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Characterization of grey water to assess its feasibility for irrigation under different soil types and depths

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Abstract

Water availability for agriculture in the country is projected to go down to around 70 percent by 2025 which undoubtedly will limit the country's capacity to provide expected food security. Water shortage around the world enhanced the search for alternative sources. Under this scenario, grey water, the relatively clean waste water from bathroom, kitchen sink etc., can be a potential water source for reducing water demand. A study conducted at Assam Agricultural University, during the month of February'17, aimed to characterize the grey water from ten different locations of the university, *viz.* Hostel 1, Hostel 2, Hostel 3, Hostel 4, Hostel 10, Hostel 11, Hostel 12, Hostel 14, New Professors' Colony and International Girls' hostel. In characterization study variations of total N were found to confine below the ideal value (<45 µg/ml) while, NO 3 - N varied within the ideal (2 µg/ml) and permissible (10 µg/ml) limit of ICMR/BIS standard. Phosphate concentrations mostly trended below the ideal value (2 µg/ml) while total soluble solids (TSS) varied far below the acceptable ideal standard of EPA (500 mg/L). Biochemical Oxygen Demand (BOD) transcended the recommended permissible limit (5 µg/ml) and pH varied below the permissible (8.5) limit of BIS. Electrical Conductivity surpassed the recommended permissible limit attaining its maximum value of 1.13 mS/cm at Hostel 11. Based on the recommended guideline for concentrations of fluoride, mean fluoride over the locations was found within the recommended range with exceedingly higher value (>1.5 (µg/ml) observed in Hostel 2, Hostel 3 and Hostel 12. Arsenic in grey water with a mean value of 30.43 µg/l varied from 13 to 53 µg/l was found to exceed the threshold level (>10 µg/l) recommended by WHO. A soil column study was carried out concurrently with two different kinds of soil(sandy loam and clay loam) and three column depths(15 cm, 30 cm and 45 cm) where all the parameters baring BOD and pH reduced significantly to the ideal desirable values and mostly tended to vary within the recommended permissible limit with the increase in soil column depths and clay content of soil, thereby overall improvement of quality standard of effluent grey water for use in irrigation.

Keywords: Assam, characterization, grey water, quality parameters, ICMR/ BIS, WHO

Introduction

The global demand for water is increasing day by day due to various human activities as population explosion, industrialization, intensification of agriculture etc. This increasing demand has sparked off an indiscriminate exploitation of the ground water resources which in return has caused its contamination. In order to overcome these severe situations, alternative resource that may supplement irrigational demand of the crops has become the need of the hour. In this regard, the reuse of grey water, which is the relatively clean domestic waste water from the bathrooms, kitchen sinks etc., has drawn considerable attention all over the world. Compared to black water, the scope of exploring the use of grey water in diversified activities of agriculture and allied sectors is reported to be more extensive with fruitful results in present day agriculture. As 50-80 percent of residential wastewater is generally grey water, therefore there is enough opportunity to exploit such potential grey water 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. As raw grey water contains considerable loads of pollutants, so efforts are to be taken to reduce contaminants levels through different technological viable options, one being the use of soils as filtering medium among others, aiming to bring down the contaminants below guide line threshold value asset by EPA. Characterization of quality of grey water will determine how it can be reused for productive purpose. In Assam, about 24340 lakh litre of greywater is wasted every day. Effort therefore should be to evaluate viable strategy for further reutilization of this potential resource.

The development of appropriate technical and policy options for grey water offers great promise for the foreseeable future.

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 greywater from ten (10) different sites *viz*., Hostel 1, 2, 3, 4, 10, 11, 12, 13, New Professors' Colony and International Girls' Hostel within the campus of Assam Agricultural University, Jorhat were collected. Each sample was drawn alternatively at 3rd day of the month of February and transported to laboratory for analysis and characterized based on their quality parameters. The greywater 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, Orthophosphate, Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), pH, EC, Sulphate and Alkalinity. The parametric analyses of raw grey water were done as per the standard methods outlined by various authors.

