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Treatment of Septic Tank Effluent for Reuse as Irrigation water

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Abstract–Conventional septic tank is the main on-site treatment system used in remote unsewered areas of Kuwait. Reclamation and reuse of septic tank effluents have a potential of being a substantial new source of water. However, the effluents of such conventional septic tanks usually do not satisfy the requirements for reuse. The Kuwait Institute for Scientific Research (KISR) has recently conducted a study that aimed at selecting the best add-on treatment system that can treat septic tank effluents to a level satisfying Kuwait's national guidelines for reuse in restricted irrigation. This paper reports the performance of one of the studied add-on treatment trains, System 1.

Keywords–wastewater, septic tank, effluent, treatment, reclamation, reuse

Introduction

Kuwait is a highly water-stressed country. Most of its water supply comes from desalinated seawater. Groundwater contributes to a small fraction of the water need, and its source is depleting alarmingly. The reuse of treated wastewater for agriculture or other restricted uses is thus highly encouraged in Kuwait. Such reuse of treated wastewater on- site augments the overall water resources in the country.

The most widely used systems for on-site treatment of wastewater in Kuwait, particularly in remote areas, is the conventional septic tank system. A conventional septic tank provides only the primary treatment of wastewater, and therefore, its effluents are not safe for direct reuse (Beavers, 2002). Thus, comprehensive treatment units should be add-ons to conventional septic tanks in order to ensure that their effluents will satisfy wastewater reuse criteria.

The Kuwait Institute for Scientific Research (KISR) has recently conducted a study that aimed at selecting the best add-on treatment system, among three systems, which can treat septic tank effluents to a level satisfying Kuwait's national guidelines for reuse in restricted irrigation. This paper reports the performance of one of the studied add-on treatment systems, namely, System 1 (Abusam et al., 2014).

II. Septic Tank Add-on System

Fig. 1 shows the tested septic tank add-on system that consisted of the following five add-on unit processes arranged in a series: sedimentation tank, aerated aerobic bioreactor (main unit), final clarifier, saturated grass bed for nutrient reduction, and chlorine and/or chlorine compound disinfection unit. These unit processes are well known for small-flow wastewater treatment (Bennette and Mar, 1999; Kaplan, 1991; and USEPA, 1984).

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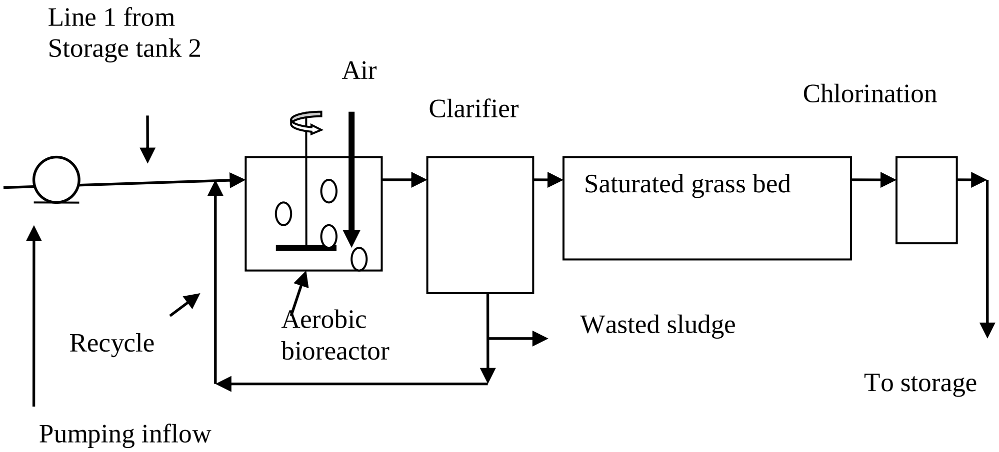

Figure 1. Aerobic bioreactor, final clarifier, saturated grass bed, and chlorine compound disinfection unit of System 1.

In this add-on system, the physical-chemical and biological processes take place in the aforementioned units as follows:

- Biochemical oxygen demand (BOD) and chemical oxygen demand (COD), nitrogen (N), phosphorus (P), and trace pollutants are reduced by biochemical reactions induced by aerobic bacteria.
- Total suspended solids (TSS) are removed in sedimentation and clarifier tanks.
- Microbial reduction takes place in sand media in saturated grass beds.
- Residual microorganisms are killed in the chlorination process.

