz.* Total Nitrogen, Nitrate, Orthophosphate, Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), pH, EC, Sulphate, Chloride, Carbonate, Bi-carbonate, Fluoride, Alkalinity, Arsenic of grey water collected from 10 different sites, a study was conducted at Assam Agricultural University and their suitability was assessed through evaluation of Water Quality Index (WQI). WQI over the 10 locations ranged from 231.31 to 304.58 with an average value of 260.02 ± 22.71 and received highest contributions from BOD and EC followed by fluoride and nitrate nitrogen. The WQI for all the locations according to their scores decreased from Site 1 to Site 10 following the trend Site 1(304.58), Site 3 (295.95), Site 6 (279.32), Site 7 (273.97), Site 2 (255.47), Site 8 (246.34), Site 4 (243.96), Site 5 (235.93), Site 9 (233.39), and Site 10 (231.31). All the sites fall under unsuitable water category for any use including drinking, fish culture and irrigation signifying the requirement of adequate treatment prior to reuse for irrigational purpose.

Keywords: Assam, characteristics, grey water, water quality index

Introduction
The demand for water is increasing day by day due to increased industrialization, population explosion, climate change and indiscriminate exploitation of water resources. This demand is posing a great challenge invoking the search of strategies for sustainable use of water, which calls for the use of rainwater, greywater and various other types of wastewater. Due to paucity of clean supply of water, efforts are now to undertake pragmatic alternative of meeting water needs for agriculture and allied sectors more particularly for irrigation so as to improve water productivity and development of sound water management policy. Considering the impounded pressure on freshwater resource for irrigation in crops and other uses like animal husbandry, fisheries etc. besides potable purpose among others; there is strategic need to reduce this pressure and therefore our effort is to search for other alternative source of water. Under this water crisis scenario, grey water - an alternate source to supplement the overall water use is the need of hour. Grey water is the relatively clean waste water from baths, sinks, washing machines, and other kitchen appliances. As 50-80 per cent of residential wastewater is generally grey water, therefore there is enough opportunity to exploit such potential greywater reserve in supplementing water demand for different sectors as an economic and resource conservation component of the integrated water resources management more particularly in water deficit areas. The physical as well as chemical properties vary from household to household and depend on different factors, such as availability of water and lifestyle of households. Greywater used for agricultural irrigation covers different qualities ranging from partially raw to diluted form that serves to reduce the pressure on potable water for irrigation purpose. Another aspect of grey water is the maintenance of water quality requirement for irrigation based on physico-chemical and microbiological characterization which determines

their effective use for further exploitation for irrigation. In order to address the question whether or not grey water is suitable for further reuse proper assessment is required.

Materials and Methods

1. Greywater Collection

A greywater collection system was installed on the drains of bathroom/ kitchen sinks, showers, tubs, and washing machines from each of the collection sites. In each case, greywater was allowed to travel down into the drain on which greywater samples were collected. A total of ten (10) representative samples of raw grey water from ten (10) different sites *viz*. Hostel 1, 2, 3, 4, 10, 11, 12, 14, New Professor's Colony and International Girl's Hostel within the campus of Assam Agricultural University, Jorhat were collected. Each sample was drawn alternatively at 3^{rd} day of the month of February and transported to laboratory for analysis and characterized based on their quality parameters. The grey water so collected was stored in large sized (2.5 L) borosilicate glass beakers and tested for water quality parameters. In the event of the samples to be preserved, it was stored in covered beaker at 4^0C. However, maximum effort was taken to get the samples analyzed within 24 hrs of the storage.

2. Laboratory Analysis

Physico-chemical properties of the greywater were determined for the selected parameters viz. Total Nitrogen, Nitrate, Orthophosphate, Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), pH, Electrical Conductivity (EC), Sulphate (SO_4^{2-}), Chloride, Carbonate (CO_3^{2-}), Bi-carbonate (HCO_3^{1-}), Alkalinity, Fluoride and Arsenic. The parametric analyses of raw greywater were done as per the standard methods outlined by various authors.

2.1 Total Kjeldahl Nitrogen (TKN)

TKN was measured by digesting the samples as per the modified Kjeldahl digestion method (Jackson, 1973) [13].

2.2 Nitrate Nirogen

Nitrate was determined by Digestion and distillation method (Jackson, 1973) [13].

2.3 Phosphate

Orthophosphate was measured using the ascorbic acid EPA-accepted method using double beam visible spectrophotometer (HACH, 1992) [1].

2.4 Total Suspended Solids (TSS)

TSS was measured by the method described by Baruah and Barthakur, (1999) [4].

2.5 Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand was measured using Standard Method 5210 B (American Public Health Association, 1992). This method employs determination of dissolved oxygen before and after a 5-day incubation period.

2.6 pH

pH of the raw greywater sample was measured using the pH meter. pH meter is first calibrated with known solutions of pH 4 and 7 (Jackson, 1973) [13].

2.7 Electrical Conductivity (EC)

Electrical conductivity of the water samples was determined using Systronic conductivity meter (Baruah and Barthakur, 1999) [4]. Conductivity meter consists of an electrode which when immersed in the sample gives reading in mS/cm. The conductivity meter works at a temperature of 27^0 C.

2.8 Sulphate

Sulphate was estimated by Turbidometric method (Baruah and Barthakur, 1999) [4] based on the precipitates of barium-sulphate in presence of sodium chloride, hypochloric acid and glycerol.

2.9 Chloride

The chloride content was determined by titrating with silver nitrate using potassium dichromate indicator (A.O.A.C, 1950) [3].

2.10 Carbonate, Bicarbonate (CO_3^{2-}, HCO_3^{1-}) and Alkalinity

CO_3^{2-}, HCO_3^{1-} and alkalinity content were evaluated by acidimetric titration in presence of phenolophthalin indicator (Baruah and Barthakur, 1999) [4].