Total KjeldahlNitrogen (TKN)

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

Phosphate

Orthophosphate was measured using the ascorbic acid EPA-accepted method using double beam visible spectrophotometer (HACH, 1992) [3]

Total Suspended Solids (TSS)

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

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demandwas measured using Standard Method 5210 B (American Public Health Association, 1992) [2]. This method employs determination of dissolved oxygen before and after a 5-day incubation period.

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).

Electrical Conductivity

Electrical conductivity of the water samples was determined using Systronics 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.

Carbonate and Bicarbonate

Alkalinity was evaluated by acidimetric titration in presence of phenolophthalin indicator (Baruah and Barthakur, 1999) [4].

3. Potential effect of soil depths and soil types

In order to assess whether or not potential contaminants of grey water upon passing through different soils with depths under varied loading rates will come down below the permissible level, a column study taking 2 soils (sandy loam and clay loam) and 3 soil depths (15, 30 and 45 cm) replicated thrice was conducted .Columns were made from 6-inch (outside diameter) extruded acrylic tubing and filled with soil material compacted to a bulk density of about 1.4 g/cm^3. Two types of soil, one sandy loam and other clay loam soil were taken. The bottom of each column lined with 2.5 cm of 0.6-cm sized pea-stone to provide proper drainage and prevent clogging of the outflow spouts were arranged. The columns after filling with the soil were covered with a 2.5-cm layer of the pea-stone to prevent swirling and crusting of the soil when the grey water was added. The columns were secured on iron racks and housed to represent average field conditions. For both the soils, loading rates of 4 cm twice daily were maintained. The treatment-wise effluent with reference to added influent grey water was collected in dishpan and transferred immediately to laboratory for analysis of key water quality parameters by adopting the standard methods mentioned above.

Results

Characterization of raw grey water based on key water quality parameters:

Characterization of grey water in respect of key water quality parameters particularly for Total Nitrogen, Nitrate, Orthophosphate, Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), pH, EC, Sulphate (SO_4), Chloride, Carbonate (CO_3), Bi-carbonate (HCO_3), Fluoride, Alkalinity, Arsenic over ten different locations within the AAU campus are shown in Table 3. Location wise key parameters are depicted in Table 4.

Effect of soil types and soil depths on key water quality parameters

The effluent water from Site 9 was selected for further filtration studies as high volume of water grey water was obtained from this site on continuous basis. Results revealed that with increase in the clay content of soil, the total N over the three soil depths of grey water was found to decrease significantly to the tune of 30% while, a similar trend was observed with increase on soil depths over the soil types where 43% reduction in total nitrogen was noticed in soil depth of 45 as compared to 15 cm depth (Fig. 1). The significant interaction effects between soil types and depths envisaged that both the clay content and soil column depths had a conspicuous role in regulating total N content in grey water which was clearly noticed in reducing (65.7%) the total N content to the tune of 0.12 µg/ml in clay loam soil at 45 cm soil depth as compared to 0.35 µg/ml in sandy loam soil at 15 cm soil depth (Table 5).

The phosphate concentrations of grey water as influenced by soil depths and types revealed that with increase in the clay content of soil, the content was found to decrease significantly to the tune of 34% over the three soil depths of soil column. Similar trend was observed with increase on soil depths over the soil types where 25% reduction in phosphate was noticed in soil depth of 45 as compared to 15 cm depth (Fig. 2). The significant interaction effects of soil types and depths envisaged that both the factors had prominent role in reducing phosphate content (56.8%) of grey water while comparing the values of 0.51 µg/ml in sandy loam soil at 15 cm soil depth in relation to phosphate content of 0.0.22 µg/ml in clay loam soil at 45 cm soil depth. (Table 7)

Results envisaged (Table 8) that with increase in clay content irrespective of soil depths, TSS was found to decrease significantly to the tune of 65 percent (from 7.59 to 2.62 µg/ml), while increasing the depth of soil column resulted to decrease the value significantly (38%) from 6.45 µg/ml at 15 cm depth to 3.98 µg/ml at 45 cm depth (Fig. 3). There existed no significant interactions between soil types and depths envisaging that both the clay content and soil column depths did not have prominent role to play in adjusting TSS content in effluent grey water.

