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Designing Tools for Anaerobic Treatment- A Study of Domestic Wastewater Quantification

Jitender Pal and Mukul S Bishnoi
Department of Environmental Science and Engineering
Guru Jambheshwar University of Science and Technology, Hisar-125001(Haryana) India
*e-mail: j_pal2k1@yahoo.com

Abstract

Domestic wastewater characteristics are the essential tool for selection and desigining of anaerobic treatment system. Raw domestic wastewater were collected from pre-identified 25 different locations of Hisar city and analyzed for physical and chemical parameters. In the study area, most of the people have been using ground water drawn by hand pumps for drinking and other purposes and have been using cesspits for sanitation. The average per capita water consumption is approximately 80 Liters per day in the study area with a range of 60-100 L/capita/day depending on the season. The results of the study indicated that domestic wastewater from Hisar city is high strength wastewater. This is ascribed to low water consumption. The anaerobic biodegradability at 30^{o}C for domestic wastewater (DW), kitchen wastewater (KW), and grey wastewater (GW) were found 71%, 49% and 52% respectively Simple model calculations revealed that the minimum HRT of 10 and 25 hours is being required, if minimum SRT is equal to 30 and 75 days at 15^{o}C respectively. At 25^{o}C, 10 hours minimum HRT is required for the application of a one-stage UASB reactor.

Keywords: Anaerobic, Biodegradability, Domestic wastewater, High strength, Mass balance

Introduction

Hisar city (29^{o} 10’ N and 75^{o} 46’ E, 215.2 m above mean sea level) falls in a hot and semi-arid south western zone of Haryana State (India) and is an emerging educational and industrial centre. All the localities have planned street pattern but most of them are lacking basic civic amenities such as water supply, sewerage network etc. Environmental problems due to inadequate provision of urban waste liquid in developing countries are a matter of concern for governmental agencies and scientists for over half-a-century now. Domestic wastewater may eventually pollute the precious water resources and cause environmental degradation unless properly collected, treated and disposed off safely. Since groundwater is the main source of water supply for the study areas, domestic wastewater management in Hisar city had been neglected for decades and no serious attempts have been made so far by the public health department in the city. Most of the people in unapproved residential areas of the city use pit latrines since pit-latrines are the only on-site treatment practices of domestic wastewater for long time in the city. Black water, i.e. toilet wastewater, is treated with on-site treatment systems including septic tanks and cesspits. The collected wastewater through sewerage network, without being subjected to any kind of treatment except naturally, has been used by the local farmers for agricultural uses (Pal and Bishnoi, 2011).

It is estimated by the survey that about 75 percent of Hisar city population is served with sewage networks, and rest 25 percent population living in unapproved localities which have no connection of domestic wastewater disposal network so far. Black water containing feces is collected in pit latrines and sullage wastewater is usually discharged beside the street or open neighboring plots in the study area. In the monsoon season, situation is further deteriorated due to mixing of domestic wastewater with rain water which flows on the street roads.

Adequate knowledge on domestic wastewater characteristics is a prerequisite for selection and sizing of anaerobic treatment technologies, i.e. Up-flow Anaerobic Sludge Blanket (UASB) systems. Anaerobic digestion has been widely acknowledged as sustainable waste management technology (Mahmoud *et al*. 2003). The feasibility of the up-flow anaerobic sludge blanket (UASB) reactor for domestic wastewater treatment has been successfully established in many developing countries. The success or failure of any specific anaerobic processes will depend upon wastewater characteristics. The applicability of anaerobic processes for domestic wastewater treatment depends on concentration of the organic and inorganic pollutants in domestic wastewater. Also, information about the wastewater characteristics is necessary for the design and operation of treatment processes. A detailed characterization of organic matter in domestic wastewater than given by the parameters BOD, COD and TOC is required to increase the information about transformations in treatment systems and the quality of wastewater as input to the wastewater treatment processes (Raunkjær, 1994). The treatability of wastewater depends strongly on the size and distribution of the pollutants concentration in the domestic wastewater. Butler *et al*. (1995) and Almeida *et al*. (1999) conducted measurement of wastewater quality and quantity in England and prepared at-source pollutographs. Almeida *et al*. (1999) found that larger toilet and kitchen contribute to total pollutant discharges for COD, nitrogen, phosphorus and suspended solids (SS) parameters in households in south-east England.

This research aims at enhancing the informations on identification and quantification of domestic wastewater, with the main focus on the conceptual assessment of the technical applicability of the UASB reactor as a core technology for sustainable domestic wastewater treatment in the upcoming cities like Hisar

Material and Methods

Study Area and Sampling

Twenty five different locations were chosen for this study; all are situated within and outside the municipality area, shown in figure 1. The sampling site has been identified on the basis of where there is no system of sanitation i.e. absence of system of sewers network. The sampling was carried out in two stages, except locations 1 and 2. The first stage of the sampling was expressed to find out the characteristic of wastewater quality around the identified locations.