2.11 Fluoride

Fluoride was determined by ion selective electrode method (A.O.A.C., 1950) [3].

2.12 Arsenic

Arsenic content was estimated by following potassium iodide method (Dhar *et al.*, 2004) [10].

In order to observe the relationships among the 14 above variables, a multiple correlations was worked out using SPSS statistical package which envisaged their degree of relationships in inferring the influence of one variable over the other(s).

3 Evaluation of WQI

Calculation of WQI was carried out by following the 'weighted arithmetic index method' (Brown *et al*. 1972) [8]. A set of 14 most commonly used water quality parameters as mentioned above was considered for generating the water quality index (WQI) using the following equation:

$$WQI = \Sigma Q_n W_n / \Sigma W_n$$

Where Q_n is the quality rating of n^{th} water quality parameter, W_n is the unit weight of n^{th} water quality parameter. The quality rating Q_n is calculated using the equation

$$Qn = 100\,[(V_n - V_i)/(V_s - V_i)]$$

where V_n is the actual amount of n^{th} parameter present, V_i is the ideal value of the parameter.

[V_i = 0, except for pH (V_i = 7) and DO (V_i = 14.6 mg/l)], V_s is the standard permissible value for the n^{th} water quality parameter. Unit weight (W_n) is calculated using the formula

$$W_n = k/V_s$$

where k is the constant of proportionality and it is calculated using the equation

$$k = [1/\ \Sigma 1/V_s = 1, 2, ..., n]$$

The weights thus obtained are assigned the status as depicted by Brown *et al.* (1972) [8] (given in table 1)

Results

In the study, the water collected from the different sites was analysed for 14 key quality parameters. The range for the different parameters over ten different locations within the AAU campus and location wise key parameters are presented in Table 2 and 3 respectively.

Water Quality Index (WQI), a dimensionless unit that combines multiple water quality factors into a single number, is considered as one of the most effective approach to categorize water quality status based on which its suitability could be established. For evaluation of WQI following the method "weighted arithmetic index", unit weight was assigned to each selected key quality parameters of grey water. Relative weight for each parameter of different unit and dimension was transformed to a common scale after considering the permissible value of each parameter in relation to overall sum of all the parameters. Water quality standardized for ideal and permissible categories and the unit weights assigned to each parameter is depicted in Table for calculation of WQI. Maximum relative weight was observed in EC (0.485) which was followed by fluoride (0.258), PO_4 (0.077), BOD (0.077), pH (0.045), NO_3-N (0.038) etc. and the minimum in total suspended solids (0.0002), suggesting thereby the key significance of the parameters in water quality assessment and their overall impact in water quality.

The actual analytical value for all the parameters in ten selected sampling sites after series of steps was transformed to WQI values which are presented in Table 5 to 14.

Out of the fourteen parameters studied, the prominent influencing parameters from the highest to the lowest in descending order on overall WQI (304.52) was BOD (211.88), EC (79.45), fluoride (10.34), NO_3-N (1.98), PO_4(1.80), HCO_3 (0.0443), arsenic (0.012), TSS (-0.006), SO_4 (-0.007), alkalinity (-0.009), chloride (-0.011), CO_3 (-0.099), total nitrogen (-0.162) and pH (-0.608) in Site 1 (Table 5).

The highest to lowest contributory parameters towards overall WQI of 255.47 in Site 2 were found to be BOD (144.70), EC (66.57), fluoride (46.51), NO_3-N (0.484), CO_3(-0.099), arsenic (0.038), TSS (-0.006), alkalinity (-0.010), chloride (-0.012), HCO_3 (0.022), SO_4 (-0.025), total nitrogen (-0.232), pH (-0.304) and PO_4(-2.32) (Table 6).

The WQI with score of 295.95 in Site 3 followed more or less similar trend towards contributing the WQI. The individual contribution of different parameters towards WQI in descending order were BOD (165.37), EC (69.86), fluoride (62.01), NO_3-N (1.45), pH (0.304), carbonate (0.155), arsenic (0.133), HCO_3 (0), TSS (-0.006), alkalinity (-0.006), chlorine (-0.010), SO_4 (-0.027), Total Nitrogen (-0.197) and PO_4 (-3.10) (Table 7).

Results showed that the estimated WQI of 243.96 received contributions from all the fourteen parameters and the maximum to minimum role were observed for BOD (167.96), EC (57.84), fluoride (20.67), arsenic (0.116), carbonate (0.166), HCO_3 (0.060), NO_3-N (0) and pH (0), TSS (-0.006), alkalinity (-0.009), chloride (-0.011), SO_4(-0.025), total nitrogen (-0.218) and PO_4 (-2.58) in Site 4 (Table 8).

Out of the fourteen key quality parameters of grey water studied, the major influencing parameters based on their contributions arranged from the highest to the lowest towards overall WQI of 235.93 in site 5 were BOD (180.88), EC (63.56), NO_3-N(0.484), carbonate (0.188),arsenic (0.185), HCO_3 (0.077), TSS (-0.006), alkalinity (-0.009), chlorine (-0.009), SO_4 (-0.014), total nitrogen (-0.22), pH (-0.912), PO_4(-3.10), fluoride (-5.16) (Table 9).

In regards to Site 6, a WQI of 279.32 was estimated with the contributions from all the 14 key quality parameters of grey water. The major parameters with their role contributing WQI in decreasing order were BOD (186.04), EC (80.33), fluoride (15.50), NO_3-N (0.484), carbonate (0.132), arsenic(0.120), TSS (-0.006), SO_4(-0.006), alkalinity (-0.009), chloride (-0.010), HCO_3 (-0.011), pH (-1.52), PO_4 (-1.55) and total nitrogen (-0.183) (Table 10).

