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Domestic Septage Characteristics and Cotreatment Impacts on Albireh Wastewater Treatment Plant Efficiency

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ABSTRACT

This paper presents and discusses the potential impacts of domestic septage on Albireh Wastewater Treatment Plant (AWWTP). Using ANAwin, a German software package for sewage works design, the results obtained from septage lab analysis were utilized to simulate the impacts of daily loads on the oxidation ditch design parameters (sludge age, biosolids production rate, specific oxygen uptake rate), treatment efficiency and annual running costs. The septage received at AWWTP revealed a heterogeneous origin, with a variable volume (115-176 m^3/d) and reached an average daily volume of 153 m^3. The results of the investigation lead to a specific septage generation rate in Albireh city of about 1.2 m^3 per capita per annum. The ANAwin software package confirmed the negative impacts of septage cotreatment on AWWTP unit operations design and deterioration of its effluent quality. However, further investigations are needed to find other septage disposal options and simulation tools to sustain domestic septage management and to protect both public health and environmental resources.

KEYWORDS: Albireh wastewater treatment plant, impact assessment, operational design parameters, oxidation ditch, septage quality, septage cotreatment, treatment efficiency.

1. INTRODUCTION

Wastewater management in Palestine has been a neglected issue over the past years. However, little technical data are recently made on urban wastewater characteristics discharged from certain urban cities in the West Bank (Tahboub, 1999; Mahmoud *et al.*, 2003). The effectiveness of the existing urban sewage collection and treatment facilities is usually constrained by limited treatment capacity, failure in system design, aging unit operations, insufficient operation and maintenance, and by the lack of experienced operational staff (Al-Sa`ed and Mubarak, 2006).

Moreover, raw or partially treated municipal wastewater is discharged into seasonal wadis, where in some cases agricultural irrigation is practiced and thus posing serious environmental and public health risks (Al Sa'ed, 2005).

The existing situation of the sewerage system is extremely critical. Approximately, 65% of houses in the main cities are connected to the sewerage system (MOPIC, 1998). According to Al-Sa`ed (2005), about 17% of collected urban wastewater by central networks is being either fully or partially treated in central sewage works. Almost 64.2% of the households in the West Bank have cesspool sanitation and almost 0.7% without any sanitation system. While the rest households (20%) with no central sewerage networks disposed of wastewater into percolating pits (PCBS, 2002). The septic tanks are emptied by the private sector; mainly through individual vacuum trucks and disposed of, either in nearby located sewage treatment plants, if any; and most likely they are overloaded, or discharged directly into small wadi beds (seasonal water courses).

There are no regulations in Palestine that govern septage management and the newly issued Palestinian Environmental Law lacks regulations for effluent quality standards for treated effluent reuse or biosolids utilization. Existing municipal by-laws on safe septage disposal are weak and lack enforcement power due to prevailing political situation and informal socio-cultural issues.

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However, for the purpose of this research, the code of the Federal Regulations, "Part 503" issued by U.S Environmental Protection Agency (USEPA, 1993), was adopted. Domestic septage is defined by the code of Federal Regulations in 40 CFR Part 503, section F as follows: "Domestic septage: either liquid or solid material removed from a septic tank, cesspool, portable toilet, marine sanitation device or similar treatment works that receive only domestic sewage, the latter is defined as waste and wastewater from humans and household operations".

According to US Environmental Protection Agency (USEPA, 1999), well-designed septic tanks will usually retain 60 to 70% of the solids, oil, and grease that enter it. The scum accumulates on top and the sludge settles at the bottom, comprising 20% to 50% of the total septic tank volume when pumped. Published literature (ATV-A 123, 1985, USEPA, 1994) indicated that septage quality could strongly differ from place to place as many factors influence the physical-chemical characteristics of septage. In the German working sheet ATV-A 123 (ATV-A 123, 1985), safety factors assumed for a safe co-treatment of septage in urban sewage works are difficult to interpret and form no guarantee for a stable nitrogen removal process. To date, few attempts were made on proper septage treatment, either in combination with wastewater or separately. Treatment options used include waste stabilization ponds, composting with municipal organic refuse, activated sludge systems, anaerobic pre-treatment and constructed wetlands (ATV-A 123, 1985; USEPA, 1994; Strauss *et al.,* 1997; Ingallinella *et al.,* 2002; Nassar *et al.,* 2006). Investigating the efficiency of constructed wetlands followed by waste stabilization ponds, Koné and Strauss (2004) found high ammonia content in septage inhibited both algal and plant growth in pond systems and constructed wetlands. Recently, Nassar *et al.* (2006) reported that constructed reed beds, which were operated and monitored for three years, were economically more attractive for municipal sludge drying in Gaza Strip than traditional sludge drying beds.