Results as mentioned in Table 9 asserted that with increase in the clay content of soil, the BOD over the three soil depths of grey water decrease significantly to the tune of 11% whereas, no significant decrease was noticed with increasing soil depth at 30 cm, the value of which was again found to be *at par* with the BOD recorded at 45 cm soil depth which otherwise was differed significantly as compared with the BOD value recorded at 15 cm soil column depth (Fig. 4). Considering the non-significant interactions between soil types and depths envisaged that both the factor in combination did not have considerable role in regulating BOD content in grey water.

Results (Table 10) revealed that with increase in the clay content of soil, the pH over the three soil depths of grey water was found to increase significantly to the tune of 1.4% while, similar trend was observed with increase in soil depths over the soil types where 5.5% increase in pH was noticed at soil depth of 45 as compared to 15 cm depth (Fig. 5). Owing to no significant interactions between soil types and depths, it indicated that both the clay content and soil column depths did not have the role in regulating pH content.

As evident from Table 11, it was seen that with increase in the clay content of soil, the EC of grey water was found to decrease significantly to the tune of 60% for all the soil depths, likewise increase in the depth of soil column decreased the EC significantly up to 30 cm which otherwise showed no significant difference with EC at 45 cm soil depth. There existed no definite trend of EC with increase in soil column depths over the soil types (Fig. 6). The non-significant interactions between soil types and depths envisaged that both the clay content and soil column depths had no or limited role in regulating EC in grey water.

Results (Table 12) showed that with increase in the clay content of soil, the alkalinity over the three soil depths of grey water was found to decrease significantly to the tune of 32.3% while, similar trend was observed with increase on soil depths over the soil types where 37.9% reduction in alkalinity was noticed in soil depth of 45 as compared to 15 cm depth (Fig. 7). The significant interactions between soil types and depths envisaged that both the clay content and soil column depths had a conspicuous role in regulating alkalinity in grey water which was clearly noticed in reducing (64.6%) the alkalinity from 34.63 µg/ml in sandy loam soil at 15 cm to12.22 µg/ml in clay loam soil at 45 cm soil depth.