Among the fourteen parameters of grey water studied over the locations, it was seen that to contribute an overall WQI of 273.97 in Site 7, the major share towards the WQI in reducing order were noticed for BOD (173.12), EC (70.25), fluoride (31.00), pH (0.304), carbonate (0.118), HCO_3 (0.077), arsenic (0.025), NO_3-N(0), TSS (-0.006), alkalinity (-0.008), chloride (-0.009), SO_4 (-0.021), total nitrogen (-0.190) andPO_4 (-0.775) (Table 11).

The overall WQI in Site 8 was observed to be 246.34 with the highest contribution from BOD and lowest from phosphate. The major share of parameters towards the estimation of WQI arranged in descending order were BOD (149.87), EC (77.52), fluoride (20.67), pH (0.608), NO_3-N(0.484), arsenic (0.051), HCO_3 (0.011), alkalinity (-0.006), TSS (-0.007), chloride (-0.010), carbonate (-0.011), SO_4 (-0.020), total nitrogen (-0.232), PO_4(-2.5) (Table 12).

Among the fourteen parameters observed towards overall estimation of WQI in Site 9, the prominent parameters in decreasing order were: BOD (175.71), EC (57.07), fluoride (5.16), carbonate (0.199), arsenic (0.077), HCO_3 (0.022), NO_3-N(0), SO_4 (-0.003), TSS (-0.006), Alkalinity (-0.007), Chloride (-0.009), Total Nitrogen (-0.253), pH (-1.21), PO_4(-3.35) in site 9 (Table 13).

With the highest contribution of BOD (191.21) on overall WQI of 231.31 in Site 10, the other parameters with their role towards the index were observed to be EC (45.34), NO_3-N(2.90), arsenic (0.116), carbonate (0.077), TSS (-0.006), SO_4 (-0.007), alkalinity (-0.009), chloride (-0.010), HCO_3 (-0.044), total nitrogen (-0.169), pH (-0.608), PO_4(-2.32) and fluoride (-5.16) (Table 14).

4.3 Categorization of Water Quality Index

WQI values presented in Table 15 and Fig. 1 depicted that all the sites fall under unsuitable water category for any use including drinking, fish culture and irrigationas their values exceeded more than the recommended value of 100. WQI values over the locations ranged from 231.31at Site 10 to 304.58 at site S1 with an average WQI value of 260.02 ± 22.71. The WQI scores for all the locations according to their decrease in order were Site 1(304.58), Site 9 (233.39), Site 8 (246.34), Site 7 (273.97), Site 6 (279.32), Site 5 (235.93), Site 4 (243.96), Site 3 (295.95), Site 2 (255.47) and Site 10 (231.31).

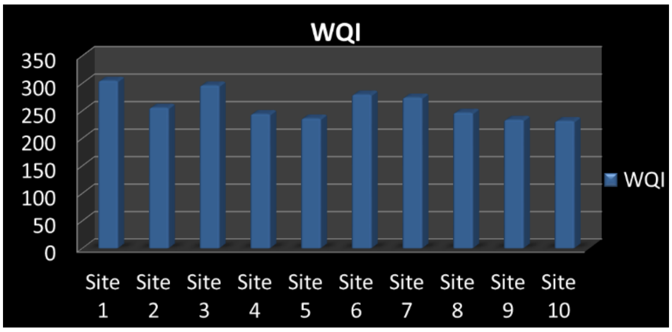

Fig 1: Graphical representation of WQI of 10 sites

Table 1: Water quality status given by Brown *et al.* (1972) [8]

WQI	Water quality status (WQS)	Possible usage
0–25	Excellent	Drinking, irrigation and industrial
26–50	Good	Drinking, irrigation and industrial
51–75	Poor	Irrigation and industrial
76–100	Very poor	Irrigation
Above 100	Unsuitable for drinking and fish culture	Proper treatment required before use

Table 2: Characteristics of grey water on certain key water quality parameter

Sl. No.	Parameters	Mean ± SD	Range
1	Total Nitrogen (μg/ml)	15.70 ± 4.32	9 - 22
2	Nitrate (μg/ml)	3.70 ± 2.00	2 – 8
3	Phosphate (μg/ml)	1.23 ± 0.59	0.7 – 2.7
4	TSS (mg/L)	24.70 ± 6.70	18 - 38
5	BOD (μg/ml)	69.60 ± 7.60	58 - 84
6	pH	6.87 ± 0.23	6.5 – 7.2
7	EC (mS/cm)	0.99 ± 0.11	0.768 – 1.129
8	Sulphate (μg/ml)	108.60 ± 23.19	79 - 141
9	Chloride (μg/ml)	45.10 ± 17.25	16 - 71
10	Carbonate (μg/ml)	49.80 ± 17.62	12 - 66
11	Bi-carbonate (μg/ml)	33.90 ± 7.66	22 - 44
12	Alkalinity (μg/ml)	56.10 ± 10.12	43 - 76
13	Fluoride (μg/ml)	1.39 ± 0.42	0.9 – 2.2
14	Arsenic (μg/L)	30.40 ± 12.84	13 - 53

Table 3: Key water quality parameters of grey water over the selected sites

Sites	Locations	TN	NO_3-N	PO_4	TSS	BOD	pH	EC	SO_4	Cl	CO_3	HCO_3	Alk	F	As
1	Hostel No.1	22	6	2.7	38	84	6.8	1.124	130	31	12	38	51	1.2	13
2	Hostel No.2	12	3	1.1	21	58	6.9	0.987	85	16	48	26	43	1.9	19
3	Hostel No.3	17	5	0.8	28	66	7.1	1.021	79	48	58	30	69	2.2	41
4	Hostel No.4	14	2	1	18	67	7	0.897	85	30	60	41	48	1.4	37
5	Hostel No.10	13	3	0.8	19	72	6.7	0.956	112	68	64	44	53	0.9	53
6	Hostel No.11	19	3	1.4	31	74	6.5	1.129	132	49	54	28	53	1.3	38
7	Hostel No. 12	18	2	1.7	25	69	7.1	1.025	94	57	64	44	58	1.6	16
8	Hostel No. 14	12	3	1	20	60	7.2	1.1	98	42	28	32	76	1.4	22
9	New Professor Colony	9	2	0.7	18	70	6.6	0.889	141	71	66	34	61	1.1	28
10	International Girls Hostel	21	8	1.1	29	76	6.8	0.768	130	39	44	22	49	0.9	37