Despite the fact that most Palestinian conventional wastewater treatment plants generally accept septage delivered by vacuum trucks, little is known about the main reasons behind malfunctioning of the treatment processes. Since the establishment of Albireh WWTP in 2000, sludge bulking-foaming associated with deterioration in the effluent quality has been annually reported (Albireh Municipality, 2003). Caused by sludge bulking-foaming, high nitrogen and suspended solids in the treated effluent render its suitability for the planned agricultural irrigation. Several attempts were made to understand the reasons behind this annual phenomenon, however, with limited success.

This study was conducted to investigate the impacts of domestic septage co-treatment at Albireh WWTP and introduce protective measures to improve operation. The potential implications of septage co-treatment on structural and unit operation design parameters based on septage volume and characteristics, energy demand and the estimated annual costs associated with receiving septage at Albireh sewage works will be presented and discussed. It provides also reliable information for decisions to proceed with the next step, which would include a detailed technical study including unit process simulation at pilot scale to evaluate the impact of septage on other biological processes including poor sludge settling properties in the current oxidation ditches.

2. MATERIALS AND METHODS

Study Area and System Description

Ramallah and Albireh governorate, located in the central region of the West Bank, is considered as one of the most important administrative and economic centers in Palestine. Albireh Wastewater Treatment Plant (AWWTP) is located approximately at a distance of 1.5 km down stream the Wadi Al-Ein to the east of Albireh city. Fig. (1) illustrates an overview of the AWWTP showing the first treatment train, which consists of two oxidation ditches; each of which has the design capacity to serve about 25,000 inhabitants (Albireh Municipality, 1998). Albireh city has a central public sewer network of a modified combined system, where part of the collected stormwater is mechanically treated at AWWTP site in the stormwater tank, which discharges the Combined Sewer Overflow (CSO) into Wadi Al-Ain. Though temporal storage of septage in the stormwater tank is not a common pre-treatment practice (Fig. 1), however, it can facilitate septage batch mode co-treatment especially during night period under controlled pumping intervals.

AWWTP received an average daily flow of 3038 m^3/d (monthly average during the time of this study, 2002). The municipal sewage in Albireh city is mainly of domestic origin with small industrial enterprises discharging about 7% of the total daily dry weather flow into the public sewer networks after proper pre-treatment stages. No industrial septage is being treated at AWWTP, Albireh city as recommended by an Industrial Cadastre, and incorporated in the draft "Sewerage By-Law" where the municipality regularly monitors all industrial discharges and comprises no harmful impacts on the treatment process (Meierjohan, 1999). The biological process includes a low loaded activated sludge system (oxidation ditch), which besides the removal of carbonaceous compounds also achieves a reduction in the nitrogen load through biological nitrification and denitrification processes.

Sampling Program and Analytical Methods

Samples were collected from different septage haulers delivering septage from different places in Albireh at different times. Composite samples were taken during the discharge of the truck content after which the material has been mixed; three individual samples were collected at the beginning, middle and at the end of the truck discharge to guarantee representative composite samples. Because of the wide variations in septage characteristics, a large number of samples were taken from truckloads (Table 1) over a period of four months (March-June, 2003). All samples were preserved during the sampling time by storing them in special cool boxes at 4°C.

Initially, the actual records of septage quantities were taken from AWWTP daily monitoring records, and later the data were verified by a field questionnaire distributed at local septage haulers during the study period. Data on AWWTP performance were utilized from the monthly reports for the calculation of dry weather flow, pollution loads and septage quantity (Albireh Municipality, 2003).

Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD_5), Total Solids (TS), Total Suspended Solids (TSS), Volatile Suspended Solids (VSS), Total Kjeldahl Nitrogen (TKN), ammonium (NH_4-N), sulfate (SO_4), hydrogen sulfide (H_2S), ortho-P, temperature, fat and grease were all determined according to *Standard Methods* (APHA, 1995). Finally, the temperature and pH were measured onsite (HACH) while the rest of analysis was conducted later at the Water Engineering Lab of Birzeit University.

Use of ANAwin Software Package for Septage Impact

This German Software package enables the layout of biological wastewater treatment plants according to ATV-guidelines, ANAwin, Version 2, 1996 (ANAwin, 1996). The ATV-A 131 (ATV-A 131, 1991), a German working sheet forms the basis of this software package to design and re-check the layout of activated sludge systems. It is worth mentioning, that AWWTP was designed according to the ATV-A131, which is considered as a German Standard. Details about the usage of this software package can be found in the users' Manual (ANAwin, 1996). ANAwin was used to simulate the impact of septage increment (%) on the unit operation design of the aeration tank including structural and biological design parameters at variable temperatures (13°C and 20°C; winter and summer periods). Ongoing research will utilize other software packages and apply advanced molecular techniques to assess the septage impacts on nitrification-denitrification processes and sludge foaming/bulking in AWWTP.

