Pathogens Removal in UASB-Septic Tanks and Albireh Oxidation Ditch Wastewater Treatment Plant

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Abstract
The reuse of treated effluent represents a national interest and is considered as an important component of the overall maximization of water resources in Palestine. However, all attempts on wastewater reuse not successful due to many reasons and illegal irrigation practices with partially treated effluent in certain areas still impose serious health hazards and environmental problems. Inadequate wastewater treatment facilities and lack of data on hygienic aspects of treated wastewater hampered the successful implementation of wastewater reuse schemes at the national level. The main objective of this research was to compare pathogens removal in Upflow Anaerobic Sludge Blanket (UASB)-septic tanks and Al-Bireh wastewater treatment plant (AWWTP). The UASB-septic tanks, located at AWWTP, fed continuously with raw municipal wastewater from the aerated grit chamber of AWWTP. The two pilot scale UASB-septic tanks (R1 and R2) were operated at two different hydraulic retention times (HRT) of 2 and 4 days for R1 and R2, respectively. AWWTP, as an extended aeration system with aerobic sludge stabilization, the HRT was about one day. Both raw wastewater and treated effluent were tested for microbial pathogens including indicator bacteria, protozoa and trophozoite using microscopic and specific culture media. Data obtained from this research study on *Fecal coliform, Fecal streptococcus, Salmonellae Shigilla, Balantedium coli, Ascaris lumbrecoudes, Amoeba* cysts, *Giardia* cysts, *Trichuris trichiura*, pathogens in the trophozoite form as *Trichomonas, Strongyloides sterorlasis, Enterobius vermicularis* are presented and discussed. The removal efficacies of R1 and R2 were 15.5% and 15% for *Fecal coliform* and 6.9% and 11% for *Fecal streptococcus*, respectively. While the removal efficacy of the oxidation ditch was 38% for *Fecal coliform* and 16% for *Fecal streptococcus*. Though *Salmonellae* was detected in 30% of analyzed influent samples, it was not detected in any sample of the effluent of both treatment systems. Also, the treated effluent of R1, R2 and oxidation ditch was parasites (cysts or trophoziote) free. The installment of a post treatment stage (disinfecting unit) in the treatment technologies under study is recommended in order to comply with national or future regional guidelines for effluent agricultural reuse or discharge into receiving water bodies.

Keywords: Albireh oxidation ditch, effluent reuse, guidelines, pathogens, waterborne disease, UASB-septic tank

1. Introduction

Wastewater management in Palestine is addressed as a high priority from the perspectives of both environmental protection and resource conservation. In many cases, traditional wastewater treatment technology, such as the aerobic activated sludge processes are inappropriate for the physical and economic characteristic of the small communities (Al-Sa'ed, 2000). Moreover, the existing treatment systems are poorly operated and the effluent is not better than the influent in most of cases, where raw or partially treated wastewater is discharged into Wadis which used for agricultural purposes in regions with a shortage of natural water resources.

Pathogens (indicator) removal in terms of *Fecal coliform, Fecal streptococcus, Salmonellae Shigella, Helminthes eggs, cysts (Amoeba, Giardia)* using technology like UASB-septic tank as anaerobic system and oxidation ditch as aerobic technology in Al-Bireh wastewater treatment plant using domestic wastewater was not investigated under the ambient conditions in Palestine. As indicated in Table 1, municipal wastewater generally contains three major types of human pathogens: bacteria, protozoa, and helminthes (Feachem *et al.*, 1983, Shuval *et al.*, 1986).

Table1: Possible pathogens in the municipal wastewater of Al-Bireh city

Type of pathogen	Species or kind
Bacteria	*Fecal coliform* *Fecal streptococcus* *Salmonella Shigilla*
Protozoa (As cysts)	*Entamoeba histolytica, Entamoeba coli* *Giardia lamblia, Amoeba*
Helminthes	*Ascaris lumbriciodes* *Trichuris trichiura and other ova*
Hookworms	*Strongylodides sterorlasis*
Trophoziote	*Trichomonas* *Enterbeous vermicularis*
Filamentous bacteria	*Nocardia*

According to the World Health Organization (1989) and EPA (2004) guidelines for irrigation specify the maximum concentration of 1 helminthes egg per liter and 10^3 *Fecal coliform* colonies per 100 ml. With regard to total suspended solids (TSS) and coliforms, excerpts of regional standards for the effluent reuse are shown in Table 2.

