Downflow Hanging Sponge (DHS) Reactor as a Novel Post Treatment System for Municipal Wastewater

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Abstract: Substantial sustainability integrates social, environmental, economic and institutionalaspects, and extends the scope of planning to distant regions and future generations. Inspite of unprecedented advancement in technology and urbanization across the world, a vast number of developing countries are lagging behind in providing basic sanitation and adequate water supply to the people. The present day speedy socioeconomic development of humanity has most vigorously stimulated the change in nature. Technological advancement, if on one hand has bettered the life of humans on this planet; on the other hand it has sharply intensified the pollution in environment. The energy and in view of a huge contamination of municipal wastewater, new technology of processing DHS reactor used to municipal wastewater treatment. The results obtained were compared with traditional activated sludge treatment plant. As far as, the experimental data showed that,97% (190-5.0mg/l) decrease in the total suspended solid in the primary effluent, chemical oxygen demand (COD) 96.4% (230-7.0 mg O2 / l), total biological oxygen demand 97.27% (180-4.0mg/l) and total kjeldahl nitrogen (TKN) 76% (4.3-1.0mg N/l) respectively.

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Key words: DHS, chemical measurements, post treatment, traditional activated sludge, tertiary treatment, municipal wastewater.

Highlights: * DHS and activated sludge worked parallel. * Physic-chemical measurements
*Wastewater treatment using down flow hanging sponge

1.Introduction

Current mainstream technologies for domestic wastewater treatment in Egypt, such as activated sludge and tertiary nutrient removal are too costly to provide a satisfactory solution for the increasing wastewater problems in rural areas. Therefore, the challenge for the coming years will be to develop integrated concepts and processes for pollution prevention and reuse of waste materials (El-Gohary et al. 2000).

The new system was named the DHS reactor which. principle on use of polyurethane sponge as a growing and supporting media for various microorganisms, providing longer mean cellresidance time and at the same time enhancing the diffusion of air into the wastewater curtailing the need of any external forced aeration unlike most of the existing aerobic treatment systems. Sponge has avoided ratio of more than 90%, which provides an excellent site for growth and attachment of active biomass Several DHS. For pre-treatment of domestic wastewater but the effluent still fail to comply with COD discharge standards as that established by Council Directive 91/271/EEC on Urban Waste Water Treatment, dictated by(EUC1991) (125 mg COD/L), or the guideline proposed by the World Health Organization(WHO1989) for unrestricted irrigation (less than 1000 fecal coli form per 100 mL, and less than 1 helminthes egg per L)Therefore, a post treatment step is required to remove the remnant portion of COD, fecal coli form (as an indicator of pathogenic microorganisms), helminthes eggs, and even nitrogen and phosphorus when direct reuse is not feasible. Various treatment processes have been proposed for post-treatment, such as: Waste stabilization ponds (WSPs) (Elliot et al.1999).

(Castillo et al.1996) Studied DHS (down flow hanging sponge-cubes) aerobic pre-treatment unit, as a low-cost and easy-maintenance process for developing countries. Over six months experiment by feeding sewage the proposed system achieved 94% of total-COD removal, 81% of soluble-COD removal, and nearly perfect SS removal and total-BOD removal at the overall HRT of 1.3 hr in DHS unit).

The down-flow hanging sponge (DHS) reactor was developed for post-treatment (Machdar et al., 2000; Tandukar et al., 2006; Tawfik et al., 2006). The DHS process uses polyurethane sponge as media to retain biomass. Wastewater is trickled from the top of the reactor and purified by microorganisms retained both inside and outside of the sponge media as the wastewater flows vertically down through the reactor.

As the sponge media in DHS reactors are not submerged in wastewater but hang freely in the air, oxygen is dissolved into the wastewater. The performance of up-flow aerobic down-flow hanging sponge (DHS) system for sewage treatment at an average wastewater temperature of 15C° has been investigated for 6 months by (Seghezzoet al.2004). It was concluded that DHS system could be a cost effective and viable option for the treatment of municipal sewage over ASP, especially for low-income countries. An aerobic down-flow hanging sponge (DHS) post treatment unit was evaluated by (Tawfik et al. 2006). Reactor has been developed so far with names such as first or generation cube type DHS (Machdar et al.1998).

In an initiative to positively contribute and provide professional strategic long term applicable, replicable, cost-effective and sustainable post-treatment solutions for reuse in Egypt, Down-flow Hanging Sponge (DHS) bio-tower system is proposed as an option for post-treatment in Egypt for this study.