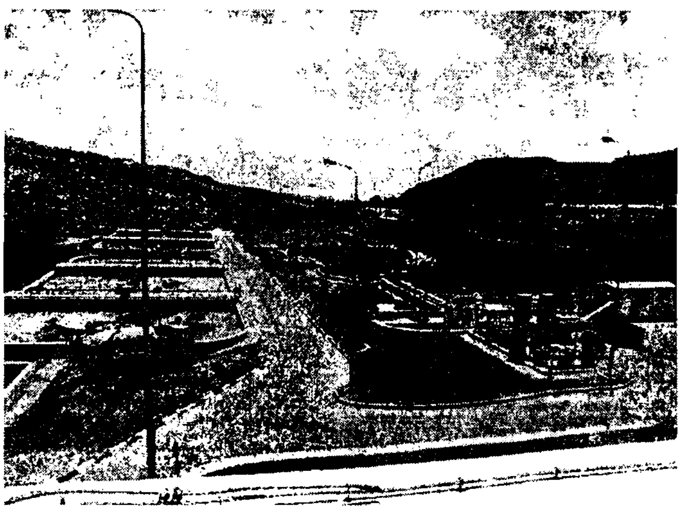

Fig. 1. Overview or Albireh Wastewater Treatment Plant (AWWTP).

Table 1. Comparison of Albireh domestic septage wastewater with published literature.

Albireh Septage (This study, 2003)					Wastewater*	Septage[1]	Septage[2]	Septage[3]
Parameters	No.	Range	Average	STD	Average	Average	Average	Range
pH	32	6.9-7.5	7.2	± 0.2	7.3	8	8.1	1.5-12.6
BOD	20	165-1107	434	± 258	495	303	10,000	440-78,600
COD	25	181-9315	1243	± 2259	1400	668	28,200	1,500-703,000
TKN	20	9-525	150	± 168	104	215		66-1,060
NH_4-N	32	5-155	91	± 48	80	152	1500	3-116
PO_4-P	24	5.4-24.2	13	± 6	13	39		
SO_4	32	33-738	128	± 146	138	132		
H_2S	28	52-79	67	± 7		95		
TS	32	328-23,028	3095	± 5663			30,450	1132-130,475
TSS	20	76-13,444	3068	± 4377	736	10,664	14,600	310-93,378
VSS	10	212-11,556	2706	± 3687	617	5105	10,366	353-71,402
Oil & grease	14	264-82,320	22,442	± 29,075				208-23,368
COD/BOD			2.86		2.83	2.20	2.82	
TSS/VSS			0.88		0.84	0.48	0.71	

* According to Mahmoud *et al.* (2003); [1] Ingallinella *et al.* (2002); [2] Cofie *et al.* (2006); [3] USEPA (1994).

3. RESULTS AND DISCUSSION

Septage Characteristics

The results presented in Table (1) illustrate the septage characteristics of the study area. Comparing the obtained results with published literature, Table (1) revealed that the US Environmental Protection Agency (USEPA, 1994; 1999) values of septage parameters are higher than the values of Albireh septage parameters. This might be due to different reasons such as septic tank design, the pump out interval, life style and hygiene approaches. In addition, separate discharge of toilet papers in plastic containers and the partial anaerobic processes as of short hydraulic retention time in the cesspools may lead to a low strength septage in developing countries.

By comparing the characteristics of domestic septage with domestic wastewater (Table 1), in many respects, the constituents of Albireh septage are similar to those of municipal wastewater. Table (1) gives also almost similar ratios of COD/BOD and VSS/TSS for septage and wastewater of Albireh city. The reason behind this is the short hydraulic retention time in the septic tanks of most urban dwellings and no industrial septage is received. However, the great difference in total solids between septage and sewage calls for adequate pre-treat of the septage before its discharge into conventional treatment. Due to different sampling points and methods of analysis between septage (truck loads; unfiltered samples) and wastewater (after aerated grit chamber and filtered samples) lead to higher values for grease and oil contents but lower COD concentrations compared to municipal sewage. The VSS/TSS ratio of 0.88 for septage is almost similar to that for sewage as reported by Mahmoud *et al.* (2003).