Table 4: Relative weights of the parameters used for determination of WQI

Parameters	ICMR/BIS Standard (V_i)	ICMR/ BIS standard (V_s)	$1/V_s$	Unit Weight (W_n)
Total Nitrogen (μg/ml)	45.00	100.00	0.010	0.003
Nitrate (μg/ml)	2.00	10.00	0.100	0.038
Phosphate (μg/ml)	2.00	5.00	0.200	0.077
TSS (mg/L)	500.00	2000.00	0.0005	0.0001
BOD (μg/ml)	2.00	5.00	0.200	0.077
pH	7.00	8.50	0.117	0.045
EC (mS/cm)	0.300	0.80	1.25	0.485
Sulphate (μg/ml)	150.00	400.00	0.002	0.0009
Chloride (μg/ml)	250.00	1000.00	0.001	0.0003
Carbonate (μg/ml)	30.00	100.00	0.010	0.003
Bi-carbonate (μg/ml)	30.00	100.00	0.010	0.003
Alkalinity (μg/ml)	120.00	600.00	0.001	0.0006
Fluoride (μg/ml)	1.00	1.50	0.666	0.258
Arsenic (μg/L)	10.00	100.00	0.010	0.003
Sum 2.57				
K 0.387				

Table 5: WQI of Site No. 1

Parameters	V_n	V_i	V_s	Q_n	W_n	$Q_n \times W_n$
Total Nitrogen (μg/ml)	22.00	45.00	100.00	-41.81	0.003	-0.162
Nitrate (μg/ml)	6.00	2.00	10.00	50.00	0.038	1.93
Phosphate (μg/ml)	2.70	2.00	5.00	23.33	0.077	1.80
TSS (mg/L)	38.00	500.00	2000.00	-30.80	0.0001	-0.006
BOD (μg/ml)	84.00	2.00	5.00	2733.33	0.077	211.88
pH	6.80	7.00	8.50	-13.33	0.045	-0.608
EC (mS/cm)	1.12	0.300	0.800	164.00	0.484	79.45

Sulphate (µg/ml)	130.00	150.00	400.00	-8.00	0.0009	-0.007
Chloride (µg/ml)	31.00	250.00	1000.00	-29.20	0.0003	-0.011
Carbonate (µg/ml)	12.00	30.00	100.00	-25.71	0.003	-0.099
Bi-carbonate (µg/ml)	38.00	30.00	100.00	11.42	0.003	0.044
Alkalinity (µg/ml)	51.00	120.00	600.00	-14.37	0.0006	-0.009
Fluoride (µg/ml)	1.20	1.00	1.50	40.00	0.258	10.33
Arsenic (µg/L)	13.00	10.00	100.00	3.33	0.003	0.012
					1.00	304.58
WQI						304.58

Table 6: WQI of Site No. 2

Parameters	V_n	V_i	V_s	Q_n	W_n	$Q_n \times W_n$
Total Nitrogen (µg/ml)	12.00	45.00	100.00	-60.00	0.003	-0.232
Nitrate (µg/ml)	3.00	2.00	10.00	12.50	0.038	0.484
Phosphate (µg/ml)	1.10	2.00	5.00	-30.00	0.077	-2.32
TSS (mg/L)	21.00	500.00	2000.00	-31.93	0.0001	-0.006
BOD (µg/ml)	58.00	2.00	5.00	1866.66	0.077	144.70
pH	6.90	7.00	8.50	-6.66	0.045	-0.304
EC (mS/cm)	0.987	0.30	0.800	137.40	0.484	66.57
Sulphate (µg/ml)	85.00	150.00	400.00	-26.00	0.0009	-0.025
Chloride (µg/ml)	16.00	250.00	1000.00	-31.20	0.0003	-0.012
Carbonate (µg/ml)	48.00	30.00	100.00	25.71	0.0038	0.099
Bi-carbonate (µg/ml)	26.00	30.00	100.00	-5.71	0.0038	-0.022
Alkalinity (µg/ml)	43.00	120.00	600.00	-16.04	0.0006	-0.011
Fluoride (µg/ml)	1.90	1.00	1.50	180.00	0.258	46.51
Arsenic (µg/L)	19.00	10.00	100.00	10.00	0.0038	0.038
					1.00	255.47
WQI						255.47

Table 7: WQI of Site No. 3

Parameters	V_n	V_i	V_s	Q_n	W_n	$Q_n \times W_n$
Total Nitrogen (µg/ml)	17.00	45.00	100.00	-50.90	0.003	-0.197
Nitrate (µg/ml)	5.00	2.00	10.00	37.50	0.038	1.45
Phosphate (µg/ml)	0.80	2.00	5.00	-40.00	0.077	-3.10
TSS (mg/L)	28.00	500.00	2000.00	-31.46	0.0001	-0.006
BOD (µg/ml)	66.00	2.00	5.00	2133.33	0.077	165.37
pH	7.10	7.00	8.50	6.66	0.045	0.304
EC (mS/cm)	1.02	0.30	0.800	144.20	0.484	69.86
Sulphate (µg/ml)	79.00	150.00	400.00	-28.40	0.0009	-0.027
Chloride (µg/ml)	48.00	250.00	1000.00	-26.93	0.0003	-0.010
Carbonate (µg/ml)	58.00	30.00	100.00	40.00	0.004	0.155
Bi-carbonate (µg/ml)	30.00	30.00	100.00	0.00	0.004	0.00
Alkalinity (µg/ml)	69.00	120.00	600.00	-10.62	0.0006	-0.006
Fluoride (µg/ml)	2.20	1.00	1.50	240.00	0.258	62.01
Arsenic (µg/L)	41.00	10.00	100.00	34.44	0.004	0.133
					1.00	295.95
WQI						295.95

