Egypt. J. Chem. **Vol. 65**, No. 5 pp. 119 - 129 (2022)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Decentralized domestic wastewater management as unconventional water resource for agricultural purposes

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Abstract

This research addresses biological compact unit (BCU) used for onsite wastewater treatment for application and replication in small communities as a non- conventional water resource for agricultural purposes. A (BCU) was fabricated and installed in the in-house experimental zone where the domestic sewage was delivered to the BCU continuously. Operation of the BCU was continuous; hence at different organic loading rates (OLR) and different temperatures .The treated sewage was fed from the BCU to a sand filter upper side. The treated wastewater quality produced from the BCU in terms of physico-chemical and biological characteristics at HRT 12h agrees with the Egyptian permissible limits for restricted irrigation. This is because of the substantial reduction of total COD resulting in an average effluent concentration of 67 mg/l and FC of 560/100 ml. The characteristics of sand filter effluent, treating BCU effluent operated at 12h HRT in terms of COD, BOD,TSS and fecal coliform were 35 ,17 ,5 mg/l and 95/100ml. These values are compatible with national legislation for wastewater reuse in un-restricted crops irrigation. The total cost of BCU construction, operation and maintenance will be US$0.34/m^3 for restricted crops irrigation. When adding a sand filter, the cost will be US$0.46 /m^3 for un-restricted crops irrigation.

Keywords: Wastewater, onsite, treatment, reuse, decentralized, agriculture

Introduction

A distinct advantage of the decentralized treatment systems is its capacity for disposal and reuse of wastewater close to the source, with an obvious saving of transportation costs. As an alternative to centralized systems it can function as a satellite system or an individual wastewater treatment unit. It could be effectively integrated into rural as well as urban settings [1,2]. This can significantly support future water resources management plans and reuse[3,4].Furthermore, introducing small communities to benefit from wastewater management services has a positive impact on public health, pollution and water scarcity. Accordingly, decentralized wastewater treatment has been recognized as an effective solution allowing the sanitation requirements to be met [5,6]. Nevertheless, onsite systems have to meet the necessary level of technology to achieve high-quality effluent, reliable operation, in-frequent maintenance and monitoring. De-centralized systems enable direct use of the treated wastewater. The main advantage of on-site, low-cost biological compact units (BCU) is the preservation of natural water resources for more essential use via the provision of highly treated wastewater for reuse. The use of treated wastewater in crops irrigation would narrow the food gap between production and consumption [3].

Three stages form the conventional compact biological treatment unit: the first stage provides room for sewage precipitation and anaerobic treatment and the liquid part flows to the second stage, an aeration chamber. Sewage is aerated, enriched with plenty of oxygen and agitated to stick to the microorganisms formed on the surface of contact materials in the second stage. In the final stage, the suspended matter in the liquid passed from the second stage is settled and the settled sludge returns back to the contact aeration compartment to stabilize the quality of the final effluent. The packing medium in the packed-bed reactor serves as a filter preventing bacterial washout and also providing a larger surface area for faster bio-film development and improved treatment .The basics for the use of packed bed and fluidized systems are the immobilization of bacteria on solid surfaces. Many

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Receive Date: 28 August 2021, Revise Date: 07 October 2021, Accept Date: 31 October 2021

DOI: 10.21608/EJCHEM.2021.91991.4395

species of bacteria and other microorganisms have the ability for adhering to support matrices. In nature, bio-films exist primarily as complex multi-species communities of bacteria in which each specie fills an ecological niche within the bio-film depending on its metabolism and morphology. The preconditioning of solid surfaces is influenced by the environmental conditions (pH and temperature) and by the surface itself [7,8].

Decentralized wastewater management relies on, collection, treatment and disposal/reuse at or close to the point of generation [9].The decentralized systems can be applied on different scales[10]. It can be applied to: individual households; a cluster of homes; a neighbourhood; public facilities; a commercial area; industrial parks; and small portions of large communities..The major advantage of decentralized systems comes from eliminating a great deal of collection infrastructure. Even in cases when a collection system is needed, the use of tanks, retaining the settleablesolids, allows the use of small-diameter collection systems. In addition, no large interceptors and few, if any, lift stations, are needed. To collect and treat the wastewater, centralized wastewater treatment requires pumps, piping , fittings, valves and energy, therefore increasing the cost of the system .