Ingallinella *et al.* (2002) reported a small ratio VSS/TSS of a week domestic septage (0.48) treated in waste stabilization ponds indicated that solids contained low organic portion compared to high percentage (80%) of organic solids in the sewage. However, the average COD/BOD ratio of Albireh septage is within the range (2.2-4) for the faecal sludge-septage mixture (Cofie *et al.*, 2006). This indicates the high portion of biodegradable organic matter in the septage delivered at Albireh wastewater treatment plant.

As a design rule, all septic tanks must be lined not only at sidewalls but also at the bottom to prevent leakage, however, in some cases this is not applied, where septage infiltrates in groundwater and biosolids accumulation prevailed by time. Finally, the wide range in septage characteristics (Table 1) gives clear evidence that annually emptied septic tanks lead to a high strength septage especially in households of rural and refugee camps areas.

Quantity of Domestic Septage

The results of the investigation lead to an annual septage generation rate in Albireh city of about 1.2 m^3 per capita (44.5 million cubic meter), which is in conformity with those published data in Germany (ATV, 1985). The annual volume of septage in Palestine was calculated by the multiplication of the annual specific generation rate of un-served population. These results were built on the assumption that 5.4 persons per household and each cesspool served one household. In reality, one cesspool served one building in most cases, and each building consists of 10 to 12 households on average. Furthermore, the cesspool size and pumpage pattern are variable. Lower specific annual production rates were published by EPA (USEPA, 1994; 1999), where estimates of annual septage produced by US onsite systems ranged between 0.4-0.6 m^3 per capita.

Population Equivalent of Septage Received at AWWTP

Based on the daily pollution load (COD) of Albireh wastewater, the Population Equivalent (PE) served by AWWTP was calculated using the German working sheet ATV-A 131 (ATV, 1991). The working sheet specifies the daily specific pollution loads; 120 g/PE (COD), 60 g/PE (BOD), 12 g/PE (TKN), 70 g/PE (TSS) and 3 g/PE (PO_4-P). The calculated PE served by AWWTP was 32,385 PE, which is only 88% of the total population in Albireh city (36,737 inhabitants). About 12% (4,352 PE) of the total population are not served by a central sewerage system and they do not use a cesspool. But the estimated number of people, which are not connected to sewerage system, is 17,280 PE; the difference (12,928 PE) came from Ramallah city or of industrial origin. Using the daily average of septage quantity (153 m^3) received at AWWTP; the PE of pollution loads caused by septage co-treatment was calculated. Population equivalent from the average values of pollution loads (BOD, COD and PO_4) of septage revealed about 1,417 PE, while the maximum PE value was found to be 41,676 PE. These variations in PE estimates stem from variable origin of septage being from urban dwellings or coming from rural households.

Power Consumption

Receiving amounts of septage at the treatment plant beyond its design capacity implies higher power consumption rates. For this purpose, the data of daily reports at the sewage works (Albireh Municipality, 2003) were utilized. The average power consumption of the treatment plant during the study period (March-June 2003) was calculated and summarized in Table (2).

Based on the daily wastewater (WW) flow rates obtained from AWWTP monthly reports, the average daily power consumption including the unaccounted for energy was 2849 kWh leading to a specific energy demand of 0.67 kWh/kg COD. Table (2) shows variable specific energy consumption rates (kWh/kg COD); this might be due to variation in monthly organic and nitrogen pollution loads received. This implied more oxygen supply to cope with increased COD and nitrogenous oxygen demand. Also, variable hydraulic loading rates might cause increased energy consumption for lifting wastewater and recycling return sludge flows.

As explained above, septage cot-treatment exerted additional energy consumption due to additional oxygen demand in the oxidation ditches for the biological processes (hetertrophs and autotrophs). Bearing this in mind, the daily average energy costs for septage treatment was calculated at US$ 410 per day, while the cost for power consumption was around US$ 3694 per month for the maximum amount received at the sewage works. Taking the volume of 15 m^3 for conventional septage suction trucks, the average cost for power consumption was calculated at a US$ 0.09 with a maximum of US$ 0.78 per m^3 septage (strong septage). Higher costs (Turcotte *et al.,* 2003) for septage co-treatment originating outside the City of Ottawa at Pickard WWTP in east Ottawa were projected to rise from the current US$ 9 to US$ 25/m^3. However, the authors are aware of the difficulties of utilizing septage costs published in the literature, as our calculated costs did not include the annual capital and running costs for pumping, hauling and co-treatment of the domestic septage received at AWWTP. Recently, more cost effective disposal methods were reported by Nassar *et al.* (2006), where they reported that the cost of sludge treatment using reed beds in Gaza Strip was 0.60 US$/$m^3$ compared with 1.01 US$/$m^3$ for treatment using conventional drying beds. However, the capital costs for larger aerial demand of such natural disposal options have to be taken into consideration.