Table 8: WQI of Site No. 4

Parameters	V_n	V_i	V_s	Q_n	W_n	$Q_n \times W_n$
Total Nitrogen (µg/ml)	14.00	45.00	100.00	-56.36	0.003	-0.218
Nitrate (µg/ml)	2.00	2.00	10.00	0.00	0.038	0.00
Phosphate (µg/ml)	1.00	2.00	5.00	-33.33	0.077	-2.58
TSS (mg/L)	18.00	500.00	2000.00	-32.13	0.0001	-0.006
BOD (µg/ml)	67.00	2.00	5.00	2166.66	0.077	167.96
pH	7.00	7.00	8.50	0.00	0.045	0.00
EC (mS/cm)	0.897	0.300	0.800	119.40	0.484	57.84
Sulphate (µg/ml)	85.00	150.00	400.00	-26.00	0.0009	-0.025
Chloride (µg/ml)	30.00	250.00	1000.00	-29.33	0.0003	-0.011
Carbonate (µg/ml)	60.00	30.00	100.00	42.85	0.003	0.16
Bi-carbonate (µg/ml)	41.00	30.00	100.00	15.71	0.003	0.060
Alkalinity (µg/ml)	48.00	120.00	600.00	-15.00	0.0006	-0.009
Fluoride (µg/ml)	1.40	1.00	1.50	80.00	0.258	20.67
Arsenic (µg/L)	37.00	10.00	100.00	30.00	0.003	0.116
					1.00	243.96
WQI						243.96

Table 9: WQI of Site No.5

Parameters	V_n	V_i	V_s	Q_n	W_n	$Q_n \times W_n$
Total Nitrogen (µg/ml)	13.00	45.00	100.00	-58.18	0.003	-0.225
Nitrate (µg/ml)	3.00	2.00	10.00	12.05	0.038	0.484
Phosphate (µg/ml)	0.800	2.00	5.00	-40.00	0.077	-3.10
TSS (mg/L)	19.00	500.00	2000.00	-32.06	0.0001	-0.006
BOD (µg/ml)	72.00	2.00	5.00	2333.33	0.077	180.88
pH	6.70	7.00	8.50	-20.00	0.045	-0.912
EC (mS/cm)	0.956	0.300	0.800	131.20	0.484	63.56
Sulphate (µg/ml)	112.00	150.00	400.00	-15.20	0.0009	-0.014
Chloride (µg/ml)	68.00	250.00	1000.00	-24.26	0.0003	-0.009
Carbonate (µg/ml)	64.00	30.00	100.00	48.57	0.003	0.188
Bi-carbonate (µg/ml)	44.00	30.00	100.00	20.00	0.003	0.077
Alkalinity (µg/ml)	53.00	120.00	600.00	-13.95	0.0006	-0.009
Fluoride (µg/ml)	0.900	1.00	1.50	-20.00	0.258	-5.16
Arsenic (µg/L)	53.00	10.00	100.00	47.77	0.003	0.185
					1.00	235.93
WQI						235.93

Table 10: WQI of Site No. 6

Parameters	V_n	V_i	V_s	Q_n	W_n	$Q_n \times W_n$
Total Nitrogen (µg/ml)	19.00	45.00	100.00	-47.27	0.003	-0.183
Nitrate (µg/ml)	3.00	2.00	10.00	12.50	0.038	0.484
Phosphate (µg/ml)	1.40	2.00	5.00	-20.00	0.077	-1.55
TSS (mg/L)	31.00	500.00	2000.00	-31.26	0.0001	-0.006
BOD (µg/ml)	74.00	2.00	5.00	2400.00	0.077	186.04
pH	6.50	7.00	8.50	-33.33	0.045	-1.52
EC (mS/cm)	1.12	0.300	0.800	165.80	0.484	80.33
Sulphate (µg/ml)	132.00	150.00	400.00	-7.20	0.0009	-0.006
Chloride (µg/ml)	49.00	250.00	1000.00	-26.8	0.0003	-0.010
Carbonate (µg/ml)	54.00	30.00	100.00	34.28	0.003	0.132
Bi-carbonate (µg/ml)	28.00	30.00	100.00	-2.85	0.003	-0.011
Alkalinity (µg/ml)	53.00	120.00	600.00	-13.95	0.0006	-0.009
Fluoride (µg/ml)	1.30	1.00	1.50	60.00	0.258	15.50
Arsenic (µg/L)	38.00	10.00	100.00	31.11	0.003	0.120
					1.00	279.32
WQI						279.32

Table 11: WQI of Site No. 7

Parameters	V_n	V_i	V_s	Q_n	W_n	$Q_n \times W_n$
Total Nitrogen (µg/ml)	18.00	45.00	100.00	-49.09	0.003	-0.190
Nitrate (µg/ml)	2.00	2.00	10.00	0.00	0.038	0.00
Phosphate (µg/ml)	1.70	2.00	5.00	-10.00	0.077	-0.775
TSS (mg/L)	25.00	500.00	2000.00	-31.66	0.0001	-0.006
BOD (µg/ml)	69.00	2.00	5.00	2233.33	0.077	173.12
pH	7.10	7.00	8.50	6.66	0.045	0.304
EC (mS/cm)	1.02	0.300	0.800	145.00	0.484	70.25
Sulphate (µg/ml)	94.00	150.00	400.00	-22.40	0.0009	-0.021
Chloride (µg/ml)	57.00	250.00	1000.00	-25.73	0.0003	-0.009
Carbonate (µg/ml)	64.00	30.00	100.00	48.57	0.003	0.188
Bi-carbonate (µg/ml)	44.00	30.00	100.00	20.00	0.003	0.077
Alkalinity (µg/ml)	58.00	120.00	600.00	-12.91	0.0006	-0.008
Fluoride (µg/ml)	1.60	1.00	1.50	120.00	0.258	31.00
Arsenic (µg/L)	16.00	10.00	100.00	6.66	0.003	0.025
					1.00	273.97
WQI						273.97