2. Materials and Methods

2.1 Downflow Hanging Sponge (DHS) system

The DHS module column consists of four identical segments connected vertically, each segment will be equipped with 25 L of polyurethane foam (PF) warped with plastic material randomly distributed in the whole reactor. The DHS system will be made of PVC, with a capacity of 0.3 m3and has an internal diameter of 0.16 m. The height of the reactor is 0.88 m. The reactor will be filled with PF which represents 34% of the total liquid reactor volume. The characteristics of the PF (sponge) are surface area 256 m2/m3, density 30 kg/m3, void ratio 0.9, and pore size of 0.63 mm. The total volume of the PF will be 100 L. The dimensions of the used sponge (PF) (cylindrical shape) will be 27 mm height ×4 mm diameter. The AR effluent will be flowed by gravity to the distributor which will be located on the top of the DHS module and will be rotated at 15 rpm.

Routine sampling was employed during dry weather to characterize water quality under normal operating condition. As the chemical characteristics of sewage vary from top to bottom of the sewage depth as well as with time from mooring to evening so the grape sample were collected at regular interval and mixed together. The samples were collected weekly from raw sewage, the Down flow Hanging Sponge (DHS) reactor Bio- tower, effluent of primary sedimentation of traditional activated sludge, effluent of traditional activated sludge. The following parameters will be monitored at retention time 6 h and 3h also use the DHS as tertiary treatment. Chemical Parameters such as TSS, COD, BOD5, total kjeldahl nitrogen (TKN), was determined according to APHA (2005) "Standard Methods for the Examination of Water and Wastewater".

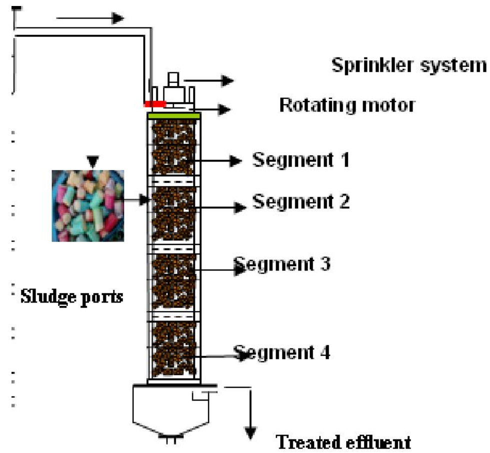

Figure 1: show the pilotof DHS

3. Results and Discussion

3.1 Part1 DHS work as post-treatment at RHT 6h:

Differences in the types of wastewater treatment technology and compare between them using chemical parameters such as total suspended solid (TSS), chemical oxygen demand (COD), chemical biological demand (BOD5)at retention time 6h was showed which technology, low–cost and more efficiency in wastewater treatment and cleaner environment.

Compares the performance of a pilot-scale of DHS system to that of activated sludge process (ASP) for the treatment of municipal sewage. Both systems were operated in parallel with the same sewage as influent. The removal efficiency of total suspended solid was 58±12% (110±25mg/L) in the primary sedimentation effluent of activated wastewater treatment plant. The removal efficiency in the effluent of wastewater treatment plant was 91±8% (25-12mg/L). The removal efficiency of TSS in the DHS was 94±5% (5-3mg/L). Suspended solids was entrapped and degraded in the sponge of the DHS system by the virtue of long sludge retention time (SRT) (fig2).

The results obtained indicated that the COD increased from 36% (410±25mg/l) in raw municipal wastewater. Excellent COD removal was rapidly established in all the reactors, which is one of the DHS system's merits. This is attributed to the temporary adsorption of organic substances onto the sponge media (Tandukar et al., 2006). According the results showed that the overall removal efficiency was COD total (90%), BOD5 total (98%), TSS(94%), ammonia (86%) (Gijzen et al. 2002). The percentage removal values of COD were 30 ±11% (270-180 mg/l) in the treated primary effluent of activated sludge treatment plant. The results obtained indicate that the COD decreased from 30% in primary effluent to 95 ±3% (11.4±7mg/l) in the DHS effluent. This could be attributed to particulate matter entrappement and degradation in DHS sponge by virtue of its long sludge retention time (SRT). The COD derived from suspended solids (SS-COD) was estimated by subtracting the COD. The superior ability of the DHS process to remove SS has been well verified in previous studies (Machdar et al., 2000; Tandukar et al., 2006; Tawfik et al., 2006).This is attributed to capturing/recapturing mechanism processes of solids in the sludge bed. The particles to be digested it should be captured first and the digestion and the biodegradation processes will be then occurred (fig3).