Septage Impact on Unit Operations Design

Adequate technical design (volume, aeration capacity, sludge yield) of the biological unit (aeration tanks) will achieve an effective treatment for BOD and nutrients and reduce process troubleshooting. The German Software Package (ANAwin, 1996) based on the German working design sheet (ATV-A 131, 1990) was used to simulate the impact of septage increment percentage (%) on the unit operation design of the aeration tank at variable temperatures (13°C and 20°C; winter and summer periods). According to the working sheet, a sludge age of 25 days was selected to achieve aerobic sludge stabilization. The results are tabulated in Table (3) and depicted in Figures (2) and (3) for the summer period. Plotting septage increment (0-30%) in both primary x-axis and secondary y-axis (Figs. (2-5)) served only for more clarification.

As indicated in Table (3), the design capacity of the first train in operation is 25,000 inhabitants including pollution load of septage received, any further increment in septage volume will lead to additional volume to cope with added pollution loads. Figure (2) and (3) illustrate that 5-30% of septage addition implies overloading of the system and lead to 7-51% additional volume in the aeration tank. Similarly, an increase in the aeration capacity (8-49%) must be achieved to cope with additional loads of both organic carbon and nitrogen; otherwise deficient oxygenation will lead to build-up of nitrite, less nitrification capacity and might cause sludge foaming/bulking.

By comparing the results for the two temperatures, 13°C and 20°C, almost the same result for oxygen input, but higher volume values were obtained for the aeration tank; nitrification and denitrification zones at 13°C. Knowing the variations in aerobic and anoxic zones (V_{DN}/V_{NN}) in the oxidation ditch, is crucial variable to adjust and monitor the aeration capacity provided for the nitrification and denitrification zones, especially in winter periods to achieve a stable nitrogen removal at low temperatures.

Table 2. Average energy consumption and costs for septage cotreatment at AWWTP.

Study Year 2003	Power consumption (kWh/day)	kg COD/day Wastewater	(kWh/kg COD)	Power costs (US$/month)
March	1813	4050	0.45	15714
April	2561	4477	0.57	16811
May	3540	4319	0.82	16758
June	3481	4177	0.83	16207
Average value WW	2849	4256	0.67	16372
Average value septage	106	158		410
Maximum value septage	952	1425		3694

Table 3. Septage impact on unit operation design of the aeration tank at 20°C (summer).

Item	DWF[1] (m3/d)	Capacity (PE)	Septage increase (%)	BOD_5 Load (kg/d)	V_{AT}[2] (m^3)	V_{DN}[3] (m^3)	V_{NN}[4] (m^3)	Excess Sludge (kg/d)	Oxygen input OC[5]
Without septage	2885	23800	0	1428	8048	3967	4081	1288	199
With septage	3038	25567	5	1534	8647	4282	4365	1388	214
	3046	26417	10	1585	8939	4453	4486	1430	221
	3053	28633	15	1718	9691	4903	4788	1551	239
	3061	31000	20	1860	10500	5385	5115	1680	258
	3069	33433	25	2006	11328	5882	5446	1812	278
	3076	35850	30	2151	12151	6348	5803	1944	297

[1]DWF: Dry weather flow; [2]V_{AT}: Volume of aeration tank [3]V_{DN}: Volume of denitrification zone; [4]V_{NN}: Volume of nitrification zone; [5]OC: Oxygen input (kg O_2/h).

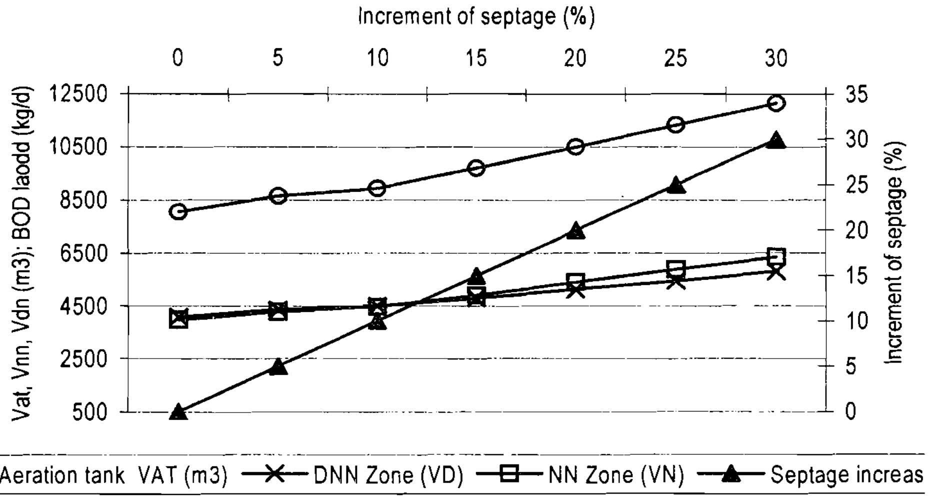

Fig. 2. Impact of septage treatment on volumes of aeration tank, VN and VD zones at 20°C.