III. Materials and Methods

The add-on system was operated at inflows of 0.5, 0.8, 1.1, 1.4, and 1.6 l/min. The flow recycling rates were 25%, 50%, 75%, and 100% of the inflow. Disinfection of the final effluent, using liquid chlorine, was investigated in the jar-test unit. At steady state conditions, weekly samples of the add-on system’s final effluent were collected and sent for analysis. Temperature, hydrogen concentration (pH), dissolved oxygen (DO), and electrical conductivity (EC) were measured in situ, using portable meters. According to APHA (2012), the following wastewater quality parameters were determined in the Wastewater Sulaibiya Research Plant (WSRP) laboratories: BOD_5, COD, TSS, total dissolved solids (TD), oil and grease (O&G), nitrate nitrogen (NO_3), total Kajeldah nitrogen (TKN), total nitrogen (TN), phosphate (PO4), phenol (C_6H_5OH), total coliform, fecal coliform, boron (B), cadmium (Cd), lead (Pb), mercury (Hg), zinc (Zn), arsenic (As), aluminum (Al), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), and magnesium (Mg). Finally, the suitability of the final effluent for reuse in irrigation was assessed according to the standards of Kuwait Environment Public Authority (KEPA).

IV. Results and Discussions

Table 1 gives a statistical summary of the quality of the feed flow (conventional septic tank effluent) and compares it to the KEPA standards. The quality of the feed was typical of the effluents of conventional septic tanks. As expected, this table shows that the concentrations of NH_4-N, TKN, total coliform, and fecal coliform were high and had not met the KEPA standards for reuse in irrigation. Effluents of conventional septic tanks are usually highly loaded with nutrients and pathogens (Beavers, 2002). This table, however, shows that the concentrations of TSS, BOD_5, COD, and NO_3-N were relatively low. Also, concentrations of the heavy metals were far below the KEPA standards.

Table 1. Quality of the Feed of Add-on System 1 Compared to KEPA Standards

Parameter	Minimum	Average	Maximum	Standard Deviation	KEPA Standards
Temperature (^{o} C)	20	21.6	25.5	1.8	---
pH (--)	7.4	7.7	8.2	0.2	6.5 – 8.5
EC (µS/cm)	588	835.9	1202	161	---
TSS (mg/l)	7	14.3	24.4	5	15
TDS (mg/l)	253	304.9	426	38	1500
NO_3-N (mg/l)	0.3	1.1	2.9	0.7	---
NH_4-N (mg/l)	30.8	56.2	80.8	15.8	15
TKN (mg/l)	31.8	57.9	83.3	16.3	35
TN (mg/l)	32.1	58	83.9	16.8	---
PO_4 (mg/l)	3.2	5.3	7.2	1.3	30
COD (mg/l)	22	37.8	61	12.4	100
BOD_5 (mg/l)	8	14.8	22	4.6	20
DO (mg/l)	0.8	1.4	2.1	0.4	>2
Oil and Grease (mg/l)	0	0.1	1	0.3	5
Total Coliform (colonies/100 ml)	2.00E+05	1.40E+07	1.30E+08	3.00E+07	400 MPN/100 ml
Fecal Coliform (colonies/100 ml)	2.00E+04	1.20E+06	1.10E+07	2.60E+06	20 MPN/100 ml
C_6H_5OH (mg/l)	0	0.1	0.2	0.05	1
F (mg/l)	0	0	0.1	0.03	25
H_2S (mg/l)	0	0.3	0.9	0.25	0.1
Al (mg/l)	0	0.7	0.9	0.3	5
As (mg/l)	0	0	0	0	0.1
B (mg/l)	0.1	0.3	1.1	0.2	2
Cd (mg/l)	0	0	0.2	0.05	0.01
Cu (mg/l)	0	0.1	0.6	0.2	0.2
Fe (mg/l)	0	0.3	1.7	0.5	5
Pb (mg/l)	0	0.1	0.4	0.2	0.5
Mn (mg/l)	0	0.1	0.2	0.1	0.2
Hg (mg/l)	0	0	0	0	0.002
Ni (mg/l)	0	0.1	0.3	0.1	0.2
Zn (mg/l)	0	0.1	0.3	0.1	2
Mg (mg/l)	3.9	15	26.5	6.8	---