Records show that nearly 60 million people in the United States use the onsite wastewater treatment systems, where most of them use conventional onsite systems.[11]. In Germany, about 15% of the population uses onsite wastewater treatment systems .In Ontario, Canada, about 10% of the population uses onsite systems for wastewater sanitation, where most of these systems are conventional septic systems .Similarly, 12% of the population in Australia relies on septic systems .In Jordan, 32% of the population is not connected to a sewer system.

De Oliveira Cruz et.al, 2019 [12] Investigated a full-scale on-site domestic wastewater treatment system that comprised a septic tank, an anaerobic filter filled with green coconut husks and an intermittent sand filter. The experiment was conducted in a rural area located in the city of Campinas (Brazil) and the quality of the effluent generated by this combination is under Brazilian and European legislation and even allows for its reuse in agricultural activities. Turkey does not opt installation of centralized treatment plants, approximately, 28 percent are served by septic systems.

In Egypt, over 95% of the Egyptian rural-area has lacked wastewater collection and treatment facilities. The wastewater produced from houses in these rural-areas is mainly treated in septic tanks .Even though decentralized treatment systems are a better option, {septic tanks if not managed properly can cause overflow of wastewater into the surrounding localities, causing detrimental health impacts .so, a new decentralized technology may be applied. The decentralized system can only be considered as a viable alternative if it is highly effective and provides advanced treatment; easy to operate; and low in cost.

The main objective of this study is the management and treatment of domestic wastewater using a biological compact unit for application and replication in small communities as a non- conventional water resource for agricultural purposes. Focus is made on this technique as it compensates for the scarcity of natural water resources and would certainly narrow the food gap between production and consumption. An economic evaluation of the proposed BCU is carried out.

Experimental

To accomplish the objectives of this study a Compact unit model of a 110 L capacity treatment unit was designed and manufactured from poly vinyl chloride (PVC) material, Figure (1).The treatment unit is composed of three stages; In the 1st stage (vol. 60 L), sewage settles down takes place. In the 2nd stage (vol.40 L), aerobic biological treatment takes place where packing materials are stacked. The Packing is composed of equal length plastic tubes (3 cm) and of similar size. In order to maximize the contact surfaces where bacteria build up, the tubes were engraved on both surfaces to create crests at an equal pitch. In the 3rd stage (vol. 10L), the sewage is settled and sludge returns to the aerobic stage. The Compact unit was located at the NRC pilot area and fed continuously with sewage via a connection to the municipality domestic sewerage intake system. Operation of the compact treatment unit continued through summer and winter seasons, hence different organic loading rates (OLR) and different temperatures. The effluent from the compact treatment unit is fed to the sand filter at the top side via equidistance nozzles to ensure uniform distribution.The function of the sand filter is polishing the effluent such that treated wastewater can be used for irrigation of vegetables and similar purposes.The sand filter was made from Perspex material with 110 liter capacity. Main dimensions of: 60 cm length x 40 cm width x 46 cm depth. Three layers of equal depth (0.15 m each) constitute the sand filter content. Top layer of gravel bed with particle size from 0.3mm to 0.45mm, middle layer of fine sand with size between 0.15 and 0.2mm, bottom layer of gravel bed with particle size from 0.3mm to 0.45mm0The hydraulic surface Loading rate of sand filters ranged between 0.25 and 1.5 m^3/m^2/day; this type belongs to slow sand filters operates in the range of 0.1 to 2.9 m^3/m^2/day [13].