Table 2: Standards for wastewater treatment effluent in some countries (EPA, 2004)

Parameter	Jordan	Israel	Palestinian*
TSS(mg/l)	200	30	50
Coliform (CFU/100ml)	1,000	250	1000

* Treated effluent for surface water body's discharge or groundwater recharge (PSI, 2003)

Few local studies were conducted to investigate the feasibility of UASB septic tanks followed by natural treatment systems with special focus on design and operational parameters (Fuqaha and Al-Sa`ed, 2004; Aljuaidy *et al.*, 2003). However, there are no Palestinian comprehensive data on pathogens content of treated effluent with respect to *Fecal coliform (FC), Fecal streptococcus, Salmonellae Shigilla, Helminthes eggs (HE), Amoeba cysts, Giardia cysts*, or pathogens in trophozoite form. Hence, the main goal of this research was to investigate the efficacy of UASB-septic tank as pre-treated sewage technology for pathogens removal and compare it with the efficiency of Albireh oxidation ditch.

2. Materials and Methods

2.1 Materials and system description

Two pilot scale UASB-septic tanks, reactor (R1) HRT 2-days, reactor (R2) HRT 4-days with 0.8 m^3 volume for each were operated in parallel, and fed with municipal wastewater from Al-Bireh city. Detailed design and material description can be found in the M.Sc. thesis of Al-Shayah (2005). The reactors were operated at ambient temperature between 30/3/2004 - 15/09/2004. The results for influent of wastewater treatment plant and the effluent from UASB-septic tank reactors R1, R2 and oxidation ditch were tested for the removal efficiency of solids, pathogens (*Fecal coliform, Fecal streptococcus, Salmonellae Shigilla, Helminthes eggs* and *Amoeba and Giardia* cysts).

Albireh oxidation ditch entails a two lain modified activated sludge process and the operational lain is serving at present about 32000 population equivalent (PE) exceeding by far the designed treatment capacity (25000 PE). The organic materials and nutrients (nitrogen and phosphate) are microbial degraded at a low sludge loading rate (≤0.05 kg BOD/kgTSS.d) with simultaneous nitrification and denitrification processes (surface aerated zone = 4900 m^3 and mechanically mixed anoxic zone = 2100 m^3). The excess biosolids (sludge) is aerobically stabilized at an average sludge age of 25 days; thickened by a gravity thickener; filter press dewatered and finally disposed off at Albireh sanitary landfill. The average hydraulic retention time (HRT) in the oxidation ditch is usually about one day (dry weather) and around 20 hours during wet weather conditions (Hithanwi and Al-Sa`ed, 2004).

2.2 Sampling and Analytical Techniques

Ayres and Mara (1996) recommended taking samples two times per week depending on the pathogens type of concern. During this study, 1-2 grab samples were taken per week at 9.00 o'clock A.M. from continuous running system. The sampling program entailed one influent and two effluent samples of the UASB-septic tanks at 2-days HRT (R1) and at 4-days HRT (R2) as well as one sample from the effluent of the oxidation ditch. Parameters like temperature, pH, and turbidity were measured onsite. Taken samples were icebox cooled during transportation (half an hour) before analysis as directed by the APHA (1995).

It has been recommend that, to ensure the collection of all eggs, at least double the theoretical settling time for any container should used. Using centrifugation leads to a good recovery of protozoa, eggs, and larvae. The samples were settled for 1 hour, about 800 ml of the settled sediment were centrifuged for 5 min at 1500 RPM, then one drop was taken from the sediment to the slide and tested using microscope with X10 and X40 (UNRWA, 1999).

The standard methods of APHA (1995) were used for analysis. The pH value was determined by using EC 10 pH meter (HACH), temperature with mercury thermometer, and turbidity was done according to manual procedures described by HACH (1996) as summarized in Table 3.