Table 2 shows that the final effluent of the add-on system satisfied all of the KEPA standards, except for TSS, BOD_5, DO, and Ni concentrations. The average concentrations of TSS, BOD_5, DO and Ni in the final effluent were 16.4 mg/l, 24 mg/l, 2.2 mg/l, and 0.2372 mg/l, respectively, whereas the KEPA standards are 15 mg/l, 20 mg/l, > 2 mg/l and 0.2 mg/l, respectively. It was noticed that the break-point chlorination concentrations of both total coliform and fecal coliforms (not shown in Table 2) were nil.

Table 2. Quality of the final effluent of the Add-on System 1

Parameter	Minimum	Average	Maximum	Standard Deviation	KEPA Standards
pH (--)	7.4	7.6	8	0.2	6.5 – 8.5
EC (µS/cm)	617	941.9	1959	339.7	---
TSS (mg/l)	2	16.4	74	17.5	15
TDS (mg/l)	250	648.9	3995	853.4	1500
NO_3-N (mg/l)	1.4	5.4	14.2	3.7	---
NH_4-N (mg/l)	1.3	3.8	6.8	1.5	15
TKN (mg/l)	1.6	1.6	1.6	1.5	35
TN (mg/l)	1.4	4.8	14.2	3.5	---
PO_4(mg/l)	3.5	8.8	18.9	4.1	30
COD (mg/l)	17	53.1	270	60.6	100
BOD_5 (mg/l)	7	24	99	27	20
DO (mg/l)	1.1	2.2	3.3	0.6	>2
Oil and Grease (mg/l)	0	0	0	0	5
C_6H_5OH (mg/l)	0	0.02	0.07	0.02	1
F (mg/l)	0.06	0.4	0.83	0.24	25
H_2S (mg/l)	0.001	0.01	0.04	0.012	0.1
Al (mg/l)	0	0.286	0.6855	0.1961	5
As (mg/l)	0	0	0	0	0.1
B (mg/l)	0.0041	0.1363	0.49	0.1253	2
Cd (mg/l)	0	0	0	0	0.01
Cu (mg/l)	0	0.0262	0.1514	0.0449	0.2
Fe (mg/l)	0	0.3109	1.3195	0.3668	5
Pb (mg/l)	0	0.1257	0.3783	0.1469	0.5
Mn(mg/l)	0	0.1033	0.2353	0.0954	0.2
Hg (mg/l)	0	0	0	0	0.002
Ni (mg/l)	0	0.2372	2.345	0.5183	0.2
Zn (mg/l)	0	0.0818	0.2163	0.072	2
Mg (mg/l)	1.057	16.3772	29.51	8.1007	---

Fig. 1 compares the quality of the feed to the effluent before and after the grass-bed sand filter, in terms of TSS, NH_4-N, COD, and BOD_5 concentrations. It is apparent that the concentrations of TSS, COD, BOD_5, and particularly NH_4-N before the grass bed (after the bioreactor) were significantly less than these in the feed, indicating that the aerobic oxidation processes in the bioreactor had helped in the removal of ammonia and organics. Fig. 1 also shows that, except NH_4-N, the concentrations of other parameters after the grass-bed filter were significantly higher than those before it, indicating the release of solids and organic matters into the water while it was passing through the grass-bed filter.

Further reduction in NH_4-N concentration after passing through the grass-bed filter was expected as planted filters are known for their efficient removal of, particularly, nitrogen compounds. It is worth mentioning that the increase in the concentrations of solids and organics was temporary as it occurred only during the first two weeks of operation as shown in Fig. 2. Generally, planted filters need a few weeks of operation before being effective in the removal of pollutants (Garcia et al., 2004).