.The treatment unit was continuously operated at different hydraulic retention times (HRT), hence different organic loading rates (OLR) in order to arrive at the optimum operating condition(Table1).Daily monitoring of temperature and pH was carried out during the study period for raw sewage and treated effluent of the treatment system. 24-hour composite samples from the raw sewage and the treated effluent were collected and analyzed on weekly basis**.**Physical–chemical analysis and bacteriological examination for the influent and effluent from each stage was carried out as per methods prescribed in the standard method for examination of water and wastewater [14]**.**

Table (1) Operating conditions of the compact treatment unit

HRT	Loading Rate ($m3/m^3$/d)	Detention Time in the Anaerobic Chambers (h)	Detention Time in the Aerobic Chamber (h)	Detention Time in the settling Chamber (h)
8	3	4.37	2.9	0.73
12	2	6.54	4.36	1.1
24	1	13.1	8.7	2.2

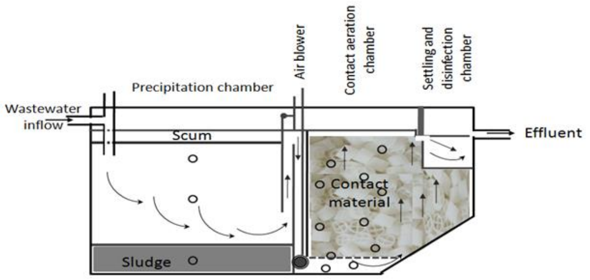

Figure 1: Schematic diagram of the compact unit

Results and Discussion

Raw wastewater characteristics

The result of laboratory analyses of raw wastewater is presented in Table (2). The raw wastewater temperature ranged from 14℃ to 32℃ with an average value of 26℃. COD and BOD values indicate that wastewater contained variable concentrations of organic matter. The raw wastewater has average values of 482 mgO2/L, 250 mgO2/L, 218 mg/L, 53mgN/L, 24mgN/L and 4.8mgP/L for COD, BOD, TSS, TKN, total ammonia and total phosphorous, respectively, These data show that this municipal wastewater is medium strength based on classification defined by Metcalf and Eddy, 2013[15]. As compared with sewage characteristics in different countries [16-17-18], the COD of raw sewage in this study is in line with the sewage of China but lower than in India and Brazil. On the other hand it is higher than the COD of sewage in Slovak.

Domestic wastewater contains pollutants such as fecal bacteria that trigger variety of diseases if discharged directly to rivers, canals and/or lakes or if directly used for crops irrigation. Unless proper regulation and control methods in wastewater irrigation are practiced, pathogenic microorganisms in wastewater can be transferred to healthy individuals and cause diseases [19].Fecal coliform is regarded as the most useful indicator for microbiological purifications achieved by wastewater treatment and disinfection. Nicoleta et al.,2020 [20] discussed the reuse of wastewater in agriculture and the possible risks to human and environmental health. The results in Table (2) show that the Total coliform and Fecal coliform concentrations recorded an average value of $6.2\times10^6$and 5.8×10^5respectively. These values are in agreement with the results obtained by Nasr et al., 2015[21]. The higher value may be caused by the lower rate of water discharge. The results of heavy metals concentration in terms of Cd, Pb, Cu, Zn and Cr indicated the presence of very low concentration [22].

Performance of the anaerobic compartment

Three compartments compose the compact unit, anaerobic treatment takes place and sewage is precipitated in the first stage. In this compartment organic matter is converted into biogas consisting mainly of methane and carbon dioxide whereas solids are entrapped. The nitrogen is converted to ammonium and the reduction of sulfate produces hydrogen sulfide. The sludge amount is little, however, any excess is digested [23].Bacteria growth occurs an aerobically, in absence of oxygen. The performance evaluation of the anaerobic treatment stage was at the HRT range from 8 to 24 h. The system was seeded with anaerobic sludge of concentration 28.6 g/l for TSS and 12.9 g/l of VSS. The physical-chemical characteristics of the effluent are shown in Table (2).The pH values of effluent ranged between 7.3 -7.5 during the investigation period. This is in agreement with Nasr *et. al*, 2015 [21] who stated that the optimal pH for methane producing bacteria ranged between 6.5 and 7.5. The temperature variations ranged from 20 to 29 °C during the study period which did not have a significant effect on the performance of anaerobic bacteria. Even at low temperature in the winter season, the temperature does not fall outside the suitable range for anaerobic bacteria.