Table 3: Methods used for the determination of chemical and physical parameter

Parameters	Standard methods 19^{th}
Solids (TS, TSS)	Analytical Methods
pH value	Standard Methods 2540
Turbidity	Standard Methods 4500-H^+ B (onsite)
Temperature	HACH manufacture guideline (onsite)

3 Results and discussion

3.1 Physical parameters

3.1.1 Turbidity

Turbidity in water and wastewater caused by suspended and colloidal matters such as clay, silts, finely divided organic, inorganic matter and other microorganisms. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction through the sample (APHA, 1995).
Correlation of turbidity with the weight or particle number concentration of suspended matter is difficult because the size, shape of the particle affect the light- scattering properties of the suspension. Variation in turbidity values with time is shown in Figure 1.

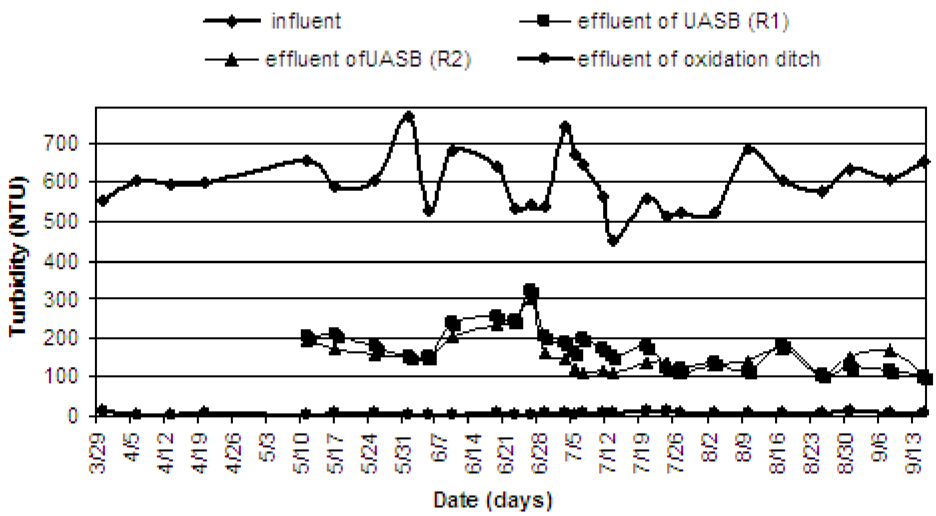

Figure 1: Turbidity values for influent, effluent of R1, R2 and oxidation ditch

Turbidity removal (%) is directly related to TSS removal. The average removal values are shown in Table 4.

Table 4: Turbidity removal (%) for (R1), (R2) and oxidation ditch*

UASB-septic tank		AWWTP oxidation ditch
R1(2-days HRT)	R2(4-days HRT)	
n=25, Av=70.48 St .dv= 9.87	N= 25, Av =73.23 St. dv =8.81	n=18, Av=98.31 St. dv = 0.52

* Data are presented as average value (± Standard deviation)

Turbidity is an important parameter for reuse and agricultural purposes, since further treatment processes depend on the turbidity results for example disinfection by using UV or chlorine the turbidity must be less than 2 NTU according to WHO and EPA guidelines.

3.1.2 Total Suspended Solid (TSS)

Total Suspended Solids (TSS) can lead to the development of sludge deposits and anaerobic condition when poorly treated wastewater is discharged in the aquatic environment. In a reuse context, it has negative impacts on maintenance of irrigation system, especially sprinkler and drip system (Pettygrove *et al.*, 1985). The average TSS values for influent, effluent of R1, R2 and oxidation ditch are shown in Table 5 where the analysis using SPSS $\rho < 0.05$ for R1, R2 and oxidation ditch for the removal of TSS.

Table 5: TSS (mg/l) for influent, effluent from (R1), (R2) and oxidation ditch*

Influent	UASB-septic tank		AWWTP (oxidation ditch)
	R1(2-days HRT)	R2(4-days HRT)	
n= 26, Av= 573.73 St .dv = 131.40	n=20, Av=120.85 St .dv= 15.65	n= 20, Av =113.85 St. dv =17.71	n=19, Av=24.42 St. dv = 22.54

* Data are presented as average value (± Standard deviation)

As shown in Table 5, a wide variation in TSS in the influent and effluent of the oxidation ditch appears in Standard deviation values, while the values for the UASB were stable. The average TSS values (mg/l) for influent, effluent of R1, R2, and oxidation ditch were 574 ± 131, 121 ± 16,114 ± 18 and 25 ± 23, respectively. The influent TSS value was high compared with other TSS values reported by Kerstens (2001) in Jordan (420 mg/l), and Orhon *et al*. (1997) for Egypt rural areas (310 mg/l). This might be due to the difference in people habits and type of sewerage systems. In addition, low water consumption might make Albireh city municipal wastewater of a high strength with reference to TSS parameter.