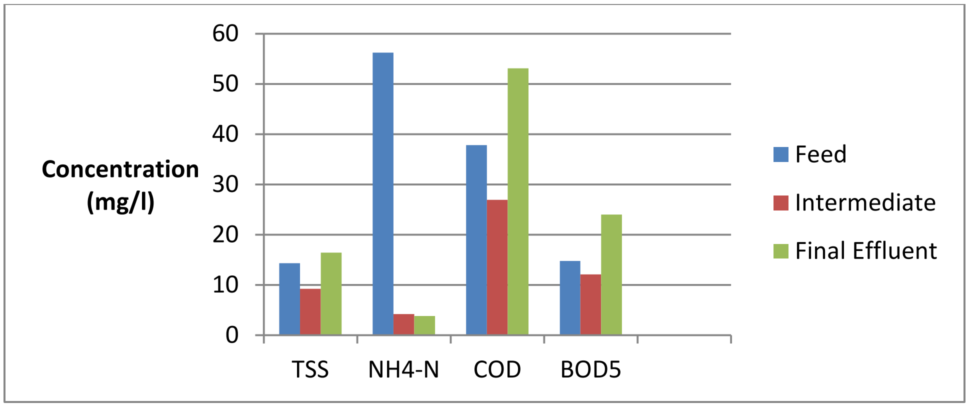

Figure 1. Comparison of the quality of the feed to the intermediate and the final effluent of process 1

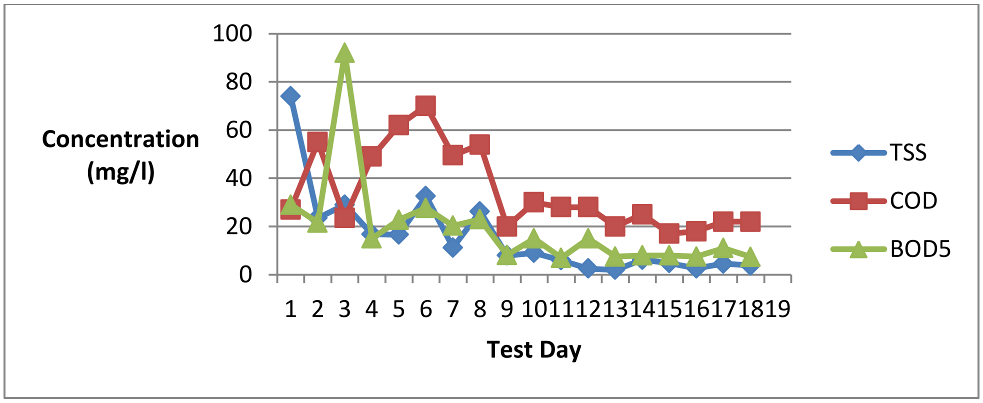

Figure 2. Changes in TSS, COD and BOD5 concentrations in the final effluent of Process 1 over time

The add-on system was operated at hydraulic loading rates (HLRs) equal to 0.50, 0.80, 1.10, and 1.60 l/min. Fig. 3 shows the effect of the variations in HLRs on the removal of TSS and BOD. This figure shows that the removal efficiencies of TSS and COD had significantly increased when the HLR increased. The removal efficiency of TSS was around 40% when HLR was 0.5 l/min and it had increased to about 58% when HLR was increased to 1.6 l/min. On the other hand, the removal efficiency of COD was around 15% when HLR was 0.5 l/min and became about 37% when HLR was 1.6 l/min. These findings indicate that an increase in HLR did not adversely affect the removal of solids and organics. That is, the add-on system was capable of absorbing volumetric and organic shock loads.