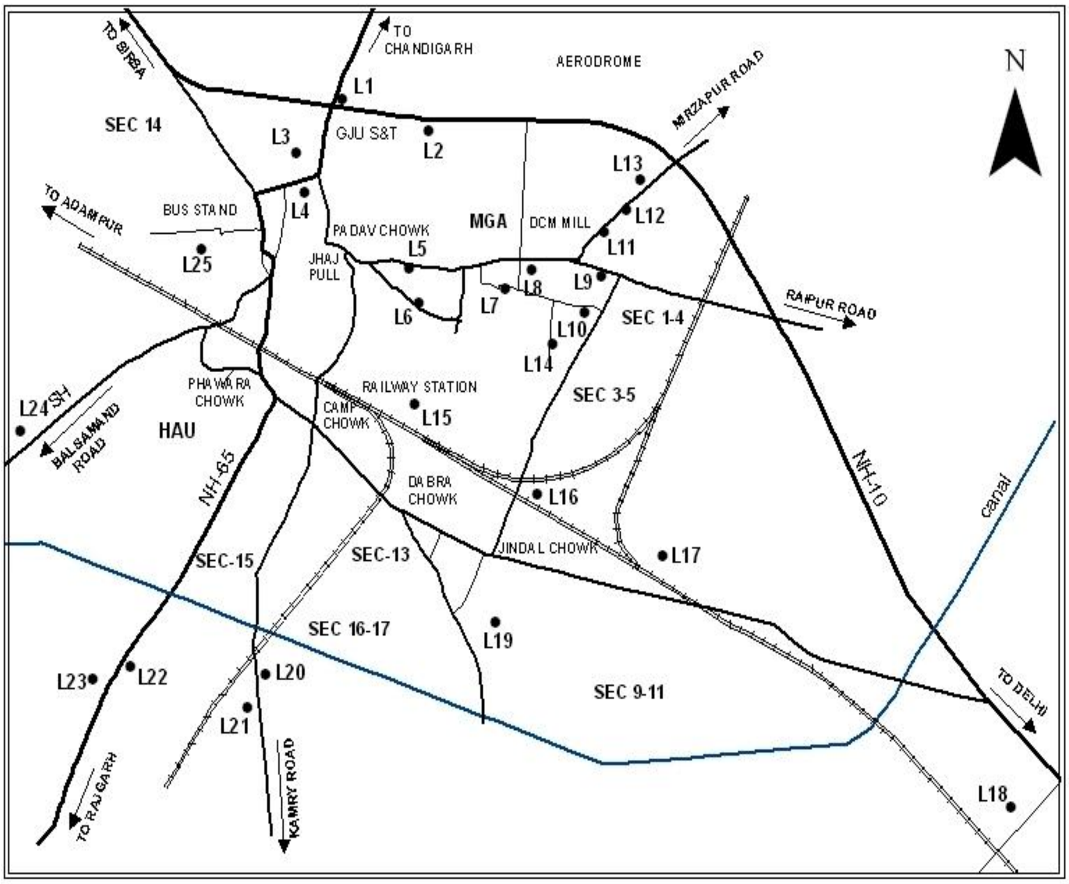

Figure 1 Location of different sampling sites

The domestic wastewater (3 grab sample of 3L from each location, 75 samples in total) was collected from pit latrines with the help of private sanitation service providers. The second stage sampling was carried to determine the characteristic of the raw domestic wastewater, kitchen and grey wastewater quality. The raw domestic wastewater (sample of 3L, 25 samples in total), kitchen wastewater (10 samples in total) from hostel mess and grey wastewater (10 samples in total) from residential quarters respectively, were collected from the university campus, which is located on the outskirts of the city. All the samples were preserved and kept at 4^{0}C until they were analyzed.

Physicochemical Analysis

All the collected samples of domestic wastewater were analyzed according to APHA (1995). The chemical oxygen demand (COD) was measured by the Spectralab COD Digester (2015 M) and COD Titrator (CT-15) using the Platinum combined electrode. Raw samples were used for measuring total COD (COD_T), Paper filtered COD (COD_F) from 4.4 µm Wattman filter paper and Dissolved COD (COD_D) from membrane filter of size 0.45 µm were determined in samples. Suspended and

Colloidal COD (COD_S and COD_C) were calculated as (COD_T - COD_F) and (COD_F - COD_D) respectively. BOD was determined in samples before filtration. Total suspended solids (TSS) and Volatile Suspended solids (VSS) were determined in the residue retained on 4.4 µm Wattman ash less filter papers. Alkanity, Volatile Fatty Acid (VFA), total kjeldahal nitrogen (TKN), Phosphate (PO_4), Sulphate (SO_4^3) were determined according to standard methods (APHA).

Carbohydrate in raw domestic wastewater was determined photometricaly, according to the method described by Bardley *et al.* (1971) with glucose as a standard and protein was estimated with the method of Lowry *et al.* (1951) and lipids was estimated by chloroform-methanol (in 2:1 ratio) extraction method. Settleable solids were measured after settling for 30 minutes in an Imhoff cone (Metcaff and Eddy, 2003).

Biodegradability test of domestic wastewater (DW), kitchen wastewater (KW), and grey wastewater (GW) was measured in 500 ml working volume batch reactors incubated at 30 ^oC for a period of 90 days. Each batch reactor was filled with 450 ml domestic wastewater, macro and micro nutrients (1ml/l) and buffer. The mineral composition of macro nutrients (g/l); NH_4Cl (0.28), $MgSO_4.7H_20$ (0.1), K_2HPO_4 (0.25), $CaCl_2.2H_2O$ (0.01), Yeast extract (0.05), $NaHCO_3$ (2.3), and 1 ml/l trace elements containing (g/l); $FeCl_2.4H_20$ (2.0), H_3BO_3 (0.05), $ZnCl_2$ (0.05), $CuCl_2.2H_2O$ (0.038), $MnCl_2.4H_2O$ (0.5), $(NH_4)_6Mo_7O_{24}.4H_2O$ (0.05), $AlCl_3.6H_2O$ (0.09), $CoCl_2.6H_2O$ (2.0), $NiCl_2.6H_2O$ (0.092),(), $Na_2SeO_3.5H_2O$ (0.164); Resazurin (0.2); EDTA (1.0); 36% HCL (1.0 ml/l). Total COD was measured at the beginning and the end of the test. All samples were analysed in duplicate.