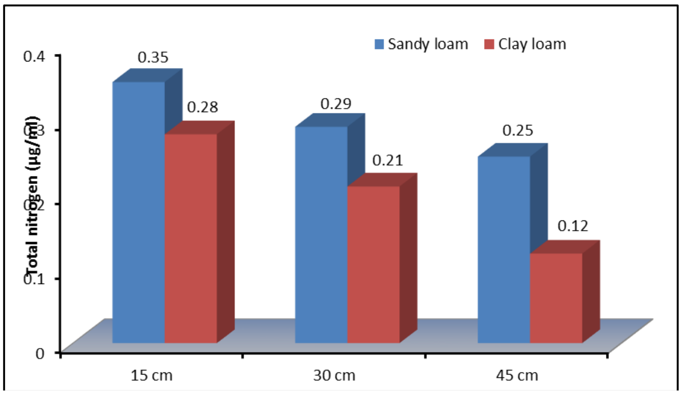

Fig 1: Effect of soil type and soil depth on total nitrogen (µg/ml) content

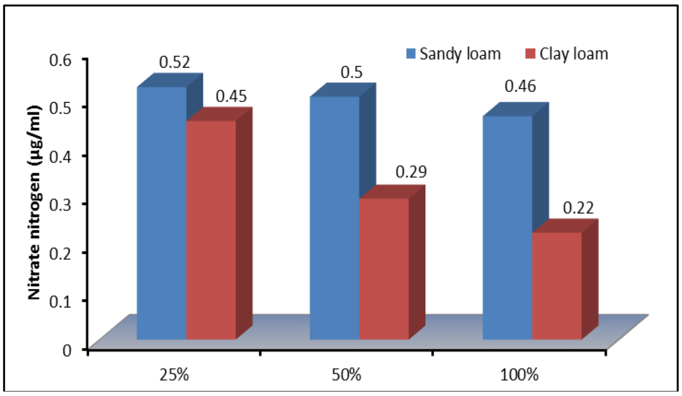

Fig 2: Effect of soil type and soil depth on nitrate nitrogen (µg/ml) content

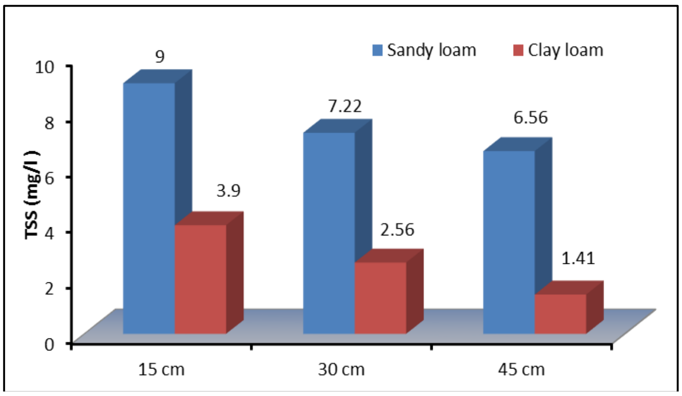

Fig 3: Effect of Soil type and Soil depth on TSS (mg/l) content

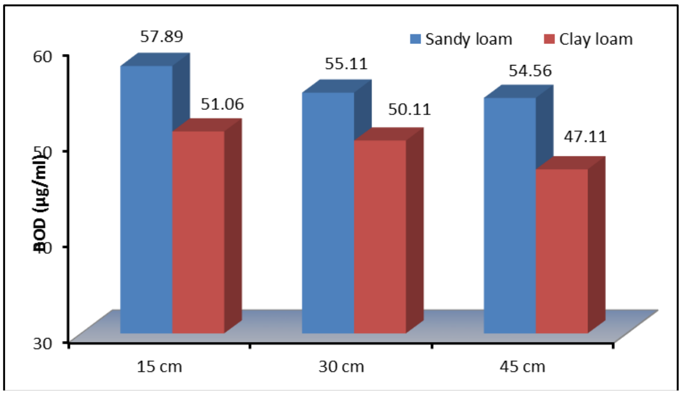

Fig 4: Effect of soil type and soil depth on BOD (µg/ml) content

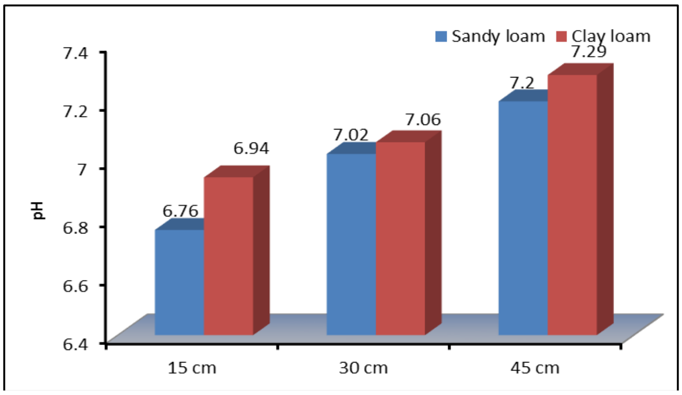

Fig 5: Effect of soil type and soil depth on pH

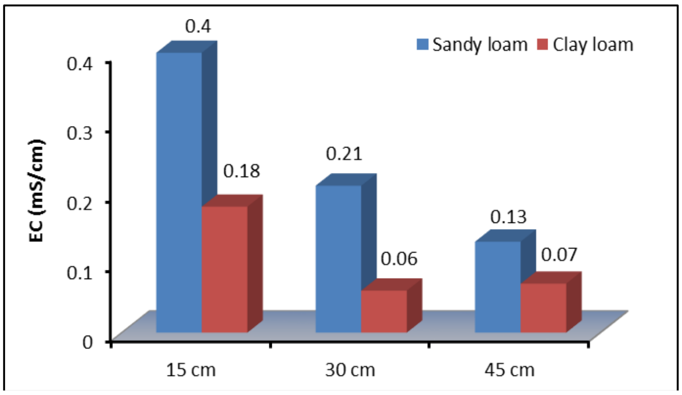

Fig 6: Effect of soil type and loading rates on EC (mS/cm)

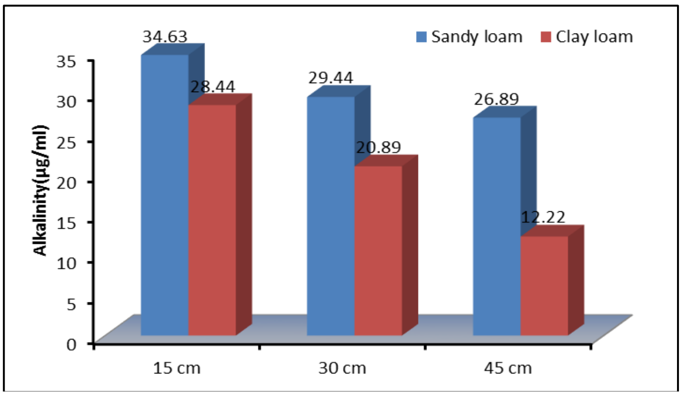

Fig 7: Effect of soil type and soil depth on Alkalinity (µg/ml)

Table 1: Fabricated unit of Grey water-Soil column study

Soil depths (cm)	Length (cm)	Diameter (cm)	Volume (T) (cm^3)	BD (g/cm^3)		ADW of soil (g)	
				cl	sl	cl	sl
15	32	15.24	5834.31	1.37	1.40	3746.72	3828.76