The results indicated a higher efficiency of 68% for COD removal at 24h, descending to 60% at 8h. Corresponding residual COD proportionally increased with the decrease of HRT. Average residual COD values at 8h, 12h, 24h are 195 ±33mg O_2/l, 176 ±31 mg O_2/l and 155 ±28mg O_2/l, respectively. These results are higher than those obtained by Panswad and

Komolmethee, 1997 [24] who used a full-scale anaerobic filter unit with retention time varying from 22.5 to 90h and achieved percentage removal of 52.1 for the COD at an average retention time of 22.5h. Also, the present study results are agreed with those obtained by Nguyen et al., 2006[25]who obtained average removal efficiencies from 48 to 65% in terms of COD, depending on the HRT in the conventional septic tank. The present study results are less than those obtained by Moussavi *et al*., 2010[26] who studied the performance of a pilot scale up-flow UASB for on-site decentralized treatment of residential wastewater at 24h HRT, and achieved a removal of 77 % for COD at steady state operation. Residual BOD values in the anaerobic compartment effluent at HRT of 8h ,12h and24h were 110±21 mg O_2/l, 92±18mg O_2/l and 75±16 mg O_2/l, respectively. The variation of HRT was significantly observed by suspended solids removal efficiency. The TSS concentrations ranged between 57 mg/l at HRT 24h and 70 mg/l at HRT 8h. Their corresponding percentages removals were 74 and 69% at HRT 24h and 8h respectively.

The results revealed that the total kjeldahal nitrogen removal in the anaerobic compartment operated at different HRT was relatively low. Average residual concentrations of TKN ranged from 42 mg N/l at 24h to46 mg N/l at 8h.The corresponding average removal efficiencies for TKN ranged from 20 to 15 %.The results indicated that ammonia concentration increased from 26mgN/l at 8h to29 mg N/l at 24h. Since anaerobic digestion takes place in the anaerobic compartment, little removal of phosphorus can be expected as being utilized for biomass growth, precipitated and entrapped with the digested sludge..

The percentage removal values were 16 and 24 %at 8h and 24h .The present study results are lower than those obtained by Burubai et al., 2007 [27]who recorded TP removal range from 49.6 to 66% at HRT of 24h and 48h treating toilet wastewater using a single compartment septic tank. The results of this study are higher than those obtained by Al-Jamal et al., 2009[28] who attributed the lower phosphorus removal achieved to the relatively low biomass production in anaerobic systems.

Regarding the microbiological indicators, fecal coliform removal efficiency is low in anaerobic systems .Bacteriological examination of the anaerobic compartment effluent revealed average residual values of fecal coliform in the final effluent of $5.2x10^4$, and $4x\ 10^4$ MPN/100 ml at 8h and 24h hydraulic retention times . This revealed a removal efficiency of faecal coliform of less than one log. Results of this study are in line with those obtained by Nasr *et al*., 2016 [29] and higher than those obtained by Burubai *et al.*, 2007 [27].

Performance of the aerobic compartment

Considering the aerobic compartment effect, it was observed that the removal efficiency was much better compared to the anaerobic compartment [30]. The TSS, COD and BOD percentage removal increased. Also, the total nitrogen and total phosphorus percentage removal were modified, concerning ammonia concentration a decrease was observed. The total coliform and fecal coliform decreased by two logs. In the aerobic system, polishing of residual concentration of suspended solids and organic matter takes place together with ammonium oxidation to nitrite/nitrate via nitrification. The results in Table (3) show that the pH value in the aerobic biological compartment effluent increased a bit, it ranged between 7.7 and 7.9. This is possibly due to the degradation of volatile fatty acids produced in the anaerobic compartment. Raising HRT from 8 h to 24h in the aerobic compartment showed an increase of the average percentages removal of organic matters from anaerobic effluent in terms of COD and BOD from 30 to 42 % and from 35 to 50 %, respectively. Also the removal efficiency of TSS increased, the average percentage removal values for TSS from anaerobic effluent increased from 37% at 8h to 52 % at 24h.Increasing the HRT, nutrient removal in the aerobic compartment increased from 21 % at 8h to 28% at 24h for TKN from an anaerobic effluent.