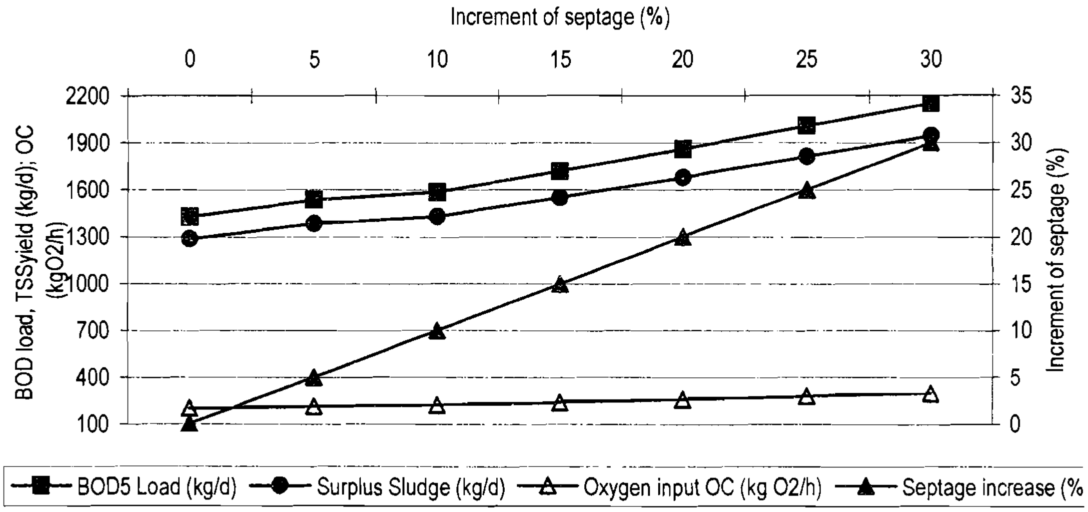

Fig. 3. Impact of septage cotreatment on aeration capacity and sludge yield at 20°C.

Table 4. Septage impact on unit operation design of the aeration tank at 13°C (winter).

Item	DWF[1] (m^3/d)	Capacity (PE)	Septage Increase (%)	BOD_5 Load (kg/d)	V_{AT}[2] (m^3)	V_{DN}[3] (m^3)	V_{NN}[4] (m^3)	Excess Sludge (kg/d)	Oxygen input OC[5]
Without septage	2885	23800	0	1428	8549	3997	4552	1368	192
With septage	3038	25567	5	1534	9185	4315	4870	1470	206
	3046	26417	10	1585	9495	4489	5006	1519	212
	3053	28633	15	1718	10294	4961	5333	1647	230
	3061	31000	20	1860	11152	5434	5718	1784	249
	3069	33433	25	2006	12032	5937	6095	1925	268
	3076	35850	30	2151	12906	6410	6496	2065	286

[1]DWF: Dry weather flow; [2]V_{AT}: Volume of aeration tank; [3]V_{DN}: Volume of denitrification zone; [4]V_{NN}: Volume of nitrification zone; [5]OC: Oxygen input (kg O_2/h).

According to the German working sheet ATV-A 131 (ATV, 1991), sufficient oxygenation capacity is necessary for a successful nitrogen removal process during storm weather flows (13 oC design parameter). During winter months (13°C), the impact of septage cotreatment on unit operations is illustrated in Table (4), Figures (4) and (5).

Similar to dry weather period, Table (4), shows that an increment range (5-30%) in septage received at Albireh sewage works resulted in an increase in the aeration tank volume and oxygenation capacity (7-51% and 7-49% respectively). In addition, fixed ratios of variable volumes for nitrification and denitrification and different aeration tank volumes were obtained.

The results depicted in Figures (3) and (4) show that during winter period the same constructional changes in the aeration tank volume must be attained to cope with prescribed national standards. Similar findings were reported by Voigtländer *et al.* (1996) where most planners forgot to include septage loads during the design phase, which later cause process failure especially in biological unit operations of most German sewage works.