30	48	15.24	8751.47	1.37	1.40	7493.44	7657.53
45	65	15.24	11850.95	1.37	1.40	11240.16	11486.29

Table 2: Soil characteristics

	Soil 1	Soil 2
a) Texture	Sandy loam (sl)	Clay loam (cl)
b) pH	5.1	4.9
c) Organic carbon (%)	0.53	0.61
d) Available N	261.4 kg/ha.	351.7 kg/ha.
e) Available P_2O_5	33.2 kg/ha.	32.7 kg/ha
f) Available K_20	133.5 kg/ha.	149.7 kg/ha.
g) SMBC (µg/g)	183.25	237.5
g) Field Capacity	23.7%	25.5%
h) Permanent Wilting Point	12.8%	13.6%

Table 3: Characteristics of grey water on certain key water quality parameters

Sl. No.	Parameters	Mean ± SD	Range	Skew
1	Total Nitrogen (µg/ml)	15.70 ± 4.32	9 - 22	0.00
2	Nitrate (µg/ml)	3.70 ± 2.00	2 – 8	1.07
3	Phosphate (µg/ml)	1.23 ± 0.59	0.7 – 2.7	1.41
4	TSS (mg/L)	24.70 ± 6.70	18 - 38	0.72
5	BOD (µg/ml)	69.60 ± 7.60	58 - 84	0.26
6	pH	6.87 ± 0.23	6.5 – 7.2	-0.13
7	EC (mS/cm)	0.99 ± 0.11	0.768 – 1.129	-0.51
12	Alkalinity (µg/ml)	56.10 ± 10.12	43 - 76	0.69