The effluent TSS values of the two UASB-septic tank and oxidation ditch varied, still acceptable according to CEC (1991) which considers values > 150 mg/l as a desirable quality and lies within the Jordanians` guidelines (200 mg/l). However, the obtained effluent value are not acceptable according to Israelis (30 mg/l) and Palestinian guidelines (150 mg/l) used for irrigation and for groundwater recharge or discharge respectively.

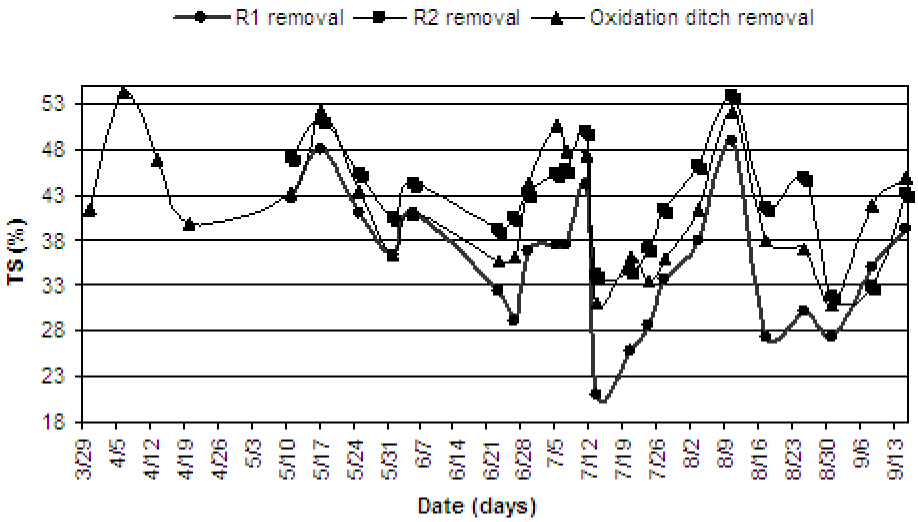

Figure 2: TSS removal from the pilot scale at Al-Bireh, R1, R2 and oxidation ditch

The removal efficiency (Fig. 2) was affected by HRT for R1, R2 HRT as shown from the result of removal efficiency compared with oxidation ditch and according to SPSS analysis $\rho < 0.05$ for R1, R2, and oxidation ditch.

3.2 Bacteriological parameters

3.2.1 *Fecal streptococcus*

The results obtained for *Fecal streptococcus* analysis on influent and effluent of both UASB-septic tanks (R1 and R2) and the oxidation ditch are summarized as average logarithmic values in Table 6.

Table 6: *Fecal streptococcus* as log (FS) for influent, effluent of R1, R2 and oxidation ditch *

Influent	UASB-septic tank		AWWTP (oxidation ditch)
	R1(2-days HRT)	R2(4-days HRT)	
n= 14, Av= 6.293 St .dv = 0.636	n=16, Av=5.757 St .dv= 0.510	n= 15, Av =5.467 St. dv =0.786	n=13, Av=5.095 St. dv = 0.642

* Data are presented as average value (± Standard deviation)

Fecal streptococcus is considered as a pathogenic indicator for reuse and agricultural purposes, as *Fecal streptococcus* causes infection on the mouth area and throat and is a common flora in the stomach and intestines. As illustrated in Figure 3, the removal efficiency for *FS* varied, since the standard deviation is greater than values which have two possible interpretations; (1) the FS values of the effluent of R1, R2 and oxidation ditch are greater than the influent values and (2) *Streptococcus* survives for a longer time, where cell duplication and accumulation might occur.