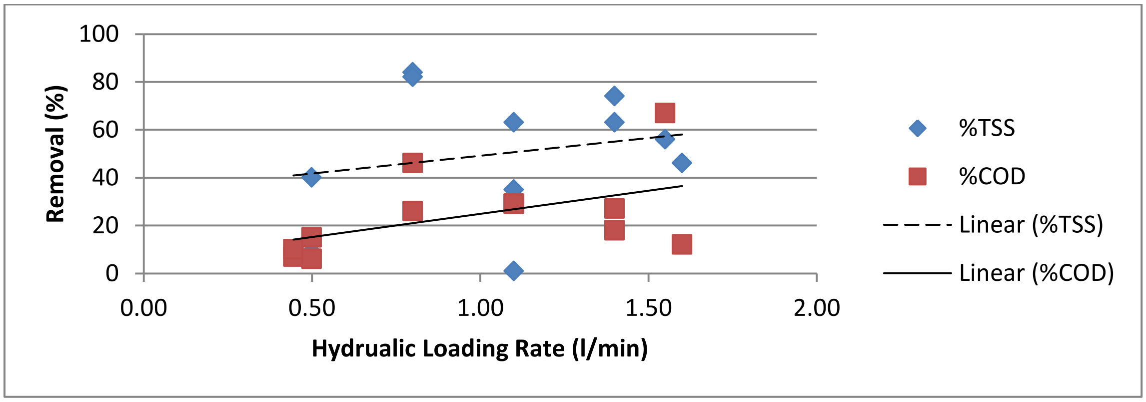

Fig.3. Process 1 alternative removal rates of TSS and COD versus applied hydraulic loads

Fig. 4 presents the effect of the changes in the HLR on the overall removal of nitrogenous and phosphorus compounds. It is apparent that the achieved removal efficiencies of NH_4-N and PO_4 were both above 90%, while that of TN was around 80%. It is also evident that an increase in HLR had a slight adverse affect on the removal efficiencies of nitrogen compounds. Nitrogen removal in the add-on system was achieved through the processes of nitrification-denitrification. When arranged in a post-denitrification mode, nitrification in System 1 took place in the aerobic bioreactor, while denitrification occurred in the anoxic grass-bed filetr. Thus, the C-source for denitification was the wastewater itself. NH_4-N removal (nitrification) ranged from 88 to 93% (mean = 91± 1%), while, due to the lack of sufficient C-source, TN removal was restricted between 71 and 89 % (mean = 81± 6%). The achieved TN removals were within the range reported in literature for such a system (Jenssen et al., 2010).

Singh et al. (2011) reported that the TN removal of a treatment train that consists of an aerobic bioreactor and a clarifier but without a grass-bed filter is about 50%. Based on this, it can be concluded that about 30% of the TN removals of System 1 (80%) occurred in the grass-bed filter unit. Reed plants are known for their ability to reduce the concentration of pollutants in wastewater through various mechanisms (Brix, 1994; Henneck et al., 2001; Vygmazal, 2007; Dennis et al., 2009). Unplanted sand filters often remove TN through the processes of nitrification, in the aerobic zones near the top of the filter, and denitrification, in the anaerobic zones near the bottom of the filter (Van Buuren et al., 1999).