An aerobic/aerobic process was developed to improve biological phosphorus removal .The average percentage removal of total phosphate reached59% at24h HRT. Total coliform and Fecal coliform counts for the aerobic compartment effluent compared to anaerobic one at the investigated HRT indicated that the average removal ranged between 2 logs and 3 logs. This may be attributed to the adsorption of Total coliform and Fecal coliform on the packing material surface.

Performance of the BCU

Performing an activated sludge treatment jointly with an anaerobic treatment was proposed by many researchers. If compared with conventional AS systems, less energy are consumed and much less excess sludge will be generated. The results of monitoring the performance at HRT of 8, 12and 24h indicate higher efficiency of 86% for COD and 90% for BOD removal at 24h descending to 81% and 84% at 8h, respectively (Table 4 &Figure2). Corresponding residual COD and BOD proportionally increased with the decrease of HRT. These results are comparable with those obtained by Gasparikova et al., 2005 [16] who worked on the principle of anaerobic pre-treatment and aerobic post-treatment for treatment of domestic wastewater and achieved78 % removal of

COD and 91% of BOD. The percentage removal values of TSS were 89, 92and 94% at8h,12h and24hHRT.These results are comparable to those obtained by Abou-Elela *et al*., 2015[31] who used a hybrid up flow anaerobic sludge blanket followed by sand filtration for treatment of domestic wastewater and achieved 91% TSS removal. The order of removal efficiency was found to be TSS > BOD >COD .Residual TKN values were 29 mg N/l,26mg N/l and 24mg N/l, respectively. The percentage removal values were 44, 49 and54 % at 8h, 12h and 24h, respectively.

These results are similar to the values reported by Mahmoud *et al*., 2011[32] in a down-flow hanging sponge fed a UASB pre-treated sewage. The TKN removal is mostly due to ammonia assimilation in new cell biomass (excess sludge) and a small fraction due to nitrification or nitrification/de-nitrification. A significant part of the TKN is present in particulate form (sludge biomass) and settled in the final sedimentation tank with additional improvement in the effluent quality. Total phosphorus were1.7mg P/l, 1.5 mg P /l and 1.3mg P /l, respectively. The percentage removal values were 65, 69 and 73 %at 8h, 12h and 24h, respectively. Bacteriological examination showed that the Total coliform and Fecal coliform were reduced by one log in the anaerobic compartment. The significant part of total and Faecal coliform was removed in the aerobic zone (maximum of 2log reduction).This result is supported by explanation of Metcalf and Eddy, 2013[15].

The COD and BOD highest percentage removal in each stage is found at the 24h HRT. TKN, TP, TC and FC follow the same analogy, the percentage removal of all parameters is observed to have near values at 24h and 12h HRT. Therefore, 12h HRT was opted based on economic advantage. The treated wastewater quality produced in terms of physico-chemical and microbiological characteristics meet Egyptian permissible limits for restricted irrigation.

Table (2) Characteristic of the anaerobic compartment effluents

Parameter*	unit	Raw Inlet to BCU	HRT 8 h	HRT 12 h	HRT 24h
pH		7.6	7.3	7.4	7.3
TSS	mg /l	218±19	70±11	64±10	57
COD	mg O_2/l	482±32	195±33	176±31	155±28
BOD	mg O_2/l	250±31	110±21	92±18	75±16
T.K.N	mg N /l	53±3	46±2.8	44±2.7	42±2.5
AMN	mg N /l	24±3	26±3.7	27±3.9	29±4
TP	mg P /l	4.8±0.8	4.1±0.6	3.8±0.56	3.6±0.52
TC	MPN/100ml	6.2×10^6 $\pm5x10^5$	5.6×10^5 $\pm1.5x10^5$	5.1×10^5 $\pm1.3x10^5$	4.3×10^5 $\pm1.2x10^4$
FC	MPN/100ml	5.8×10^5 $\pm2x10^4$	5.2×10^4 $\pm1.2x10^4$	4.5×10^4 $\pm1.1x10^4$	4×10^4 $\pm1.3x10^4$