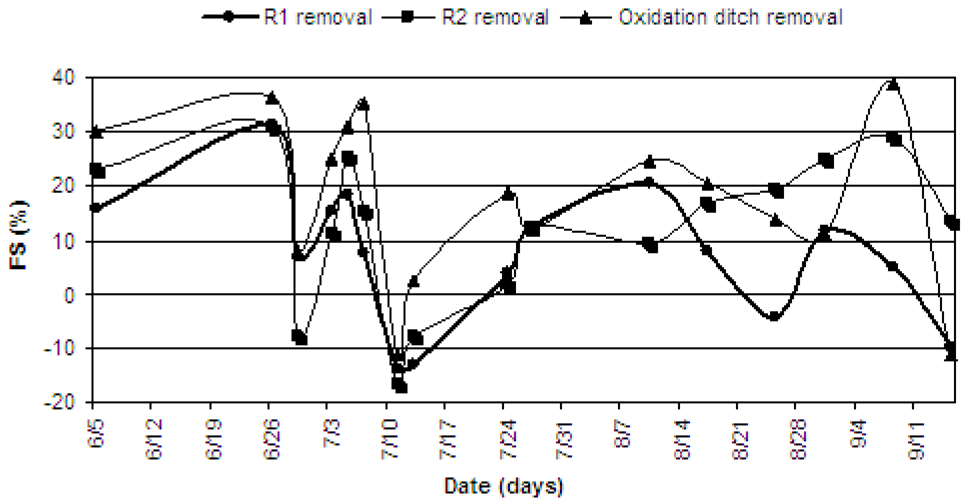

Figure 3: *Fecal streptococcus* removals for R1, R2 and oxidation ditch

3.2.2 *Fecal coliform*

There are variations in *Fecal coliform* in the influent, while treated with two processes using anaerobic (UASB)-septic tank, and aerobic system using oxidation ditch. The average values for FC in logarithmic form are shown in Figure 4. *Fecal coliform* results are plotted against time in logarithmic format, where the significance results using SPSS were $\rho > 0.05$ for R1 and R2, while Albireh oxidation ditch was $\rho < 0.05$.

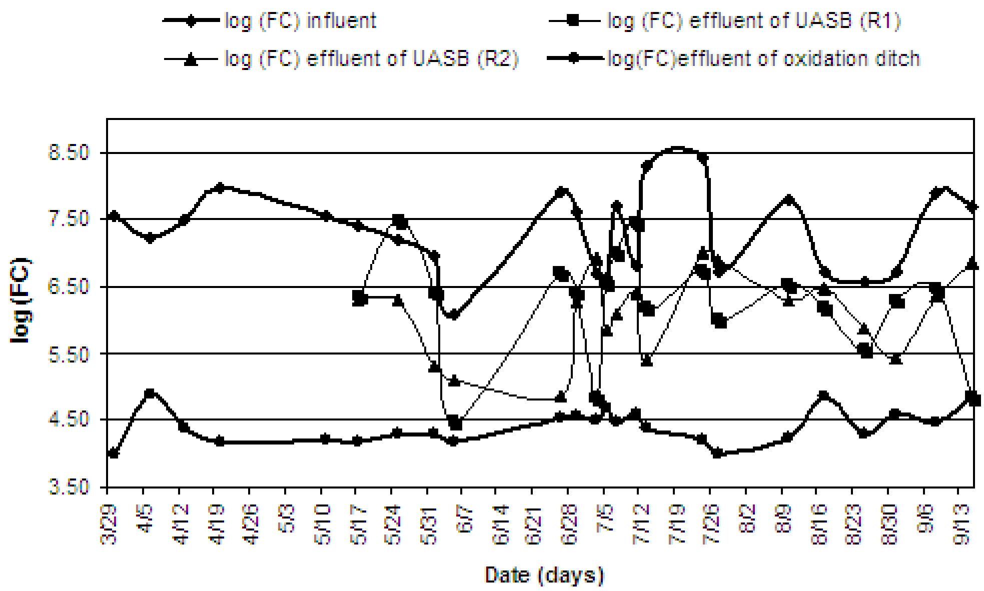

Figure 4: *Fecal coliform* result for influent, effluent of the R1, R2 and oxidation ditch

The removal efficacy (%) for FC by the UASB-septic tanks were lower than the oxidation ditch, since the removal of FC depends upon the technology used where the removal increases under aerobic conditions. The behavior of *Fecal coliform* and *Fecal streptococcus* was the same in terms of concentration and removal values, but the difference between them was the survival time, as FS survives the environmental condition over a long time compared with FC, which is more sensitive to the environmental conditions change. Moreover, the content of both microorganisms in the effluent exceeded the influent values as of accumulation in the reactors, hence affected the removal values (negative values) as shown in Figure 5.