Calculations: The Biodegradability of the wastewater has been calculated according to Mahmoud *et. al.* (2003).

$$\text{Biodegradability} = COD_{T\ t=0d} – COD_{T\ t=90d}/ COD_{T\ t=0d}$$

Where, $COD_{T\ t=0d}$ = Initial total COD of the wastewater when time equal to zero day

$COD_{T\ t=90d}$ = Final total COD of the wastewater when time equal to 90 day

Results and Discussion

Quantification of wastewater

General observations

Characterization of domestic wastewaters is the essential starting point of any study. Table 1 gives the result of 25 different locations and provides an indication that how domestic wastewater quality is site specific and varies from one location to another. It also shows that the mean results associated with Hisar city reflect a typical high strength domestic wastewater quality. The main two observations of domestic wastewater characteristic of the study locations have been observed. Firstly the domestic wastewater of all the pre identified locations is classified of medium strength wastewater with high COD_T and COD_S concentrations. The reason for the high COD concentration of domestic wastewater is due to low consumption of water.

Since, the mean value of BOD, COD, TSS, VSS, TKN, phosphorous, sulphate, ammonia and settleable solids are very high according to the strength of domestic wastewater classification proposed by Metcalf and Eddy (2003) for untreated domestic wastewater and compare with domestic wastewater characteristics in several countries shown in table 4. The characteristics of analyzed parameters are very similar in all the locations, except L_2, L_4, and L_7 locations showing higher pollutants concentration.

Anaerobic biodegradability test

The knowledge on anaerobic biodegradability of a particular domestic wastewater can be a first indication of the potential applicability of anaerobic treatment. However, temperature, domestic wastewater composition and anaerobic biodegradability are changes from place to place (Mahmoud, 2003). Therefore, a complete quantification of domestic wastewater is advisable prior to design of anaerobic treatment facilities (Metcalf and Eddy, 2003). The ratio of BOD/COD, which comprises the biodegradability of domestic wastewater, was in the range from 0.49 (minimum) to 0.59 (maximum) for the influent at locations, L_4 and L_8 respectively. The lower ratio (BOD/COD) of the effluent of domestic wastewater indicates the preferential removal of biodegradable organic matter through the biological treatment process. The organic matter removal appears to be more effective for particulate organic matter compared to dissolve organic matter. The anaerobic biodegradability test of domestic wastewater of location (L_2) was carried out for 90 days for attaining a stabilization of organic matter. The anaerobic biodegradability at 30^oC for domestic wastewater (DW), kitchen wastewater (KW), and grey wastewater (GW) were found 71%, 49% and 52% respectively. Elmitwalli *et. al.* (2001) described the domestic wastewater biodegradability in a Netherlands village was 21% after 43 days and further enhanced to 74% after 135 days at 30^oC. Therefore, biodegradability of DW, KW and GW is first indication of the potential applicability of anaerobic treatment process for domestic wastewater for Hisar city.

Mass balance of COD and its size fractionation

The carbonaceous contents of wastewater are generally estimated by COD. The typical COD subdivision into three main fractions, suspended solids, colloidal and dissolved COD. Domestic wastewater has usually low concentrations of COD and the quite high concentration of particulate matter present in domestic wastewater requires an initial hydrolysis step, which is significantly affected by temperature and is usually the rate-limiting step in sub-tropical climate regions (Kalogo and Verstraete, 2000). The results of the COD fractions of all the locations are presented in Table 1. The results revealed that the main fractions of suspended solids COD constitutes a high fraction of the COD_T, around 57.99% at location L_{22}, and lower 40.71% at location L_2, similarly, for COD_C fraction of 21.12% at location L_{15} and minimum 12.94% at location L_{20} of the Total COD. For dissolved COD fraction, 36.18% at location L_{24} and minimum 2.5.39% at location L_{11} of the Total COD were found. Levine *et al.* (1985) also found that the COD fraction of the particles larger than 0.1 mm is in the range of 30–85% of the total amount of organic materials present in the pre-settled domestic wastewater.

Table 1 Average concentration of domestic wastewater quality parameters at different locations of Hisar city.