Table 12: WQI of Site No. 8

Parameters	V_n	V_i	V_s	Q_n	W_n	$Q_n \times W_n$
Total Nitrogen (µg/ml)	12.00	45.00	100.00	-60.00	0.003	-0.232
Nitrate (µg/ml)	3.00	2.00	10.00	12.50	0.038	0.484
Phosphate (µg/ml)	1.00	2.00	5.00	-33.33	0.077	-2.58
TSS (mg/L)	20.00	500.00	2000.00	-32.00	0.0001	-0.006
BOD (µg/ml)	60.00	2.00	5.00	1933.33	0.077	149.87
pH	7.20	7.00	8.50	13.33	0.045	0.608
EC (mS/cm)	1.10	0.300	0.800	160.00	0.484	77.52
Sulphate (µg/ml)	98.00	150.00	400.00	-20.80	0.0009	-0.020

Chloride (µg/ml)	42.00	250.00	1000.00	-27.73	0.0003	-0.010
Carbonate (µg/ml)	28.00	30.00	100.00	-2.85	0.003	-0.011
Bi-carbonate (µg/ml)	32.00	30.0	100.00	2.85	0.004	0.011
Alkalinity (µg/ml)	76.00	120.00	600.00	-9.16	0.0006	-0.005
Fluoride (µg/ml)	1.40	1.00	1.50	80.00	0.258	20.67
Arsenic (µg/L)	22.00	10.00	100.00	13.33	0.003	0.051
					1.00	246.34
WQI						246.34

Table 13: WQI of Site No. 9

Parameters	Vn	Vi	Vs	Qn	Wn	Qn×Wn
Total Nitrogen (µg/ml)	9.00	45.00	100.00	-65.45	0.003	-0.253
Nitrate (µg/ml)	2.00	2.00	10.00	0.00	0.038	0.00
Phosphate (µg/ml)	0.700	2.00	5.00	-43.33	0.077	-3.35
TSS (mg/L)	18.00	500.00	2000.00	-32.13	0.0001	-0.006
BOD (µg/ml)	70.00	2.00	5.00	2266.66	0.077	175.71
pH	6.60	7.00	8.50	-26.66	0.045	-1.21
EC (mS/cm)	0.889	0.300	0.800	117.80	0.484	57.07
Sulphate (µg/ml)	141.00	150.00	400.00	-3.60	0.0009	-0.003
Chloride (µg/ml)	71.00	250.00	1000.00	-23.86	0.0003	-0.009
Carbonate (µg/ml)	66.00	30.00	100.00	51.42	0.003	0.199
Bi-carbonate (µg/ml)	34.00	30.00	100.00	5.71	0.003	0.022
Alkalinity (µg/ml)	61.00	120.00	600.00	-12.29	0.0006	-0.007
Fluoride (µg/ml)	1.10	1.00	1.50	20.00	0.258	5.16
Arsenic (µg/L)	28.00	10.00	100.00	20.00	0.003	0.077
					1.00	233.39
WQI						233.39

Table 14: WQI of Site no. 10

Parameters	V_n	V_i	V_s	Q_n	W_n	$Q_n×W_n$
Total Nitrogen (µg/ml)	21.00	45.00	100.00	-43.63	0.003	-0.169
Nitrate (µg/ml)	8.00	2.00	10.00	75.00	0.038	2.90
Phosphate (µg/ml)	1.10	2.00	5.00	-30.00	0.077	-2.32
TSS (mg/L)	29.00	500.00	2000.00	-31.40	0.0001	-0.006
BOD (µg/ml)	76.00	2.00	5.00	2466.66	0.077	191.21
pH	6.80	7.00	8.50	-13.33	0.045	-0.608
EC (mS/cm)	0.768	0.300	0.800	93.60	0.484	45.34
Sulphate (µg/ml)	130.00	150.00	400.00	-8.00	0.0009	-0.007
Chloride (µg/ml)	39.00	250.00	1000.00	-28.13	0.0003	-0.010
Carbonate (µg/ml)	44.00	30.00	100.00	20.00	0.003	0.077
Bi-carbonate (µg/ml)	22.00	30.00	100.00	-11.42	0.003	-0.044
Alkalinity (µg/ml)	49.00	120.00	600.00	-14.79	0.0006	-0.009
Fluoride (µg/ml)	0.900	1.00	1.50	-20.00	0.258	-5.16
Arsenic (µg/L)	37.00	10.00	100.00	30.00	0.003	0.116
					1.00	231.31
WQI						231.31

Table 15: Summary of WQI of the sites

Sampling Station	WQI	Water Quality Status
Site 1	304.58	Unsuitable
Site 2	255.47	Unsuitable
Site 3	295.95	Unsuitable
Site 4	243.96	Unsuitable
Site 5	235.93	Unsuitable
Site 6	279.32	Unsuitable
Site 7	273.97	Unsuitable
Site 8	246.34	Unsuitable
Site 9	233.39	Unsuitable
Site 10	231.31	Unsuitable
Average	260.02±26.71	

Discussions

In respect of total nitrogen, it varied from 9 to 22µg/ml with a mean value 15.70µg/ml and found to retain their content below the ideal value of 45µg/ml. In most of the grey water nitrogen content is governed by the levels of reduction of nitrate, nitrite, ammonia and organic nitrogen forms which might otherwise be regulated by the amount of total suspended solids. Similar results relating the total nitrogen content with TSS was earlier reported by Wang *et al.* (2015) [25]. In regard to nitrate nitrogen it ranged from 2 to 8µg/ml with mean value 3.25µg/ml and found to confine within the recommended permissible (10 µg/ml) limit. This availability of nitrate in grey water is attributed to be governed by the oxidation of ammonical and nitrite form which is highly soluble and remains stable for longer period of time. Variation of nitrate nitrogen in relation to TSS in waste water was earlier reported Michael R. Rosen (2003) [18].