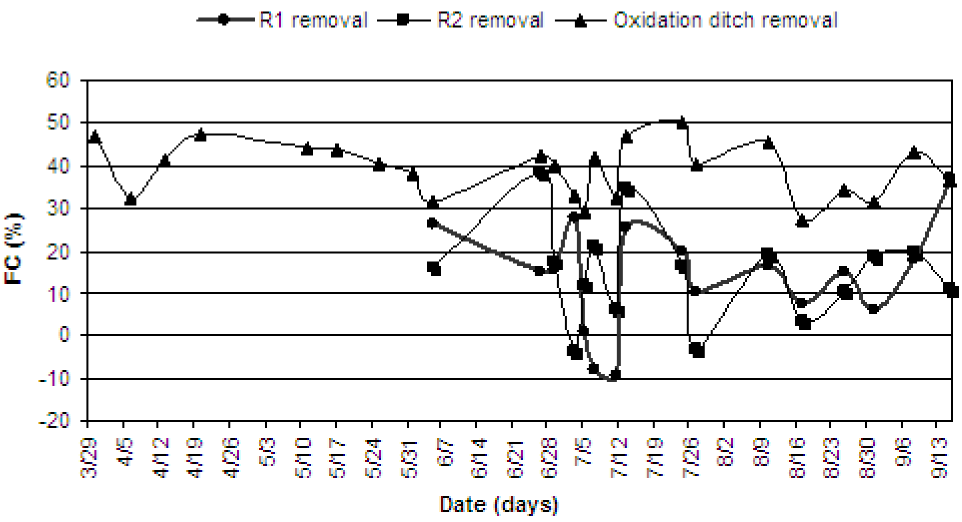

Figure 5: *Fecal coliform* removals from R1, R2 and oxidation ditch

3.2.3 *Salmonellae*

The result obtained from *Salmonellae* analysis revealed its presence in only 30% of the total samples (13 samples) analyzed for the influent during the whole study period. However the treated effluent of both pilot scale (R1 and R2) and Albireh oxidation ditch (AWWTP) were free of *Salmonellae*. The removal rate of *Salmonellae* was less significant than that of *Fecal coliform* or *Fecal streptococcus* in the same reactor, as *Salmonellae* bacteria is less resistance compared to *Fecal coliform* and *Fecal streptococcus*. This complies with our results as R1, R2 and oxidation ditch were able to remove the *Salmonellae* completely.

3.3 Pathogens in Al-Bireh oxidation ditch influent

A summary of all potential pathogens found during the study period (190 days) are shown in Figure 6. However, the presence of these pathogens was not detected on a regular frequency, where some of them were detected 2 to 5 times only. It is worth mentioning that not all of the pathogens detected in the influent were found in the effluent of the investigated systems. Moreover, *Ascaris lumbriciodes* were absent and not detected during the analysis, this is an indication that Ascarisis infection is not common among the inhabitants of Albireh city including other communities connected to Albireh wastewater treatment plant.