*Average of five samples

Table (3) Characteristic of the aerobic compartment effluents

Parameter*	unit	HRT 8 h	HRT 12 h	HRT 24h
pH		7.7	7.8	7.8
TSS	mg /l	44±10	36±8	31±7
COD	mg O_2/l	135±26	107±22	92±21
BOD	mg O_2/l	72±15	52±13	37±12
T.K.N	mg N /l	36±3.2	34±3	30±2.9
AMN	mg N /l	18±4.3	16±4	14±3.7
TP	mg P /l	2±0.7	1.7±0.5	1.5±0.5
TC	MPN/100ml	4.9×10^4 $\pm2.2x10^4$	4×10^4 $\pm2x10^4$	2.5×10^4 $\pm1.8x10^4$
FC	MPN/100ml	4.2×10^3 $\pm1.9x10^3$	3.5×10^3 $\pm1.7x10^3$	2×10^3 $\pm1.5x10^3$

*Average of five samples

Table (4) Characteristic of the BCU Effluents

parameter*	unit	HRT 8 h	HRT 12h	HRT 24h	Egyptian restricted irrigation limits
pH		7.7	7.8	7.9	-
TSS	mg /l	22±5.2	16±5	13±4.3	40
COD	mg O_2/l	93±16	67±12	58±12	80
BOD	mg O_2/l	41±12	28±10	24±7	40
T.K.N	mg N /l	29±3	26±2	24±2	-
AMN	mg N /l	13±5	11±3	10±4	-
TP	mg P /l	1.7±0.2	1.5±0.17	1.3±0.14	-
TC	MPN/100ml	1.7×10^3 $\pm5.1\times10^2$	1.1×10^3 $\pm4.4\times10^2$	6.9×10^2 $\pm1.8\times10^2$	-
FC	MPN/100ml	8.4×10^2 $\pm2.7\times10^2$	5.6×10^2 $\pm1.9\times10^2$	4.1×10^2 $\pm1.5\times10^2$	1000