Figure (6) illustrates the performance of Albireh sewage works during the first six months including the study period. For this analysis, it is assumed that the existing capacity of the first treatment lain has been exceeded by the daily pollution load of the served population and the septage co-treatment exacerbated the deterioration of the effluent quality. The total organic pollution load must remain under the design daily sludge lading rate (F:M = 0.05 kgBOD/kgTS) and is thus the limiting design parameter in analyzing annual unit operations.

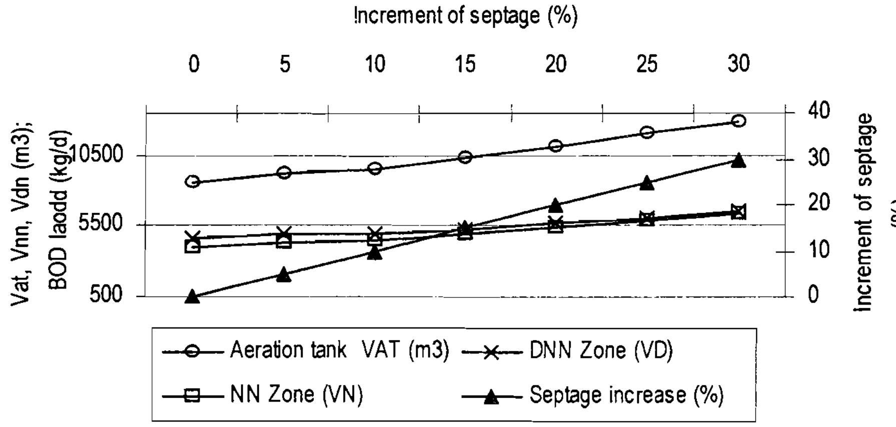

Fig. 4. Septage impact on volumes of aeration tank, VN and VD zones at 13°C.

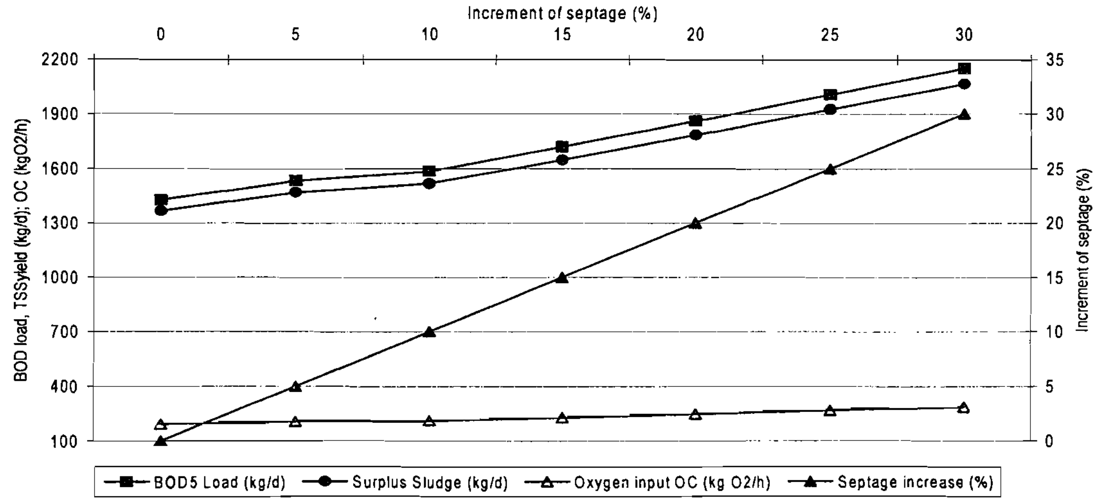

Fig. 5. Septage impact on oxygen input and sludge yield at AWWTP at 13°C.