Table 1:summary of laboratory values of TSS, COD, BOD and TKN in raw sewage, primary effluent, finial effluent of activated sludge and DHS at RHT was 6h.

Tim (week	TSS(mg/L)				COD(mgO2/L)				BOD(mg/L)				TKN(mg N/L)			
	Raw	Prim	AS	DHS	raw	Prim.	AS	DHS	Raw	Prim.	AS	DHS	raw	Prim.	AS	DHS
1	270	116	25	4	384	225	30	5.70	225	183	10	3.35	5.3	4.5	0.7	2.67
2	220	96	19	5.02	320	200	29	6.16	230	150	15	3.62	-	-	-	-
3	260	97	15	3.11	310	180	28	4.42	190	142	12	2.6	-	-	-	-
4	240	115	13	4.01	380	230	25	5.34	170	130	8	3.14	4.8	3.8	0.5	2.2
5	270	120	15	3.98	413	290	30	5.7	242	160	17	3.35	-	-	-	-
6	280	110	18	5.04	360	210	24	6	200	120	12	3.52	-	-	-	-
7	255	128	23	4.13	380	268	20	5.1	228	160	26	3	6	4.5	0.5	1.85
8	240	125	28	4.97	436	215	21	6.2	256	180	27	3.64	-	-	-	-
9	250	120	13	4.10	312	200	20	5.8	180	119	13	3.5	-	-	-	-
10	275	130	16	3.97	430	230	36	4.6	220	130	20	3.11	4.6	4	0.9	3.5
11	250	105	12	4.1	389	210	22	5	150	125	13	3.2	-	-	-	-
12	210	116	23	4.02	402	230	32	5.2	200	130	12	3	3.5	3	0.5	0.94
13	250	115	16	3.4	340	225	28	4	215	105	12	2.2	6	4.7	1.8	3.7
14	255	130	18	3.5	315	220	30	4.1	190	125	20	2.5	-	-	-	
15	275	125	18	3.02	375	250	31	5.1	225	150	15	3	7	5.3	3.7	2.06

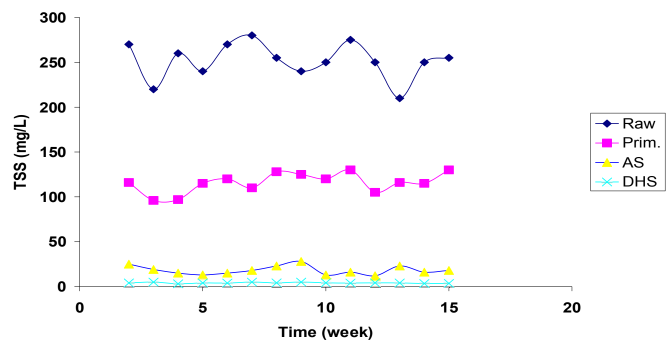

Figure 2: showed the variation of TSS in raw, primary effluent, finial effluent of activated sludge and DHS effluent.

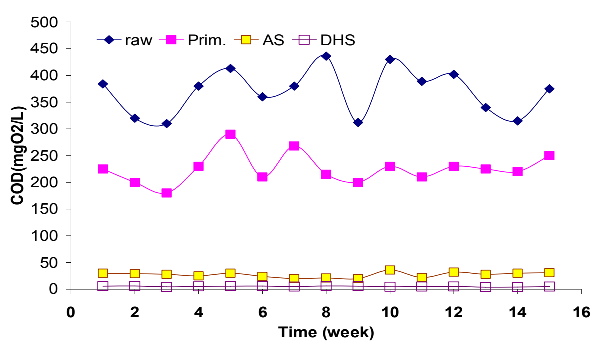

Figure 3: showed the variation of COD in raw, primary effluent, finial effluent of activated sludge and DHS effluent.