Phosphate in grey water with its mean and range of 1.23µg/ml and 0.7 - 2.7µg/ml across the locations had concentration below the ideal value of 2 µg/ml. The lower value might be discussed in the light of quantity-intensity factor of phosphate which owing to presence of suspended solid led to increase the adsorption (quantity) at the cost of decrease in solution phosphate (intensity) concentration in grey water (Jones, 2008).

Total Suspended Solids which reflected the overall deposition of suspended particles in grey water varied from 18 – 38 µg/ml with mean value 24.70µg/ml and found to be far below the ideal value as recommended by EPA (500 mg/L). The TSS content of grey water is largely influenced by the original source of water along with the use pattern of habitants. The wide variability of TSS content as affected by the use pattern of habitants was reported by Eriksson *et al.* (2002) [12] and Al-Jayyousi (2003) [20].

The Biochemical Oxygen Demand, which is the measure of dissolved oxygen needed (i.e. demanded) by aerobic biological organisms to break down organic material present in a given grey water sample, ranged from 58 to 84 µg/ml with its mean value 69.60 µg/ml surpassed the guideline value (>5 µg/ml) as recommended by BIS. The higher BOD value of grey water was due to higher demand of oxygen in water and vice-versa. The transcended value of BOD might be attributed to the increased demand of oxygen for microbial decomposition of suspended solids present in grey water. The result was in conformity with the findings supported by Patel *et al.* (1983) [21], Morel and Diener (2006) [19], Li *et al*. (2009) [16] and Edwin *et al.* (2014) [14].

pH, an indicative parameter to define the extent of acidity and alkalinity of grey water, was found to vary from 6.5 to 7.2 with a mean of 6.87 which suggested values tended towards slight acidity. This might probably be due to use shampoos by the inhabitants, the pH of which actually found to confine from slight acidic to near neutral. The results were in close conformity with the findings outlined by Li *et al.* (2009) [16], Morel & Diener (2006) [19], Raude *et al*. (2009) [22].

Electrical conductivity that ranged from 0.768 to 1.13 mS/cm with mean value of 0.99 mS/cm was found to be above the permissible value of 0.8 mS/cm. This might be attributed to dissolution of salts like carbonates and bicarbonates of calcium, magnesium, sodium and chloride producing positively and negatively charged ions which conduct electricity in relation to their concentration. This could be supported by the works published by Maiga *et al*. (2013) and Jeppesen, 1996

Chloride and Sulphate content for all the selected sites of grey water found to confine far below the ideal value as recommended by ICMR/ BIS. Chloride content with its mean 45.10 µg/ml varied from 16 – 71 µg/ml. As the chloride level found to be far below the recommended standard, therefore infection level of all the grey water samples was likely to be towards higher side. Winward *et al.* (2008) [26] reported that chloride being a strong disinfectant when its concentration is high the level of infection will be less and vice-versa. Lower value of sulphate might be due to low level of sodium lauryl sulphate used commonly as surfactant for cleaning products, cosmetic and personal care product (Braga *et al.,* 2014) [7].

In regard to carbonate and bicarbonate content of grey water, both was found to vary within the permissible limit (100 µg/ml). Likewise alkalinity, which is again considered to be influenced by dissolved carbonate and bicarbonate content, was found to be far below the ideal (120 µg/ml) recommended value. The variations of these parameters might be associated with the consumption pattern of water by the inhabitants. Similar observations were reported by Ledin *et al*. (2001) [15] and Devi *et al*. (2017) [9].

Fluoride in all the grey water samples was found ranging from sub-optimal to close to higher level. Higher concentration of fluoride might be attributed to higher fluoride content in tooth pastes, soaps etc. used by the habitants which got release from washing basins, bath room water etc. The low concentration of fluoride might be due to dilution effect of effluent grey water. The result was found in conformity with the published work by Bouwer (1991) [6].

In all the selected locations, grey water arsenic concentration varied from 13 to 53 µg/l with mean value 30.43 µg/l inferring that all the samples exceeded the permissible limit as set by WHO. The higher arsenic concentration in grey water might probably be due to use of every day products used by habitants and increased concentration of original water source (Tjandraatmadja *et al.,* 2008) [24]. Shankar *et al.* (2014) [23] reported that higher concentration of arsenic at source of groundwater has immense role in increasing the toxic level of arsenic.

Water quality index, a helpful tool in assessment and management of water quality provided valuable insight into the status of overall suitability of grey water based on WQI values. WQI values over the locations ranged from 231.31 to 304.58 with an average WQI of 260.02 ± 22.71. As the estimated value of WQI was found far above the guideline value as outlined by Brown *et al.*, (1972) [8], therefore the water quality status across the location was considered to be unsuitable for any other purpose. Similar kinds of result were observed from the study conducted on *Kolong* river by Bora and Goswami (2017) [5]. Among all the key parameters studied, BOD contributed immensely towards increasing the overall WQI across the locations causing the water most unsuitable for any purpose. Increase in BOD indicates dropping of dissolved oxygen reflecting more quantity of oxygen used by microorganisms (e.g., aerobic bacteria) in the oxidation of organic matter (TSS). This finding is in conformity with the results obtained by Morel and Diener (2006) [19].