Locations		pH	BOD	COD_T	COD_S	COD_C	COD_D	TSS	TDS	VSS	VFA	TKN	NH_4^+-N	PO_4^{3-}	SO_4^{2-}	SS
Police line	L_1	7.1	358.2	716.2	414.8	101.5	199.9	566.7	688.0	401.9	3522.3	36.9	27.1	16.13	48.5	11
GJUST, Hisar	L_2	6.9	598.0	1120.0	641.0	201.2	277.8	595.8	740.0	414.1	3280.4	34.3	24.6	17.59	41.9	12
Vikas Nagar	L_3	7.2	416.8	801.6	440.2	108.2	253.2	685.5	860.0	372.5	3486.2	84.5	63.4	13.6	27.5	18
Auto Market	L_4	7.3	656.1	1350.3	648.5	283.8	418.4	556.3	1568.0	452.3	3860.5	43.1	32.4	14.7	78.3	16
4Sham LalDhani	L_5	7.4	406.1	721.3	395.1	140.5	185.7	405.6	1236.0	332.7	3835.7	62.7	38.8	16.3	28.3	13
12 Quater Area	L_6	7.2	436.6	790.7	430.9	155.3	204.5	583.1	1124.0	470.8	3723.0	82.3	58.8	19.6	21.7	12
Vinod Nagar	L_7	7.2	522.6	910.5	507.1	140.2	263.2	496.9	1392.0	334.5	3756.1	53.5	33.7	13.4	28.5	15
Shiv Nagar	L_8	7.3	420.7	718.1	398.3	132.7	187.1	505.5	1252.0	402.9	3942.6	58.3	35.8	16.7	29.9	15
New Jahwahar N	L_9	7.3	432.1	840.7	450.6	119.4	270.7	548.7	1120.0	425.2	3856.7	40.7	23.6	14.1	25.6	17
Tarshem Nagar	L_{10}	7.4	438.4	785.7	430.3	149.4	200.3	580.6	1314.0	370.3	3934.5	85.1	61.5	17.7	20.4	12
Viskarma Colony	L_{11}	7.4	381.5	725.3	398.5	142.6	184.2	610.3	1320.0	440.7	3784.8	64.9	46.3	18.6	23.2	18
Sree Nagar	L_{12}	7.4	431.5	790.3	405.7	124.2	260.4	729.6	978.0	540.4	3989.3	42.5	25.3	15.9	25.8	15
Aman Nagar	L_{13}	7.2	455.5	780.5	421.7	148.2	210.4	675.5	1352.0	468.8	3808.2	82.4	57.7	18.1	22.2	14
Aadresh Nagar	L_{14}	7.3	442.8	820.2	445.4	114.3	260.5	780.6	1170.0	524.1	3878.8	43.5	24.3	18.5	26.7	16
Sant Nagar	L_{15}	7.3	366.5	730.1	386.4	154.2	189.5	720.3	1336.0	540.7	3766.2	65.3	38.5	18.8	29.6	19
Surya Nagar	L_{16}	7.3	384.2	770.5	418.7	147.7	204.1	776.4	1224.0	566.3	3928.8	75.7	48.5	15.3	33.9	20
Shiv Colony	L_{17}	7.4	469.3	830.6	410.3	132.1	288.2	802.2	950.0	646.5	3844.4	48.1	33.7	16.8	36.1	21
Aadresh Colony	L_{18}	7.4	428.7	745.5	406.8	142.3	196.4	650.7	1022.0	445.8	3864.8	68.3	43.5	16.8	37.3	26
Model Town Ext.	L_{19}	7.3	379.6	720.4	391.2	100.1	229.3	896.4	1132.0	584.3	3755.6	34.6	25.6	18.5	38.5	29
Sham Enclave	L_{20}	7.3	426.5	798.8	420.2	103.4	275.2	502.8	830.0	382.1	3966.4	43.9	32.5	15.9	25.3	24
Navdeep Colony	L_{21}	7.4	381.9	740.2	400.5	141.4	198.3	424.6	750.0	310.3	3821.6	68.2	38.8	19.5	28.4	21
Azad Nagar	L_{22}	7.3	409.7	760.2	395.3	114.8	250.2	801.1	1110.0	564.5	3721.3	53.1	34.9	17.1	23.9	19
Shaket Colony	L_{23}	7.3	428.4	784.6	425.3	135.1	224.2	714.7	1332.0	564.1	3642.2	55.7	31.6	16.2	30.3	20
Chandan Nagar	L_{24}	7.4	393.7	734.5	377.2	151.4	265.8	570.3	1238.0	388.3	3772.5	64.1	35.2	13.8	29.5	27
New Rishi Nagar	L_{25}	7.4	385.5	750.7	398.6	142.5	209.6	660.5	1370.0	450.3	3956.8	70.4	41.3	16.9	37.3	23
Mean		**7.3**	**434.0**	**810.0**	**434.0**	**141.0**	**236.0**	**634.0**	**1136.0**	**456.0**	**3788.0**	**58.0**	**38.0**	**17.0**	**32.0**	**18**

Note: All units are mg/l, except pH and settleable solids (SS) (ml/l)

Table 2 Different ratio for domestic wastewater of Hisar city at different locations

Location		BOD_5/COD_T	VFA/COD_T	VFA/COD_D	COD_D/COD_T	VSS/TSS	COD_S/VSS	COD_T/SO_4
Police line	L_1	0.50	4.93	17.62	0.279	0.709	1.03	14.79
GJUST, Hisar	L_2	0.53	2.93	6.17	0.475	0.695	1.10	26.76
Vikas Nagar	L_3	0.52	4.35	13.76	0.315	0.543	1.18	16.00
Auto Market	L_4	0.49	2.86	9.22	0.309	0.813	1.43	17.24
Sham LalDhani	L_5	0.46	5.32	20.65	0.256	0.821	1.18	25.48
12 Quater Area	L_6	0.55	4.71	18.20	0.258	0.807	0.92	36.43
Vinod Nagar	L_7	0.57	4.13	14.27	0.289	0.673	1.52	31.90
Shiv Nagar	L_8	0.59	5.49	21.07	0.261	0.797	0.99	24.00
New Jahwahar N	L_9	0.51	4.59	14.25	0.322	0.775	1.05	32.84
Tarshem Nagar	L_{10}	0.56	5.00	19.60	0.254	0.638	1.16	26.72
Viskarma Colony	L_{11}	0.53	5.22	20.55	0.253	0.722	0.90	31.26
Sree Nagar	L_{12}	0.55	5.04	15.31	0.329	0.741	0.75	30.63
Aman Nagar	L_{13}	0.58	4.88	18.09	0.269	0.694	0.89	35.16
Aadresh Nagar	L_{14}	0.54	4.73	14.89	0.317	0.671	0.85	30.72
Sant Nagar	L_{15}	0.50	5.16	19.87	0.259	0.651	0.71	24.67
Surya Nagar	L_{16}	0.50	5.19	19.25	0.265	0.729	0.74	22.73
Shiv Colony	L_{17}	0.57	4.63	13.33	0.346	0.810	0.63	23.00
Aadresh Colony	L_{18}	0.58	5.18	19.68	0.263	0.685	0.91	19.98
Model Town Ext.	L_{19}	0.53	5.21	16.38	0.318	0.652	0.67	18.71
Sham Enclave	L_{20}	0.53	4.97	14.41	0.344	0.759	1.09	31.57
Navdeep Colony	L_{21}	0.52	5.16	19.27	0.267	0.731	1.29	26.00
Azad Nagar	L_{22}	0.54	4.89	14.87	0.329	0.705	0.70	31.80
Shaket Colony	L_{23}	0.55	4.64	16.25	0.284	0.789	0.75	25.89
Chandan Nagar	L_{24}	0.54	5.14	14.19	0.362	0.681	0.97	24.90
New Rishi Nagar	L_{25}	0.51	5.27	18.87	0.279	0.682	0.89	20.13
Mean		**0.53**	**4.78**	**16.4**	**0.300**	**0.718**	**0.97**	**25.97**