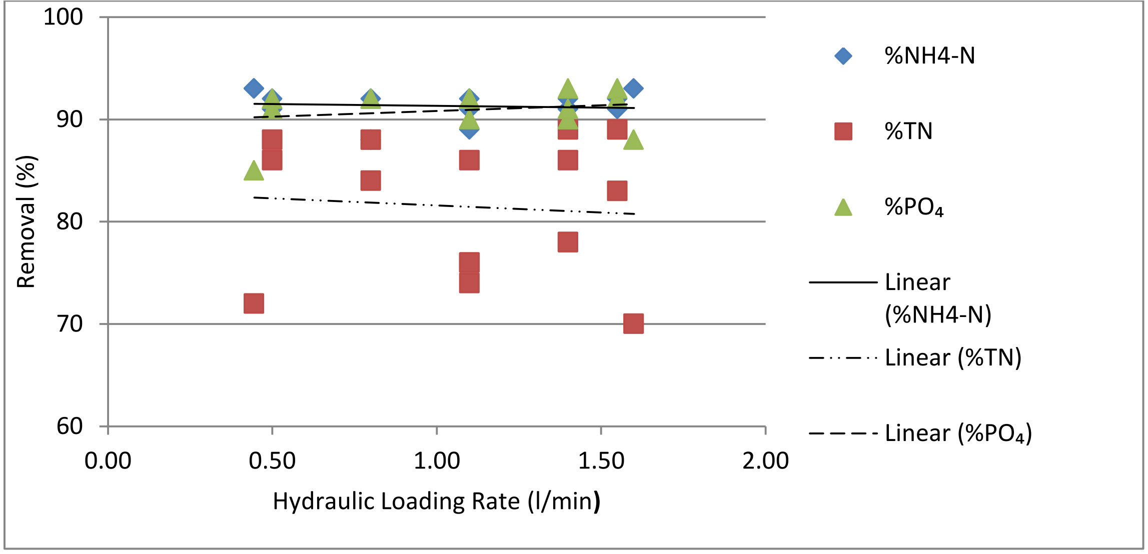

Figure 4. Effects of hydraulic loading rate on nutrients removal of System 1

As presented in Tables 1 and 2, the average concentrations of total coliform and fecal coliform in the feed (septic tank effluent) were 1.4E+7 CFU and 1.2E+6 CFU, respectively, while they were 4.3E+6 CFU and 3.6E+7 CFU, respectively, in the final effluent of the add-on system. These results indicate that System 1 reduced the concentrations of coliform by only 1.0 log unit, which is much lower than the average 3 log unit reduction reported in literature for sand filters (Duggan et al., 2001; Manios et al., 2002). Chlorination often results in up to 6 log reduction units (99.9999%) of pathogen concentrations (WHO, 2006). This explains why the chlorinated final effluent of System 1 satisfied the KEPA standards for coliform.

With respect to heavy metal removal by System 1 (Fig. 5), more than a 50% reduction in the concentrations of Al, B, and Cu; negative impacts on the concentration of Ni (150% increase); and almost no effect on the concentrations of the other heavy metals. The increase of Ni concentration can be attributed to the leach from the soil and grass and also to the slight drop in pH value. A drop in pH represents an unfavourable condition for the precipitation of Ni (Lee and Scholz, 2007). Efficient removal of some heavy metals (Al, B, and Cu) by the grass-bed sand filter makes it more suitable for use in industrial settings where wastewater is more likely polluted with heavy metals.

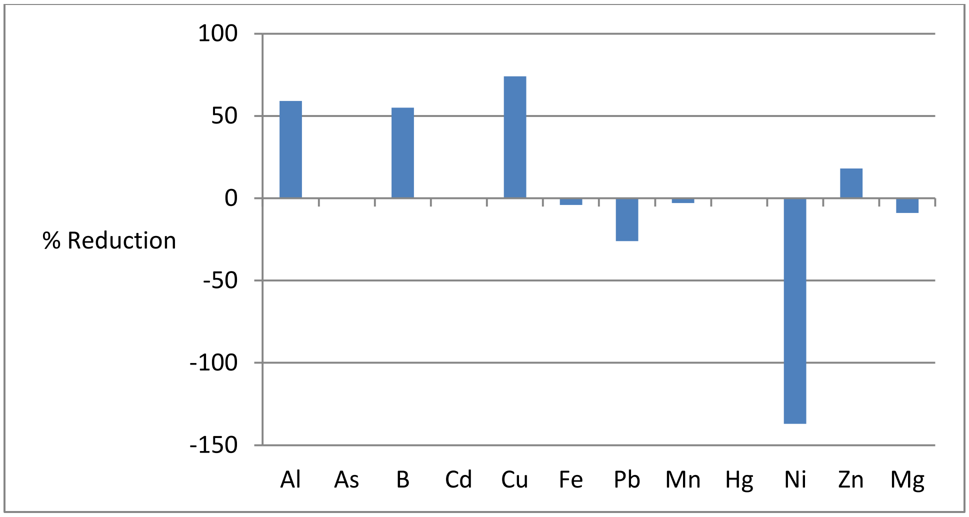

Figure 5. Process 1 reduction percentages of heavy metals

V. Conclusions

Based on the results of the testings, the following conclusions were drawn for the final effluent of the septic tank add-on System 1 (sedimentation tank, aerobic bioreactor, final clarifier, and grass-bed sand filter):

- The final effluent generally satisfied the KEPA standards for the reuse of treated wastewater in irrigation, except for the concentrations of TSS, BOD_5, DO, and Ni, which were slightly higher than the standards.
- System 1 achieved excellent removal of nitrogen (91% for NH_4-N and 81% for TN) and good reduction of some heavy metals (59% for Al, 55% for B, 74% for Cu, and 18% for Zn). However, its removal rates for TSS and COD were low.
- Due to the release of solids and organics from the grass-bed filter during the first weeks of operation, the system's TSS removal rates averaged between 40% and 15%.
- Increase of HLR did not show any adverse effects on the removal rates of the solids, organics or nitrogen, which indicates the robustness of the system to changes in hydraulic and volumetric loadings.