*Average of five samples

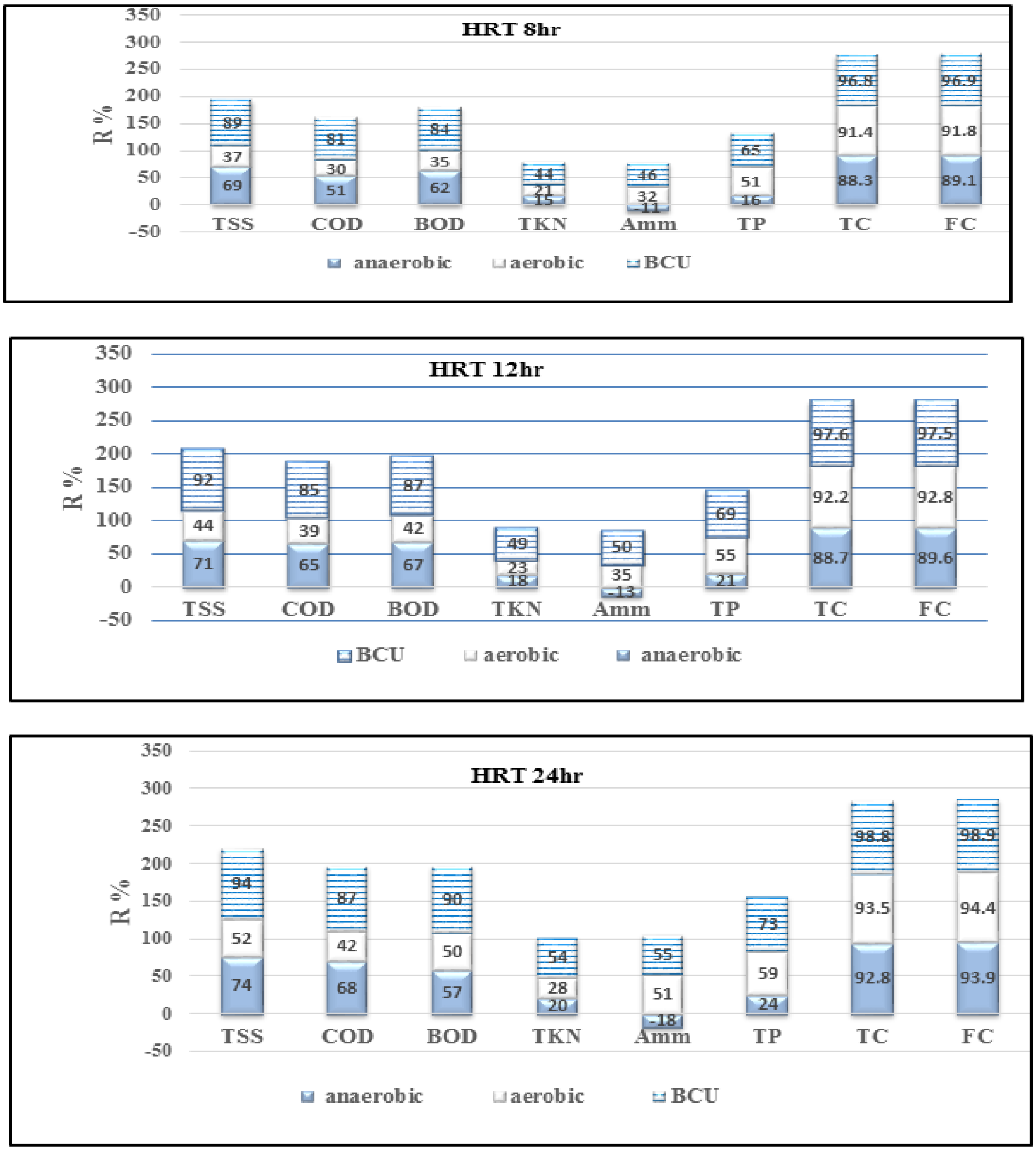

Figure (3): Performance of the BCU at different HRT

Table (5) characteristics of sludge accumulated in an anaerobic compartment at different HRT

Time(d)	amount of sludge accumulated (cm3)	amount of sludge accumulated (g)	average sludge accumulated per day(g/d)	sludge volatile organic matter(%)
HRT,24hr				
30	2500	98	2.24	69
60	3200	180	3.15	66
100	5050	360	4.31	64
HRT ,12hr				
Time(d)	**amount of sludge accumulated (cm3)**	**amount of sludge accumulated (g)**	**average sludge accumulated per day(g/d)**	**sludge volatile organic matter(%)**
30	3300	212	7	72
60	5400	336	11.2	71
100	6100	536	17.87	69
HRT ,8hr				
Time(d)	**amount of sludge accumulated (cm3)**	**amount of sludge accumulated (g)**	**average sludge accumulated perday(g/d)**	**sludge volatile organic matter(%)**
30	5500	364	12.3	74
60	7300	624	20.8	72
100	8800	1242	41.4	71

The BCU desludging plan

Because the excessive build-up of sludge in the anaerobic compartment reduces the solid separation and aerobic treatment performance of the system, the accumulated sludge should be discharged on regular basis. Figuring out the amount of sludge expectedly to accumulate is essential for efficient systems design. The amount of sludge produced is influenced by the organic loads. The volume of sludge in the anaerobic compartment was thoroughly monitored versus retention time .It was observed that the accumulated volume and weight depends on the HRT(Table 5) . When comparing the sludge volatile organic matters at each HRT, it was found that average values are almost equal. Assuming that sludge accumulation is proportional to time of operation and that desludging should occur at 60% of the septic tank volume . Tyler, 1999 and Ichinari , 2008[33,34]reported tha tthe design volume of a anaerobic tank is usually dependent on the liquid detention interval and the desludging frequency, which usually varies from three to five years. it was observed that the due time for desludging is directly proportional to the HRT. The present study shows that the desludging will be required after 14 months, months, 24 months at 8h, 12h and 24h, respectively.