Table 3 Characteristic of domestic wastewater at different countries

Parameter	This study*	Israel [a]	Egypt [b]	Palestine [c]	Belgium [d]	Spain [e]	Brazil [f]
BOD_5 (mg/l)	434	290	-	502	-	360	-
COD_T (mg/l)	810	566	508	905	589	693	436
COD_S (mg/l)	434	326.6	251	396	313	322	-
COD_C (mg/l)	141	94.7	109	135	-	-	198
COD_D (mg/l)	236	214	148	350	-	-	-
TSS (mg/l)	634	211.2	-	371	213	226	176
VSS (mg/l)	456	189.3	-	313	128	191	155
TKN (mg/l)	58	-	62	70	51	38	41
NH_4-N (mg/l)	38	39.2	47	39.2	37	20	-
SO_4^{2-} (mg/l)	32	-	-	94.7	-	38.5	32
PO_4^{3-} (mg/l)	17	-	-	10.1	5	5.5	14
TSS/VSS	1.39	1.12	-	0.83	1.66	1.18	1.12
BOD_5/COD_T	0.54	0.51	-	0.55	-	0.52	-
COD_S/COD_T	0.54	0.57	0.49	0.44	0.53	0.46	-
COD_C/COD_T	0.17	0.17	0.21	0.15	-	-	0.45
COD_D/COD_T	0.29	0.38	0.29	0.38	-	-	-

*Average concentration of 25 different locations, [a] Lew *et. al.* (2009), [b] Tawfik and Klapwijk, (2010), [c] Al-Jamal and Mahmoud, (2009), [d] Mendoza *et. al.* (2009), [e] Ruiz *et. al.* (1998), [f] Sarti *et. al.* (2007),

Total suspended solids (TSS) and volatile suspended solids (VSS)

The results presented in Table 2 reveal range of VSS/TSS ratio for the all locations are 0.54-0.82. This ratio indicates bacterial biomass enrichment inside the reactors, increased biodegradability and are likely to cause granulation if the ranging of VSS/TSS lies between 0.7 to 0.85 (Aiyuk *et al.*, 2006). Apparently, the data presented in Table 3 indicate that the VSS/TSS ratio of domestic wastewater in Israel, Belgium, Spain and Brazil are high in comparison with the present study but the ratio of Palestine is found to be almost the same. It may indicate the bacterial enrichment and increased biodegradability. This might be due to difference in people's habits. The CODss/VSS ratio is in the range of 0.63-1.52 in all the locations. The high CODss/VSS of location L_4 wastewater indicates high oil and grease contents, possibly due to washing of vehicles as the area hosts a large automobile market.

Volatile fatty acids (VFA)

The results of VFA and COD ratios presented in Table 2 show that the VFA/COD ratios were very high, with values ranging from about 2.86 to 5.49 indicating that hydrolysis was the rate-limiting step. The minimum 9.22% of the dissolved COD are in the VFA form for location L_4, and maximum 20.65% for location L_{11}. The acidified fraction of total COD (VFA/COD_T) is minimum 29.3% for location L_4 and maximum 54.9% for location L_8. The higher concentration of the VFA of domestic wastewater in all the studied locations are high (Table 1) is probably due to some hydrolysis and acidification taking place during the accumulation in the cesspits.