Table 4: Key water quality parameters of grey water over the selected sites

Sites	Locations	TN	NO_3-N	PO_4	TSS	BOD	pH	EC	Alkalinity
		µg/ml	µg/ml	µg/ml	mg/l	µg/ml		mS/cm	µg/ml
1	Hostel No.1	22	6	2.7	38	84	6.8	1.124	51
2	Hostel No.2	12	3	1.1	21	58	6.9	0.987	43
3	Hostel No.3	17	5	0.8	28	66	7.1	1.021	69
4	Hostel No.4	14	2	1	18	67	7	0.897	48
5	Hostel No.10	13	3	0.8	19	72	6.7	0.956	53
6	Hostel No.11	19	3	1.4	31	74	6.5	1.129	53
7	Hostel No. 12	18	2	1.7	25	69	7.1	1.025	58
8	Hostel No. 14	12	3	1	20	60	7.2	1.1	76
9	New Professor Colony	9	2	0.7	18	70	6.6	0.889	61
10	International Girls Hostel	21	8	1.1	29	76	6.8	0.768	49

Table 5: Effect of soil types and depths on total Nitrogen (µg/ml) content

Soil types(S)/Depths(D)	15 cm	30 cm	45 cm	Mean
Sandy loam	0.35	0.29	0.25	**0.30**
Clay loam	0.28	0.21	0.12	**0.21**
Mean	0.32	0.25	0.18	
	CD (0.05)		0.01(S)	
	CD (0.05)		0.01(D)	
	CD (0.05)		0.02(S×D)	
	CV (%)		7.93	

Table 6: Effect of soil types and depths on Nitrate Nitrogen (µg/ml) content

Soil types (S)/ Soil depths (D)	15 cm	30 cm	45 cm	Mean
Sandy loam	0.12	0.08	0.08	**0.09**
Clay loam	0.07	0.07	0.08	**0.07**
Mean	0.10	0.07	0.08	
	CD (0.05)		0.01 (S)	
	CD (0.05)		0.01 (D)	
	CD (0.05)		0.02 (S×D)	
	CV (%)		8.86	

Table 7: Effect of soil types and depths on Phosphate (µg/ml) content

Soil type(S)/Soil Depth(D)	15 cm	30 cm	45 cm	Mean
Sandy loam	0.51	0.50	0.47	0.49
Clay loam	0.44	0.30	0.22	0.32
Mean	0.47	0.40	0.35	
	CD (0.05)		0.04 (S)	
	CD (0.05)		0.05 (D)	
	CD (0.05)		0.07 (S×D)	
	CV (%)		9.87	

Table 8: Effect of soil types and soil depths on TSS (mg/l) content

Soil Type(S)/Soil Depth(D)	15 cm	30 cm	45 cm	Mean
Sandy loam	9.00	7.22	6.56	7.59
Clay loam	3.90	2.56	1.41	2.62
Mean	6.45	4.89	3.98	
	CD (0.05)		1.27 (S)	
	CD (0.05)		1.56 (D)	
	CD (0.05)		NS (S×D)	
	CV (%)		15.10	

Table 9: Effect of soil types and depths on BOD (µg/ml)

Soil Type(S)/Soil Depth(D)	15 cm	30 cm	45 cm	Mean
Sandy loam	57.89	55.11	54.56	55.85
Clay loam	51.06	50.11	47.11	49.43
Mean	54.48	52.61	50.83	
	CD (0.05)		1.78 (S)	
	CD (0.05)		2.18 (D)	
	CD (0.05)		NS (S×D)	
	CV (%)		6.12	

Table 10: Effect of soil types and depths on pH

Soil Type(S)/Soil Depth(D)	15 cm	30 cm	45 cm	Mean
Sandy loam	6.76	7.02	7.20	7.00
Clay loam	6.94	7.06	7.29	7.10
Mean	6.85	7.04	7.25	
	CD (0.05)		0.09 (S)	
	CD (0.05)		0.11 (D)	
	CD (0.05)		NS (S×D)	
	CV (%)		2.34	

Table 11: Effect of soil types and depths on EC (mS/cm)

Soil Type(S)/Soil Depth(D)	15 cm	30 cm	45 cm	Mean
Sandy loam	0.40	0.21	0.13	0.25
Clay loam	0.18	0.06	0.07	0.10
Mean	0.29	0.13	0.10	
	CD (0.05)		0.07 (S)	
	CD (0.05)		0.09 (D)	
	CD (0.05)		NS (S×D)	
	CV (%)		13.14	