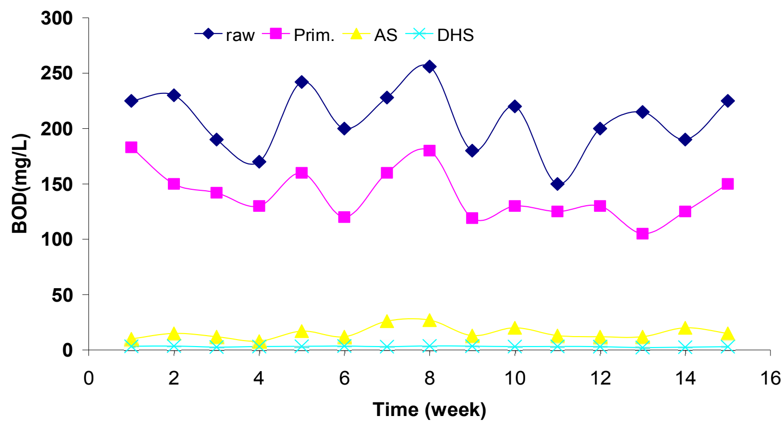

Figure 4: showed the variation of BOD in raw, primary effluent, finial effluent of activated sludge and DHS effluent.

The removal efficiency of BOD5 was 32±11% (183±105 mg/L) in the treated primary effluent of activated sludge treatment plant, and in it's effluent of activated sludge treatment plant the removal efficiency of BOD5 was 90±6% (27±6 mg/L) and the overall removal efficiency of BOD5 in the DHS was 96±3%(3.6-2.2mg/L), treatment due to biodegradation.

Nitrogen balance and removal the nitrogen reduced in aerobic DHS via nitrification and de-nitrification process. Nitrification in DHS takes place in the lower portion of the reactor where the organic loading is relatively lower and dominance of autotrophy over heterotrophy for oxygen utilization is less intense. DHS received total nitrogen loading of 0.142 Kg-N/m3.d, which includes 0.01 Kg-N/m3.d of ammonium nitrogen. 79% removal of total kjeldahl nitrogen in DHS. In of average, TKN in the final effluent were 1.76 mg N/ l. The DHS reactor was capable of performing high (73–78%) nitrification. Adown-flow hanging sponge (DHS) reactor has been successfully applied for removal of organic matter in wastewater (Tandukar et al. 2005).This study showed that the sponge media sizes of the DHS reactors are, the better the removal efficiencies of COD, ammonium nitrogen, and BOD. This phenomenon could occur for the following reasons: 1) Sponge media allows better oxygen uptake in the stream flowing down through the reactors. 2) With sponge media, contact between the sludge and the wastewater is better.

3.2 Part 2 DHS work as post - treatment at RHT 3h:

The actual HRT of the sponges with accumulated biomass is closer to the theoretical HRT than that of the new, clean sponges (Machdar et al., 2000; Tandukar et al., 2006; Tawfik et al., 2006). The hydrophobicity of new sponges is high, so they resist water, resulting in actual HRTs for sponge that are much shorter than the theoretical HRT. It is reasonable to think that biomass gradually spreads and extends uniformly towards inside of the sponge media during the operational period, making the whole sponge media hydrophilic. This could explain why the sponges with biomass had actual HRTs close to the theoretical HRTs. At present, it is difficult to ascribe effects on death rate of F. coli to DO concentration. This study complete to another HRTs was 3h to investigated the treatment in this condition. In this part studied the performance of DHS at 3h.

An accumulation of white precipitant was found in the middle layer between the biomass and sponge in the DHS reactor, which could be an obstacle to normal development of microorganisms (Machdar et al., 2008). The white precipitant was likely calcium or magnesium because high concentrations of both were used in the medium (Wagner et al 2000).Total suspended solid removal efficiency was 90±7 %(5-3 mg/l) for the DHS system Chemical oxygen Demand removal COD were 94±3% in DHS reactor. The relatively higher COD removal efficiency in DHS reactor may be due to physical entrapment and/or packed in the upper part of the reactor. Results were obtained after the wastewater was further treated by DHS treatment system the removals of COD were consistently achieved at 94±1% (6-3.6 mgO2/L) ruby the whole system. On the other hand, this is may attributed to particulate matter entrapment and degradation in DHS sponge by virtue of its long sludge retention time (SRT) (table 2).

Table (2): Summary of laboratory values of TSS, COD, BOD and TKN in finial effluent DHS at R.H was 3h.