Table 4 Characteristic of Kitchen and Grey wastewater

Analyzed parameter	Kitchen Wastewater (KW)			Grey Wastewater (GW)		
	Range	**Mean ± SD**		**Range**	**Mean ± SD**	
pH	8.6-10.3	9.32±0.59	(10)	7.9-8.7	8.26±0.29	(10)
Alkalinity (mg $CaCo_3$/l)	3156-3582	3364±171	(5)	328.0-746.0	583.2±164	(5)
BOD (mg/l)	1995-2581	2213±180	(6)	336.6-554.7	469.0±77	(6)
COD_T (mg/l)	3941-4870	4411±343	(10)	632.0-1246.0	936.8±192	(10)
COD_C (mg/l)	812-1051	926±89	(10)	91.7-286.2	147.4±61	(10)
COD_D (mg/l)	179-655	373±159	(10)	140.3-289.1	208.7±47	(10)
COD_S (mg/l)	2759-3567	3149±280	(10)	337.0-799.2	552.0±179	(10)
TOC (mg/l)	907-1275	1106±130	(6)	151.7-282.2	211.3±49	(6)
Carbohydrate (mg/l)	25.54-40.4	33.3±6.2	(5)	1.5-4.8	2.92±1.6	(5)
Protein (mg/l)	1.58-2.34	2.03±0.3	(5)	0.07-0.2	0.14±0.04	(5)
Lipids (mg/l)	35.2-66.5	50.1±11.7	(5)	ND	ND	
TSS (mg/l)	1980-2266	2125±104	(5)	1760-2166	1953 ±168	(5)
TDS (mg/l)	2990-3355	3195±160	(5)	1840-2200	1988±149	(5)
VSS (mg/l)	4210-4650	4443±167	(5)	4218-4524	4376±123	(5)
VFA (mg/l)	8560-8956	8764±154	(5)	7745-7997	7876±102	(5)
TKN (mg/l)	54.4-63.5	59.4±3.6	(6)	33.0-65.1	48.6±11.2	(6)
NH_4 as N (mg/l)	34.2-41.9	37.9±2.9	(6)	21.8-38.4	30.2±6.5	(6)
PO_4^{3-} (mg/l)	19.6-29.4	25.2±3.9	(6)	30.9-41.8	36.8±3.8	(6)
SO_4^{2-} (mg/l)	75.9-84.2	80.3±3.2	(6)	101.7-132.4	117.2±12.9	(6)
Settleable Solids in 1h	4.2-6.2	5.3±0.8	(5)	4.6-5.4	4.96±0.30	(5)

Figures in parentheses indicate number sample, ND = not detected.

Sulphate (SO_4) and phosphate (PO_4)

The sulphate concentration in the domestic wastewater of all the studied locations was in the range of 21.7-78.3 mg/l shown in Table 1. The high sulphate content (78.3 mg/l) was found at location, L_6. According to the classification proposed by Metcalf and Eddy (2003) sulphate concentration is medium. Chemical oxygen demand (COD) to sulphate ratio ranges from minimum 14.79% to maximum 36.43% at location, L_1 and location, L_6 respectively (Table 2). In general practice, anaerobic treatment always proceeds successfully with COD/ sulphate ratios exceeding 10. At COD/sulphate ratios less than 10, anaerobic reactors failures have been reported (Souza, 1986; Aiyuk *et al.*, 2006). Since, the excess sulphide concentration can lead to several problems such as toxicity to microorganism, bad smell from the wastewater, problem of corrosion, deteriorated quantity and less production of the biogas and decline of the COD removal efficiency. The measured values of total phosphorus are presented in Table 1. The concentration of total phosphorus in all the locations was high, according to the classification proposed by Metcalf and Eddy (2003). The results showed that the minimum concentration of total phosphorus (13.4 mg/l) value at location, L_7 and maximum concentration (19.6 mg/l) at location, L_6.

Total Kjeldahl Nitrogen (TKN), NH_4^+-N and Proteins

The TKN values for all the different locations are shown in Table 1. The results show that the minimum concentration (34.3 mg/l) values at location, L_2 and maximum concentration (85.1 mg/l) at location, L_{10}. Comparing the values of TKN and NH_4^+ –N showed that the NH_4^+ - N is the major fraction of TKN. The results also revealed that the highest protein content (more than 20mg/l) occurred in few locations (L_8, L_{12} and L_{16}) in the wastewater. In most of the locations, the concentration of the protein was less than 2mg/l. This might be due to the reason that people residing at these locations are consuming fish, meat and other products having rich in protein content.

Table 5 Characteristic of kitchen and grey waste water at different countries

Parameter	This study		Jordan [a]		UK [b]	Sweden [c]
	Kitchen	Grey	Kitchen	Grey	Grey	Grey
pH	9.32	8.26	5.8	6.35	7.47	7.5
BOD_5	2213	469	1100	1035	146	418*
COD_T	4411	937	2244	2568	451	588
TSS	2125	1953	644	845	100	-
TKN	59.4	48.6	51	128	8.73	9.68
NH_4^+	37.9	30.2	32	75	-	-
SO_4	80.3	117.2	48	89	-	-
PO_4	25.2	36.8	18.25	19.5	-	7.53
BOD_5/COD_T	0.50	0.50	0.49	0.41	0.32	0.71
COD_S/COD_T	0.71	0.58	-	0.46	-	-
COD_C/COD_T	0.21	0.20	-	0.20	-	-
COD_D/COD_T	0.08	0.22	-	0.30	-	-

*BOD_7, [a] Halalsheh *et. al.* (2008), [b]Jefferson *et. al.*, (2004), [c] Palmquist and Hanaem (2005),

Kitchen and Grey wastewater

Grey water consists of diluted domestic wastewater streams coming from the shower, laundry facilities and/or the wash basins etc. In some studies kitchen wastewater is included as grey water (Eriksson et al., 2002; Jefferson et al., 2004; Elmitwalli and Otterpohl, 2007; Ghunmi et al., 2010). Grey water is defined as wastewater without any input from toilets or heavily polluted industrial process (Eriksson et al., 2002). The characteristics of grey wastewater changes due to the activities involved in its production, the quality and quantity of grey wastewater vary significantly due to people habits.

Average concentrations of different physico-chemical parameters found in kitchen and grey wastewater are presented in Table 5. Kitchen and grey wastewater in the study area is characterized by very high concentrations. The average BOD was 2213±180 and 469±77 mg/l; total COD was 4411±343 and 937±192 mg/l; and TSS was 2125±104 and 1953±168 mg/l for kitchen and grey wastewater, respectively. The high concentration of these parameters is apparently due to the very low per capita water consumption, mainly due to the inadequacy of the local water supply in the area.