Conclusion: The characterization results obtained in this study has provided information on the inherent variability of greywater quality from sites. Grey water characteristics are highly variable as they depend on source of water, the day to day living standards the activities and habits of the residents. Grey water characterization with respect to key quality parameters help categorizing their suitability based on recommended guidelines for further reuse. The characteristics of the grey water obtained in this investigation conducted indicate the necessity of treatment prior to disposal into the environment or for reuse in irrigational purpose as the Water Quality Index of all the ten sites fall under the unsuitable for drinking and fish culture range as given by Brown *et al*. (1972) [8].

References

1. Anonymous. Hach water analysis handbook. 2nd ed. Hach Company, Loveland, CO, 1992.
2. Anonymous. Standard methods for the examination of water and wastewater. 18th ed. American Public Health Association, Washington, DC, 1992.
3. AOAC. Association of Official Agricultural Chemist Publication, 1950.
4. Baruah TC, Barthakur HP. A Text Book of Soil Analysis.Vikas Publ. House Pvt Ltd., New Delhi, 1999.
5. Bora M, Goswami DC. Water quality assessment in terms of water quality index (WQI): Case study of the Kolong River, Assam, India. Applied Water Science. 2017; 7:3125-3135.
6. Bouwer H. Ground Water Research with Sewage Effluent. Water Science Technology. 1991; 23:2099-2108.

7. Braga JK, Varesche MBA. Commercial Laundry Water Characterisation. American Journal of Analytical Chemistry. 2014; 5:8-16.
8. Brown RM, McClelland NI, Deininger RA, O'Connor MF. A water quality index-crashing the physiological barrier. Indic Environ Qual. 1972; 1:173-182.
9. Devi RC, Nirmala Devi D, Shrinithivihahshinil. Removal of Physicochemical Parameters of Grey Water Using Biofiltration Techniques. International Journal of Recent Research and Applied Studies. 2017; 4(8):31-45.
10. Dhar RK, Zhenga Y, Rubenstone J, Geen AV. A rapid colorimetric method for measuring arsenic concentrations in groundwater. Analytica Chimica Acta. 2004; 526:203-209.
11. Edwin GA, Gopalsamy P, Muthu N. Characterization of domestic gray water from point source to determine the potential for urban residential reuse: a short review. Appl. Water Sci. 2014; 4:39-49.
12. Eriksson E, Auffarth K, Henze M, Ledin A. Characteristics of grey wastewater. Urban Water. 2002; 4(1):85-104.
13. Jackson ML. Soil Chemical Analyisis. Prentice Hall of India. Pvt. Ltd. New Delhi, 1973.
14. Jeppersen B, Solley D. Domestic Grey water Reuse: Overseas Practice and its Applicability to Australia. Research Report No 73. Urban Research Association of Australia, Brisbane City Council, 1994.
15. Ledin A, Eriksson E, Henze M. Aspects of groundwater recharge using grey wastewater. P. Lens, G. Zeemann and G. Lettinga (Editors), Decentralised Sanitation and Reuse, London, 2001, 650.
16. Li F, Wichmann K, Otterpohl R. Review of the technological approaches for grey water treatment and reuses. Science of the Total Environment. 2009; 407:3439-3449.
17. Maiga Y, Moyenga D, Ushijima K, Sou M, Maiga AH. Greywater characteristics in rural areas of the Sahelian region for reuse purposes: The case of Burkina Faso. Revue des Sciences de l'Eau. 2014; 27(1):39-54
18. Michael R. Rosen. Trends in Nitrate and Dissolved-Solids Concentrations in Ground Water, Carson Valley, Douglas County, Nevada, 1985-2001. *U.S. Geological Survey*. Water-Resources Investigations Report 03-4152, 2003.
19. Morel A, Diener S. Grey water Management in Low and Middle-Income Countries, Review of different treatment systems for households or neighbourhoods. Swiss Federal. Institute of Aquatic Science and Technology (Eawag). Dübendorf, Switzerland. 2006; 5:9.
20. Al-Jayyousi OR. Grey water Reuse: Towards Sustainable Water Management: *Desalination*. 2003; 156(1-3):181-192.
21. Patel RN, Bose HR, Mandy WJ, Hoare DS. Physiological studies of methane- and methanol-oxidising bacteria: comparison of a primary alcohol dehydrogenase from Methylococcus capsulatus (Texas strain) and Pseudomonas species M27. Journal of Bacteriology. 1972; 110:570-577.
22. Raude JM, Mutua BM, Chemelil MC, Sleytr K. Characterization of Greywater from Urban and Peri-urban Areas of Nakuru Municipality, Kenya. Water, Sanitation and hygiene: Sustainable Development and Multi-sectoral Approaches. Reviewed Paper 247. 34th international Conference, Addis Baba, Ethiopia, 2009.
23. Shankar S, Shanker U, Shikha. Arsenic Contamination of Groundwater: A Review of Sources, Prevalence, Health Risks, and Strategies for Mitigation. The Scientific World Journal. Article ID 304524, 2014.
24. Tjandraatmadja G, Pollard C, Sheedy C, Gozukara Y. Sources of Contaminants in Domestic Wastewater: Nutrients and Additional Elements from Household Products. CSIRO: Water for a Healthy Country National Research Flagship, Australia, 2010, 12-13.
25. Wang X, Zhao-cunLiuJi-lun, Zuo MN. Relationship between nutrient pollutants and suspended sediments in upper reaches of Yangtze River. Water Science and Engineering. 2015; 8(2):121-126.
26. Winward GP, Avery LM, Stephenson T, Jefferson B. Chlorine disinfection of grey water for reuse: effect of organics and particles. Water Resources. 2008; 42(1-2):483-91.