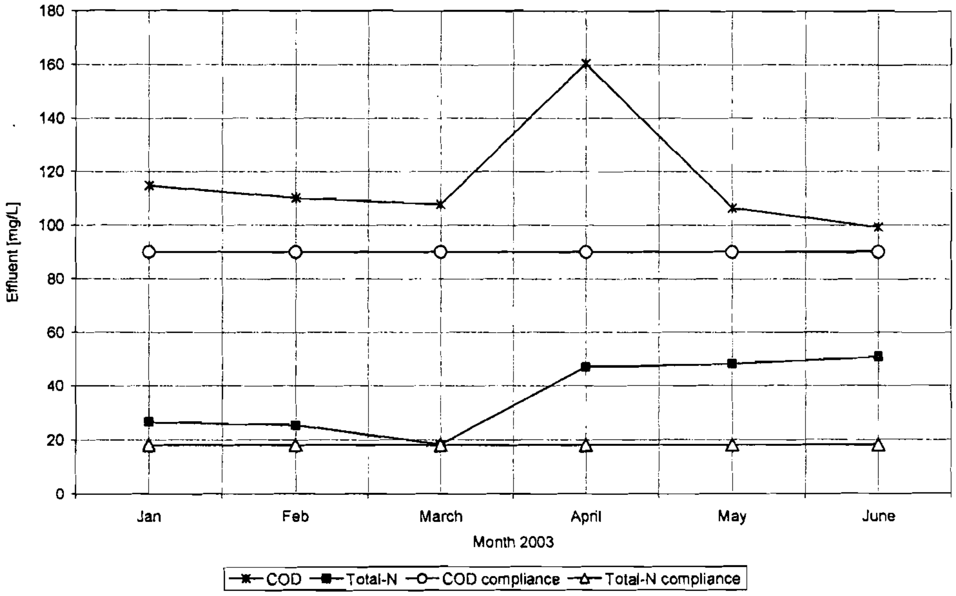

Fig. 6. Effluent COD and total nitrogen concentration compared with compliance guidelines.

As illustrated in Figure (6), should Albireh sewage works continue to achieve adequate COD and total nitrogen in the treated effluent (90 and 18 mg/l, respectively) then ongoing compliance with the criteria in the certificate of approval is unlikely. The existing situation of AWWTP revealed an overloaded capacity (32,385 PE) and improvement can only be achieved if the second oxidation ditch is put into operation. COD and nitrogen compliance is a monthly issue and removal rates of 90% and 80% have been achieved to comply with national prescribed effluent standards (TSS= 20; COD= 90; Tot. N= 18 mg/l).

Continuous co-treatment of septage will dramatically affect the issue of non-compliance related to COD and nitrogen. These results show that the German standards (ATV-A 123, 1985) beside assuming safety factors with respect to the capacity of municipal sewage treatment plants (capacity 10,000 PE and above) to receive and handle septage, exact design data and the potential impacts of septage loading rates on the efficiency and design parameters of municipal sewage works are crucial. Even for under-loaded wastewater treatment plants, the maximum septage load that a WWTP can handle without affecting its treatment efficiency should be also well known (Voigtländer and Schwerdtfeger, 1998).

4. CONCLUSIONS

The values of septage parameters in Albireh are lower than the values of USEPA septage parameters, as the source of septage in Albireh is from central unsewered urban dwellings, where a short hydraulic retention time prevailed in most septic tanks leading to weak anaerobic processes. Hence, the liquid material (supernatant) pumped from the cesspools is septage water and not a real domestic septage with almost similar municipal wastewater characteristics. Septage generation rate in Albireh city is approximately 1.2 m^3 per capita per year. Based on this, the annual volume of septage from households un-served by public sewer networks in Albireh city was calculated at 44.5 million cubic meters.

The average daily volume of septage received at Albireh wastewater treatment plant is 153 m^3. The additional population equivalent resulted from the average septage pollution loads (BOD, COD and PO_4) ranged between 1,417 PE and 41,676 PE. Co-treatment of septage exerts electrical power consumption (kWh), the energy running costs for the average values of septage reached about US$ 3,694 per month. Not taking into account the capital and other operating costs, Albireh municipality should charge septage haulers US$ 1.3 to US$ 11.68 per truck load (15 m^3) as specific costs for septage co-treatment. The impact of septage loads increments (5-25%) on the design parameters of the biological unit was assessed using the German Software Package (ANAWIN). The results revealed that substantial increment in structural (aeration tank) and unit operation design parameters (oxygenation capacity and sludge age).

However, lack of scientific data on the impact of septage co-treatment on the biological processes (nitrification, enhanced biological phosphorus removal, sludge foaming/bulking) further research including process simulation is needed to mitigate non-compliance of wastewater treatment plants.

Performance improvement of Albireh sewage works such as 90% COD and 75% nitrogen removal can be reliably achieved under capacity extension and governed by the daily organic load. Operation of an improved system will still be subject to noncompliant months during additional co-treatment of septage, which creates legal issues with subsequent actions. Septage co-treatment will dramatically affect the issue of non-compliance related to both COD and nitrogen under present operating conditions. The municipality should investigate other septage disposal alternatives and work in close cooperation with the septage haulers and the Palestinian regulatory water bodies. The recommendations may generally hold for similar climatic conditions and septage characteristics in other countries. Differences may occur in the septage type (industrial or domestic) and biodegradability (COD fractions) of septage based on pumpage intervals prior to delivery for final disposal. Further studies are needed to investigate the extent to which these factors affect sludge age, nutrient removal and biosolids settling properties, and how to achieve a sustainable septage management through low-cost disposal methods.

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