The measured dissolve COD represents 8% and 22% of the total COD for kitchen and grey wastewater, respectively, which is much higher compared with 30% for grey wastewater (Halalsheh *et. al.*, (2008). The suspended COD fractions are more in kitchen wastewater about 71% as compared with grey wastewater 59% of the total COD. COD due to colloidal particles is about, 21% and 16% in kitchen and grey wastewater, respectively. This may be due to throwing away the remaining food and used residual cooking oil in kitchen sinks is believed to play a major role in increasing domestic wastewater strength.

The variations in grey water characteristics with respect to the source show that wash basin has the lowest organic load compared with wastewater produced by kitchen and other sources like bathroom. Moreover, high organic loads present in the kitchen and grey wastewater and the high suspended fraction of the COD complicate the treatment process.

Table 6 Design values for UASB reactor

Parameters	Units	At 15^{O}C	At 25^{O}C
SRT	d	75[a]	75[c]
COD	g COD/l	0.810[b]	0.810[b]
SS	-	0.54[b]	0.54[b]
X	g COD/l	15[a]	15[a]
R	-	0.8[a]	0.9[c]
H	-	0.15[a]	0.7[c]

[a] Mahmoud *et al.* (2006); [b] present study; [c] de Graaff., *et al.* (2011)

Applicability of UASB reactor of Hisar city

On-site domestic wastewater treatment systems such as septic tanks and cesspits are commonly used by local residents for domestic wastewater treatment/management. Therefore, quantitative summarization of pollutants generation and discharge are important for wastewater management. The ultimate removal efficiency BOD and/or COD and conversion of organic matter to methane gas in UASB systems depend on both physical and biological processes. For domestic wastewater, removal of suspended solids are carried out by physical processes like settling, adsorption and entrapment. The subsequent hydrolysis of solids depends on the process, temperature, biomass concentration and the existing sludge retention time (SRT). Zeeman and Lettinga (1999) developed a model for the calculation of the hydraulic retention time (HRT) when a certain SRT is a pre-requisite [Eq. (1)].

$$HRT = \left[\left(\frac{COD_{influent}\,.\,SS}{X}\right).R.(1-H).SRT\right]$$

Where, HRT= Hydraulic Retention Time, $COD_{influent}$ = Influent COD concentration (g COD/l), SS = Fraction of influent suspended solids, X = Biomass concentration in the reactor (g COD/l); 1g VSS = 1.4 g COD, R = Fraction of COD_{SS} removed, H = fraction of removed solids that are hydrolyzed, SRT = Sludge retention time (days). SRT=30 days, estimated minimum SRT to achieve methanogenic conditions during winter time (Elzen and Koppers, 2000). The initial input data were taken into consideration for design of HRT from Table 6.

Accordingly, the model calculation revealed that a minimum HRT of 10 and 25 hours is being required, if minimum SRT is equal to 30 and 75 days at 15 ^{o}C respectively. At 25 ^{o}C, 10 hours minimum HRT is required for the application of a one-stage UASB reactor for Hisar city. An HRT of 6 hr is generally recommended for design of UASB reactors under tropical conditions. At low temperature, long HRT is to be required due to the high concentration organic load in winter. The influent suspended solids are partially captured in the UASB reactor and conveyed to the digester, which is operated under optimal process surroundings environment with respect to temperature and SRT. The methanogen enriched digested sludge is recirculated to the UASB reactor to improve the methanogenic capacity of the UASB reactor.

Conclusions

The results of this study reveal that the domestic wastewater in Hisar is characterized by high strength and solid contents. Accordingly, the application of a one-stage UASB reactor in Hisar city is only possible if designed at an extended HRT due to low solids hydrolysis during winter time. However, reform in the household sanitation habits will reduce the solids content, and therefore, influence the selection of the proper treatment technology. In addition, if any industry comes to Hisar, than it should apply a pre-treatment step before discharging their wastewaters in the municipal sewerage system. In the light of the experimental results summarized and evaluated, the concluding remarks of this study may be expressed as follows:

1. Raw domestic wastewater from Hisar city with average COD_T concentration of 810 mg/l, can be classified as high strength wastewater.
2. The main fractions of suspended solids COD constitutes a high fraction of the COD_T, around 57.99% at location L_{22}, and lower 40.71% at location L_2,
3. For COD_C fraction of 21.12% at location L_{15} and minimum 12.94% at location L_{20} of the Total COD.
4. For dissolved COD fraction, 36.18% at location L_{24} and minimum 2.5.39% at location L_{11} of the Total COD.
5. The anaerobic biodegradability at 30^{o}C for domestic wastewater (DW), kitchen wastewater (KW), and grey wastewater (GW) were found 71%, 49% and 52% respectively.
6. Judging by composition and anaerobic biodegradability, it can be concluded that raw domestic wastewater from Hisar city well suitable for anaerobic treatment in UASB reactors.
7. The minimum HRT of 10 and 25 hours is being required, if minimum SRT is equal to 30 and 75 days at 15 ^{o}C respectively. At 25 ^{o}C, 10 hours minimum HRT is required for the application of a one-stage UASB reactor.

***Authors' contribution**:Er.* Jitender Pal, *(Assistant professor), Research scholar, contributed in experiment design and final editing of the manuscript; Dr.* Mukul S Bishnoi, *(Associate Professor), Supervisort, contributed in experiment design.*

References

Aiyuk, S., Forrez, I., Lieven, D. K., Haandal, A. V., Verstraete, W., 2006. Anaerobic and complementary treatment of domestic wastewater in regions with hot climates-A review. *Bioresource Technology*, 97, 2225–2241.