Table 12: Effect of soil types and depths on alkalinity (µg/ml)

Soil Type(S)/Soil Depth(D)	15 cm	30 cm	45 cm	Mean
Sandy loam	34.63	29.44	26.89	30.32
Clay loam	28.44	20.89	12.22	20.52
Mean	31.54	25.17	19.56	
	CD (0.05)		1.06 (S)	
	CD (0.05)		1.30 (D)	
	CD (0.05)		1.84 (S×D)	
	CV (%)		7.59	

Discussions

In regard to decrease in total N content due to increase in clay content and soil column depth might be attributed to increase in the number of fine pores that helped retaining nitrogen in the fine textured soil along with increased surface area to retain the parameters with higher soil depth. Similar removal of total nitrogen and nitrate nitrogen in the effluent grey water was earlier reported by Veneman and Stewart (2002) [10] and Houshia *et al.* (2012) [6].

Fine textured soil helped to reduce the amount of phosphorus in effluent grey water to larger extent due to high fixation by iron and aluminium and the process was found to be aggravated with increasing soil depth and loading rates owing to highest exposure to iron and aluminium to get it fixed. Similar observations were earlier reported by Albalawneh *et al.* (2015) [1].

Decrease in TSS in effluent grey water might be attributed to the filtering effect of soil types associated with clay percentage and the degree of decrease was found promising with increase in soil depths. This could be supported with the retentions of suspended solid by the soil mass accommodated in the soil column. The results are in conformity with the finding of Pugazh *et al.* (2016) [8] and Govahi *et al.* (2014) [5].

Biochemical Oxygen Demand (BOD), an indicative of dissolved oxygen present in a given sample, reduced significantly with increase in clay content of soil which might be attributed to less demand (more dissolved oxygen) for oxygen by microbes in decomposing the organic load present in the system. Additionally, owing to higher porosity in clay dominated soil, the tendency of dissolve oxygen content observed to be high indicating less demand for oxygen by the microbes in decomposition of suspended solids. Prasad *et al.* (2006) [7] reported similarly the effect of clay content and soil depths on decreasing the BOD in marginal water.

With the increase in clay percentage, higher pH was imputed to higher buffering capacity of soil. Increase in pH due to increase in soil depths might be attributed to the availability of more reactive surfaces to release hydroxyl ions owing to holding more volume of soil in the system. This result is in conformity with the research findings of Sinha *et al.* (2008) [9].

Significant decrease in electrical conductivity with the increase in clay content and depths of soil column might be due to the process like fixation/ precipitation of soluble solids by sequioxides/bases present in fine textured soil and high degree of such process might be facilitated owing to increased volume of accommodated soils. The results was in conformity with the findings of Pugazh *et al.*, 2016 [8].

Alkalinity as carbonate and bicarbonate bears significant role in assessment of quality standard of grey water and found to be influenced by all the factors namely soil types and depths of influent grey water. Decrease in alkalinity as both carbonate and bicarbonate with percent increase in clay content could be imputed to adsorption of dissolved solids responsible for causing more alkalinity by reactive soil sites. Considering the accommodation of comparatively more soil at higher soil column depth, the alkalinity along with the carbonate and bi-carbonate value decreased owing to high exposure of soil sites binding the parameters causing high alkalinity. Alkalinity contributed through carbonate and bi-carbonate as influenced by soil types and depth were earlier described by Prasad *et.al.* (2006) [7].

Conclusion

The results obtained in this study has provided information on the inherent variability of greywater quality from different 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. Although most of the parameters are within the permissible limits, yet proper treatment is mandatory for its reuse in irrigation. Fine-textured soils generally provided better treatment efficiency and more consistent compliance with EPA standards. At the end of the study the overall quality of grey water was improved to several extent due to the combined effect of soil type and soil depth.

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