Post treatment of BCU effluent using sand filter

All varieties of domestic wastewater are treated using BCU, mainly for removing COD, BOD, TSS and Fecal coliform, TKN and phosphate to a certain degree. Using gravity slow Sand filter treatment process, the quality of the produced effluent is improved. The organic matter removal represented in residual COD forms an indicator of the sand filter performance where COD values were32mg O_2/l at 24h and70 mg O_2/l at 8h (Table 6). Effluent residual BOD values were15mg O_2/l at 24h and30 mg O_2/l at 8h. The corresponding average TSS values are 4mg /l and 7 mg/l. The average residual TKN and ammonia concentration values in the effluent are 16and 7mg/l at 24h, 23 and 11 at 8h.The average residual FC values in effluent were 90 /100ml and 180 /100ml at 24h and 8h.Using the sand filter, the total coliform and fecal coliform decreased by two logs. The characteristics of sand filter effluent treating BCU effluent operated at12h HRT in terms of COD, BOD, TSS and fecal coliform were 35 ,17 ,5 mg/l and 95/100ml. These values are compatible with national legislation for wastewater reuse in unrestricted crops irrigation.

Economic evaluation of the proposed BCU.

The economic evaluation is made for the proposed BCU, capable of treating 60 m^3/d of medium strength wastewater generated from a small community. The proposed BCU consists of three stages (anaerobic, aerobic and final sedimentation) of volume 30$m^3$and 12h HRT for the treatment of domestic wastewater. The economic evaluation is based on the construction, operation and maintenance costs. The operation and maintenance costs evaluation consider the following: Power consumption (electricity) required for system operation and for pumping, Labours required for system operation and maintenance, spare parts, cleaning, changing of media every 3 years and removal of sludge from the BCU every 20 months. The total cost for treating (1 m^3) of wastewater for restricted irrigation will be: US$ 0.34. When a gravity slow sand filter process is added to qualify waste water for unrestricted irrigation, the treatment cost will become US$ 0.46per m^3.

Table(6)Characteristic of post treated effluent in sandfilter

parameter	unit	HRT 8 h	HRT 12h	HRT 24h	Egyptian unrestricted irrigation limits
pH		7.8	7.8	7.8	-
TSS	mg /l	7±2	5±3	4±2	20
COD	mg O_2/l	70±12	35±4	32±6	40
BOD	mg O_2/l	30±10	17±3	15±3	20
T.K.N	mg N /l	23±1.7	18±1.5	16±1.4	-
AMN	mg N /l	11±3	9±2.8	7±2	-
TP	mg P /l	1.5±0.4	1.2±0.3	0.9±0.3	-
TC	MPN/100ml	$5x10^2$ ±$1.4x10^2$	$3.5x10^2$ ±9x10	$3.1x10^2$ ±8x10	-
FC	MPN/100ml	$1.8x10^2$ ±8x10	9.5x10 ±9.8x10	9x10 ±4x10	100

Conclusion

The average removal of pollutants of BCU in terms of COD, BOD and TSS improves in direct proportion to HRT.. The same trend applies to the aerobic stage and BCU effluent. The COD and BOD highest percentage removal in each stage is found at the 24h HRT. TKN, TP, TC and FC follow the same analogy. The produced wastewater quality in terms of physical-chemical and biological characteristics at HRT 12h agrees with the permissible standards given by the Egyptian law for restricted irrigation. The low removal efficiency of Total Coliform (TC), Fecal Coliform (FC), was observed in 1st compartment where the anaerobic reaction occurs.The main portion of TC, FC extraction in the BCU occurred in the aerobiccompartment, guided by the large contact surface of the packing materials. The BCU compartmentalized structure gave results higher than other systems as compared to the performance of aerobic lagoon, rotating biological contactor. Using gravity slow sand filter treatment process, the quality of the produced effluent is improved to be suitable for un-restricted crops irrigation.An economic evaluation of the proposed BCU proves to be worthy for installation as an on-site wastewater treatment system in remote areas and locations deprived 0f sanitation. total cost for treating (1 m^3) of wastewater will be: US$0.34for restricted irrigation and US$ 0.46 per m^3 for unrestricted irrigation.

Acknowledgement

The authors would like to thank the Egyptian National Research Centre (NRC),) for basic, and research Grant No.10080304.

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