Time (week)	TSS(mg/l)	COD (mgO_2/l)	BOD (mg/l)	TKN (mg N/l)
1	5.2	6.5	4	6.8
2	4.9	6	4.4	-
3	6.02	8	5	-
4	3	5	4	-
5	5.11	6.4	4.8	4.4
6	4.023	5.4	4.11	-
7	5.8	7.1	5	-
8	5.21	6.2	4.1	-
9	4.8	7.5	3.5	-
10	5	6.1	4.6	5.5
11	4.2	8.4	5.3	-
12	4.23	7.2	5	-
13	4.23	6.4	5.9	6.3
14	4	7	3.5	-
15	4.5	6.3	3.7	7.4

Biological oxygen Demand efficiency was 96±1 %(4.6 -3 mg/l) DHS. On the other hand, this is may attributed to particulate matter entrapment and degradation in DHS sponge by virtue of its long sludge retention time (SRT) (fig5).

Nitrogen reduced in aerobic DHS via nitrification and de-nitrification process. According (Machdar et al 1997) increased flow rate allows deeper penetration of wastewater into the sponge material. Increases in nitrogen removal and dinitrogen production were observed. In this study the removal of TKN and conversation of NO2 to NO3 (data not shown) in high rate (3h) is less than low rate (6h), may relative to nitrobacteria not take enough time to make nitrification well. In DHS total nitrogen (4.4-6.8 mg N/l), 76% removal of total kjeldahl nitrogen. In average, TKN in the final effluent were (5 - 3 mg N/l).

3.3 Part 3: Use DHS as tertiary treatment.

The 1989 WHO guidelines for using treated wastewater in agriculture stated that wastewater treatment systems should produce effluents with F. coli concentrations with geometric means of less than 103/100mL to permit their use for unrestricted irrigation of crops (WHO, 1989). So in this part use the DHS worked as tertiary treatment which take the effluent of traditional activated sludge as influent.

The removal efficiency of TSS was 80±7% (5 - 3 mg/l) in the DHS system. Suspended solids was entrapped and degraded in the sponge of the DHS system by COD removal fractions concentrations in the treated effluent in DHS system operated as post treatment (from final effluent) was 65±5 %(7-3mgO2/L). Biological oxygen demand decrease from the effluent of activates sludge to DHS from 9-6 mg/l to 4-3mg/L respectively, so the removal efficiency of BOD5 from the finial effluent of activates sludge to DHS was 70±3% (fig6).

Table (3): Summary of laboratory values of TSS, COD, and BOD in DHS which worked as tertiary treatment.

Time/week	TSS(mg/l)	COD(mgO_2/l)	BOD(mg/l)
1	2.8	3.2	2
2	3.4	4	3.1
3	3.6	5.1	3
4	4.20	4.8	3.2
5	3.20	4.6	3
6	4	6	3.5
7	5	7	4

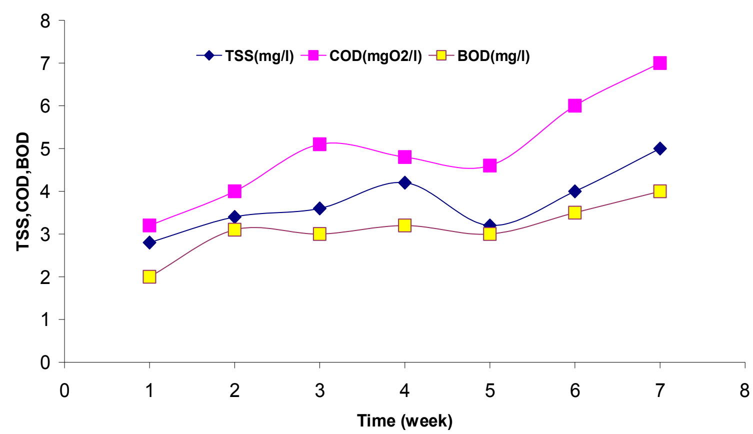

Fig. 6: the variation of BOD, COD, TSS in finial effluent of DHS.

4. Conclusion

Improve the quality of water treated (with low coast) to can use it in agriculture and different ways as safety water. In this study, four identical DHS reactors employing same sizes of sponge media with the same total sponge volume were used for the direct treatment of settled sewage. All four DHS reactors performed satisfactorily in removal of COD, ammonium nitrogen, BOD and TSS at a fixed hydraulic retention time of (6h, 3h and tertiary treatment) based on the sponge volume. This study showed that the smaller the sponge media sizes of the DHS reactors are, the better the removal efficiencies for all the parameters above. From the Parts (1, 2 and 3) prove the efficiency of DHS at high flow at HRT was 3 h and low flow at HRT 6 h and work efficiency as tertiary treatment. So we can use DHS in small village that cannot service by wastewater network as secondary treatment and use after secondary treatment in the traditional plants or any system

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