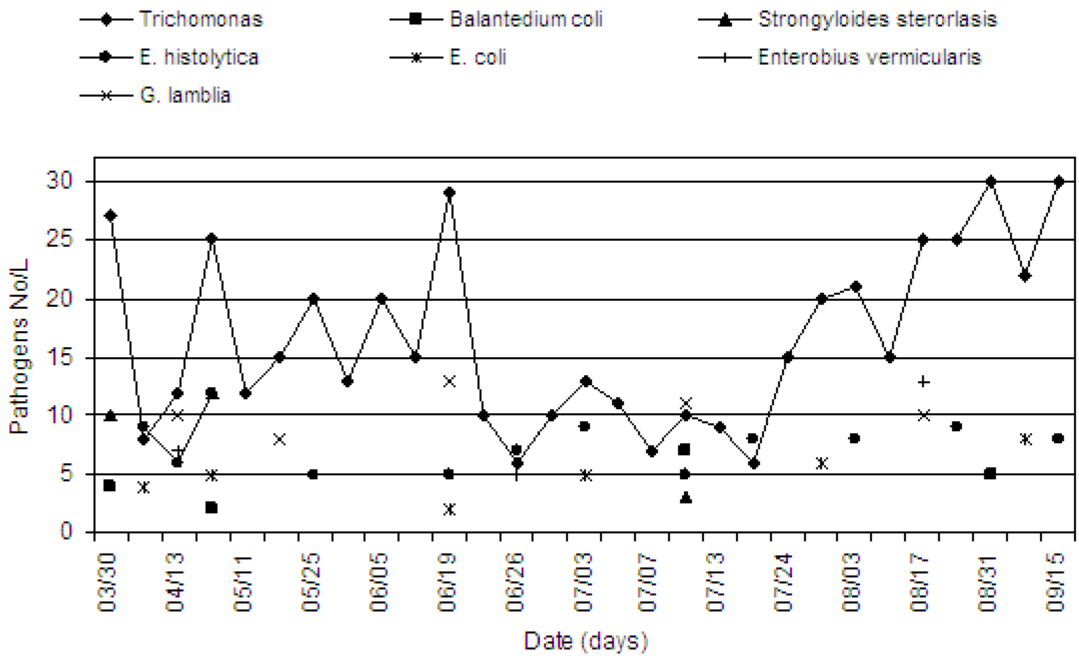

Figure 6: Pathogens in the influent of UASB pilot scale at Albireh oxidation ditch site

4. Conclusions and Recommendations

4.1 Conclusions

- No helminthes eggs were detected in the influent of Al-Bireh AWWTP, as the *Ascaris lumbriciodes* was not found during the analysis period (April - September). However, in terms of parasitological analysis for the influent of AWWTP, the result revealed that the presence of *Entamoeba histolytica*, *Entamoeba coli*, *Gairdia lamblia*, *Trichuris trichiura*, *Strongyloides stercoralis*, *Enterobius vermicularis*, *Trichomonas*, and *Balantidium coli* indicating that the wastewater must be treated before discharged into the Wadis or reused for irrigation.

- The effluent from R1, R2 and oxidation ditch were free from the mentioned pathogens except for *Trichomonas* from the effluent of R1 and R2 where enrichment for its growth was noticed. The *Fecal coliform (FC), Fecal streptococcus (FS) and Salmonella*e varied influent of AWWTP as log (*FC*) and log (*FS*) and were 7.325, 6.293, respectively, where *Salmonellae* was confirmed three time during the analysis. Likewise, the removal efficiency for *Fecal coliform* in R1, R2 and oxidation ditch were 16%, 15%, and 39%, respectively. Moreover, the removal efficiency for *Fecal streptococcus* using R1, R2 and oxidation ditch were 7%, 11% and 16%, respectively. Finally, the removal efficiency for *Salmonellae* was 100% since the effluent from R1, R2 and oxidation ditch are free from *Salmonellae*.

- The average value for turbidity in the influent of R1, R2 and oxidation ditch was 598, 174, 158 and 9 NTU, respectively. Moreover, the removal efficiency for R1, R2 and oxidation ditch was 71%, 73% and 98%. Moreover, ($\rho < 0.05$) which is significant for R1, R2 and oxidation ditch. High NTU values might impair UV- disinfecting units. Moreover, the value of less than 2 NTU is considered to be appropriate water for recycled water, as this permits effective disinfection.

4.2 Recommendations

As this study was conducted during summer period, further investigations on UASB-septic tank efficacy for the removal of pathogens during winter months is highly recommended. Further studies for on adequate post-treatment of the UASB effluent is crucial to reduce the turbidity and TSS that directly related to the pathogens. Health risk studies on the types of pathogens caused by direct use of domestic wastewater in some rural areas should be carried out especially where hygienic services are poor and more infected people are expected. Finally, further analysis on pathogens identification and characterization should be made as only *Salmonella*e were identified during this study. To minimize public health risks and improve the environment of receiving water bodies, disinfecting units must be installed if reuse of treated effluent is envisaged. Finally, raise awareness, train operators and farmers on possible waterborne diseases are protective measures if untreated or partially treated effluent is used for agricultural irrigation, irrespective of being planned or unplanned reuse.

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