Al-Jamal, W., Mahmoud, N., 2009. Community onsite treatment of cold strong domestic wastewater in a UASB-septic tank. *Bioresource Technology*, 100, 1061–1068.

Almeida, M. C., Butler, D., Friedler, E., 1999. At-source domestic wastewater quality. *Urban Water*, 1, 49–55.

American Public Health Association (APHA), 1995. Standard methods for the examination of water and wastewater. 19th edition.

Bardley, R. A., Krone, R. B., Asch, M., 1971. Shearing effects on the settling of activated sludge. *Journal of Sanitation Engineering, American Society of Civil Engineering*, 97, 59-79.

Butler, D., Fnedier, E. & Gatt, K., 1995 Characterising the quantity and quality of domestic wastewater inflows. *Water Scince and Technology*, 31(7), 13–24.

De Graaf, M. S., Temmink, H., Zeeman, G., Buisman, C. J. N., 2011 Anaerobic Treatment of concentrated black water in UASB reactor at a short HRT. Water, 2, 101.doi:10.3390/w2010101 <http://www.mdpi.com/journal/water>

Elmitwalli, T., Otterpohl, R., 2007. Anaerobic biodegradability and treatment of grey water in upflow anaerobic sludge blanket (UASB) reactor. *Water Research*, 41 (6), 1379–1387.

Elzen, J. den Koppes, J., 2000. Controlling Scum Formation during Anaerobic Sewage Treatment under Middle East Conditions, MSc thesis, Department of Environmental Technology, Wageningen University, Wageningen, The Netherlands.

Eriksson, E., Auffarth, K., Henze, M., Ledin, A., 2002. Characteristics of grey water. *Urban Water*, 4 (1), 85–104.

Ghunmi, L. A., Zeeman, G., Fayyad, M., van Lier, J. B., 2010. Grey water treatment in a series anaerobic – Aerobic system for irrigation. *Bioresource Technology*, 101, 41–50.

Halalsheh, M., Dalahmeh, S., Sayed, M., Suleiman, W., Shareef, M., Mansour, M., Safi, M., 2008. Grey water characteristics and treatment options for rural areas in Jordan. *Bioresource Technology*, 99, 6635–6641.

Jefferson, B., Palmer, A., Jeffrey, P., Judd, S., 2004. Grey water characterization and its impact on the selection and operation of technologies for urban reuse. *Water Scince and Technology*, 50 (2), 157–164.

Kalogo, Y., Verstraete, W., 2000. Technical feasibility of the treatment of domestic wastewater by a CEPS-UASB system. *Enviromental Technology*, 21, 55–65.

Levine, A. D., Tchobanoglous, G., Asano, T., 1985. Characterisation of the size distributions of contaminants in wastewater: treatment and reuse implications. *Journal of Water Pollution and Control*, 57 (7), 805–816.

Lew, B., Tarre, S., Beliavski, M., Green, M., 2009. Anaerobic degradation pathway and kinetics of domestic wastewater at low temperatures. *Bioresource Technology* 100, 6155–6162.

Lowry, O. H., Rosenbrough, N. J., Farr,A. L., Randall, R. J., 1951. Protein measurement with the Folin Phenol Reagent. *Journal of Biological Chemistry*, 193, 265-275.

Mahmoud, N., Amarneh, M. N., Al-Sa'ed, R., Zeemana, G., Gijzend, H., Lettinga, G., 2003. Sewage characterisation as a tool for the application of anaerobic treatment in Palestine. *Environmental Pollution*, 126, 115–122.

Mendoza, L., Carballa, M., Sitorus, B., Pieters, J., Verstraete, W., 2009. Technical and economic feasibility of gradual concentric chambers reactor for sewage treatment in developing countries. *Electronic Journal of Biotechnology*, 12 (2).
<http://www.ejbiotechnology.info/content/vol12/issue2/full/8/>

Metcalf Eddy, 2003. Wastewater engineering, Treatment and Reuse, 4th edition, Tata McGraw-Hill Publishing Company Limited, New Delhi.

Pal, J., Bishnoi, M. S., 2011. Current Environmental Management Practices: Some unauthorized localities of Hisar city, India. *Environment & We: An International Journal of Scicnce & Technology* 6, 101-112.

Palmquist, H., Hanaeus, J., 2005. Hazardous substances in separately collected grey- and blackwater from ordinary Swedish households. *Science of the Total Environment*, 348, 151–163.

Raunkjær, K., Hvitved-Jacobsen T., Nielsen, P. H., 1994. Measurement of pools of protein, carbohydrate and lipid in domestic wastewater. *Water Research*, 28(2), 251-262

Ruiz, I., Soto, M., Veiga, M. C., Ligero, P., Vega, A., Blázquez, R., 1998. Performance of and biomass characterization in a UASB reactor treating domestic waste water at ambient temperature. *Water*, 24(3), 215-222.

Sarti, A., Garcia, M. L., Zaiat, M., Foresti, E., 2007. Domestic sewage treatment in a pilot-scale anaerobic sequencing batch biofilm reactor (ASBBR). *Resources, Conservation and Recycling*, 51, 237–247.

Souza, M. E., (1986) Criteria for the utilization design and operation of UASB reactors. *Water Science and Technology*, 18, 55-69.

Tawfik, A., Klapwijk, A., 2010. Polyurethane rotating disc system for post-treatment of anaerobicallypre-treated sewage. *Journal of Environmental Management* 91, 1183–1192

Zeeman, G., Lettinga, G., 1999. The role anaerobic digestion in closing the water and nutrient cycles at community level. *Water Science and Technology*, 39(5), 187-194.