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References

[1] A. Abusam, A. B. Shahalam, M. I. Ahmed and A. Mydlarczyk, "Bench-scale studies to improve the quality of conventional septic tank effluent," Kuwait Institute for Scientific Research, Final Report, KISR 12273, Kuwait, 2014.

[2] APHA, "Standard methods for examination of water and wastewater." American Public Health Association, Washington, D.C., USA, 2012.

[3] P. Beavers, "On-site sewerage facilities – guidelines for the use and disposal of greywater in unsewered areas," Queensland Government Department of Natural Resources and Mines, Brisbane, 2002.

[4] D. B. Bennette, and M. M. Mar, Onsite Wastewater Treatment System, Hogarth House Ltd., Madison, WI, USA, 1999.

[5] H. Brix, "Use of constructed wetlands in water pollution control - historical development, present status and future perspectives," Water Sci. and Technol. vol. 30(8), *pp. 209–223, 1994.*

[6] P. G. Dennis, P. R. Hirsch, S. J. Smith, R. G. Taylor, E. Valsami-Jones, and A. J. Miller, "Linking rhizoplane pH and bacterial density at the microhabitat scale," J. Microbiological Methods, vol. 76, pp. 101–104, 2009.

[7] J. Duggan, M. P. Bates, and C. A. Phillips. "The efficacy of subsurface flow reed bed treatment in the removal of Campylobacter spp., fecal coliforms and Escherichia colifrom poultry litter," Int. J. Environ. Heal. R., vol. 11, pp. 168–80, 2001.

[8] J. Henneck, R. Axler, B. McCarthy, S. Monson-Geerts, S. Heger, J. Anderson, and J. Crosby, "Onsite treatment of

septic tank effluent in Minnesota using SSF constructed wetlands: Performance, costs, and maintenance," In Proceedings of the 9th National Symposium on Individual and Small community Sewage Systems, Fort Worth, TX, pp. 650–662, American Society of Agricultural Engineers, St. Joseph, Michigan, USA, March 11-14, 2001.

[9] J. Garcia, P. Aguirre, R. Mujeriego, Y. Huang, L. Ortiz, J. M. Bayona, "Initial contaminant removal performance factors in horizontal flow reed beds used for treating urban wastewater," Water Res., vol. 38, pp. 1669–1678, 2004.

[10] P. D. Jenssen, T. Krogstad, A. M. Paruch, T. Mæhlum, K. Adam, C. A. Arias, A. Heistad, L. Jonsson, D. Hellström, H. Brix, M. Yli-Halla, L. Vråle, and M. Valv, "Filter bed systems treating domestic wastewater in the Nordic countries-performance and reuse of filter media," Ecol. Eng., *vol.* 36, pp. 1651-1659, 2010.

[11] B. O. Kaplan, Septic Systems Handbook, Second Edition. Chelsea, M. I., USA: Lewis Publishers, 1991.

[12] B.H. Lee, and M. Scholz, "What is the role of Phragmites australis in experimental constructed wetland filters treating urban runoff", Ecological Engineering, vol. 29, pp. 87-95, 2007.

[13] T. Manios, E. I. Stentiford, and P. A. Millner, "The removal of indicator microorganisms from primary treated wastewater in subsurface reed beds using different substrates," Environ. Technol., vol. 23, pp. 767–774, 2002.

[14] S. Singh, N. J. Raju, and G. Sagar, "Process design for decentralized sewage treatment system with total natural resource management," Int. J. Water Res. Environ. Eng. Commun., vol. 3, pp. 233–237, 2011.

[15] US-EPA, Handbook: Septage Treatment and Disposal. Cincinnati, OH, USA: USEPA Publications, 1984.

[16] J. C. L. van Buuren, A. Abusam, G. Zeeman, and Lettinga G. "Primary effluent filtration in small scale installations," Water Sci. and Technol., vol. 35, pp. 195–202, 1999.

[17] J. Vygmazal, "Removal of nutrients in various types of constructed wetlands," Sci. Total Environ., vol. 380, pp. 48–65, 2007.

[18] WHO, Guidelines for the Safe Use of Wastewater, Excreta and Greywater, World Health Organization: Sweden, 2006.