Performance Evaluation of a Full-Scale Extended Aeration System in Al-Bireh City, Palestine

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Research Article

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Major challenges attributed to dysfunctional wastewater treatment facilities in developing countries include lack of commitment and poor informed decision making by the higher municipal administration. This paper presents how process monitoring and control during full scale operation ensures sustainability of civic infrastructures like Al-Bireh wastewater treatment plant (AWWTP). It is written from the perspective of practical process selection to evaluate the performance of AWWTP, a single-sludge nitrification–denitrification process with aerobic sludge stabilization. Process monitoring data (July 2000–April 2007) from available monthly operating reports were analyzed and evaluated. Additional data on microbiological analysis and information about facility unit operations were gathered through review of published local literature and interviews with AWWTP personnel. Influent and effluent data evaluated were the chemical oxygen demand (COD), biological oxygen demand (BOD), total nitrogen (TN), and total phosphorus (TP). Despite annual and seasonal variations in AWWTP influent for COD, BOD, TN, and TP, the Palestinian wastewater reuse requirements for restricted irrigation were met. Process design and proper facility operation have direct impacts on effluent quality. The study concludes that regardless of the design capacity and process type, adequate administrative and operational management dictate the sustainability of AWWTP and reuse schemes.

Keywords: Biological nutrient removal; Operation; Pathogen; Reuse; Wastewater treatment

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1 Introduction

Palestinian communities face an emergent management issue depicted by delayed maintenance, repair, and replacement in wastewater treatment infrastructures, which in most communities is overlooked and under-financed. Current wastewater treatment systems in urban centers are aged and deeply stressed due to limited financial and natural resources [1]. Recently, Al-Sa'ed [2] reported that more than 70% of the Palestinian population lack central sewer networks and only 48% of the annual collected municipal sewage is treated. About 30% of collected wastewater from Palestinian urban centers is treated in regional wastewater treatment plants. Although a few municipal sewage treatment facilities (four in the West Bank and three in Gaza Strip) have been built in few large cities, most semi-urban and rural communities still discharge raw wastewater directly into receiving water bodies including seasonal streams. Thus, innovative and sustainable options for wastewater management are essential to reduce public and environmental health hazards. However, the political, economical, and sociocultural effects must be taken into consideration while choosing appropriate treatment and reuse facilities for urban cities and rural communities [3–5].

Among the seven urban sewage works in Palestine, Al-Bireh wastewater treatment plant (AWWTP), is the only new urban sewage works in operation since 2000, while the rest are either overloaded or recently upgraded with minimum performance improvement. The performance of all wastewater treatment facilities, except AWWTP, suffered from a history of a limited financial investment in maintenance and repair often due in large part to the ''build and forget'' nature of the wastewater management systems, reflected in minimal maintenance for many years. Moreover, there is a lack of quality data of sufficient detail, both temporally and spatially, on past and current urban wastewater treatment plants [6]. All this has resulted in annual increment of organic and inorganic pollution loads discharged into surface water and quality deterioration in marine environment in Gaza Strip and groundwater in the West Bank [7, 8]. In recent years, building capacity efforts and few studies on the performance of urban sewage works have been conducted in Palestine [9–11]. Pathogens removal efficacy of AWWTP and its effluent quality for agricultural reuse was investigated by Al-Sa'ed [12], while the poor settling properties of biosolids in AWWTP secondary settling tanks due to the prevalence of foam/sludge bulking microbial communities was tackled by Hussein et al. [13]. All past efforts on Palestinian urban sewage works have been conducted in

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Abbreviations: **ATV-A131**, German working sheet for WWTP design; **AWWTP**, Al-Bireh wastewater treatment plant; **BOD**, biological oxygen demand; **COD**, chemical oxygen demand; **JWC**, Joint Water Committee; **ortho-P**, ortho phosphate; **OUR**, oxygen uptake rate; **PCBS**, Palestinian Central Bureau of Statistics; **PNA**, Palestinian National Authority; **PWA**, Palestinian Water Authority; **SLR**, sludge loading rate [F:M ratio]; **SVI**, sludge volume index; **TN**, total nitrogen; **TP**, total phosphorus; **TSS**, total suspended solids; **tTS**, sludge age; V_{AT}, aeration tank volume; **WWTP**, wastewater treatment plant short-term, pilot-scale, or lab-scale experiments. Therefore, long-term data on operating performance of urban wastewater treatment plants are needed.

The aim of this study was to evaluate the treatment efficiency and overall function of AWWTP, a full-scale extended aeration system. For this purpose, a large pool of measured data during a long-term (6-year) operation and records of seasonal and annual variations in removal of chemical oxygen demand (COD), biological oxygen demand (BOD_5), total nitrogen (TN), and phosphorus (TP) were used. Also, the potential for using the treated effluent for agricultural irrigation was evaluated based on effluent quality and practical experience gained from past efforts. The results of this study will have practical implications for both administrative and operational levels pertinent to various process design features in the operation of given municipal wastewater treatment plants to achieve sustainable management of wastewater treatment and reuse schemes.

2 Materials and methods

2.1 Study area and wastewater management issues

From pristine freshwater springs, Wadi Al Ein originates in Al-Bireh mountains watershed area and passes by several small communities joining other tributaries before discharging into Wadi Alqilt drainage system, a south-eastern aquifer recharge area (Fig. 1). The climatic conditions reflect a semi-arid area. The mean annual precipitation during the rainy season (November–March) is around 690 mm. The monthly average temperature during January is about 10°C and in summer (August) 25°C, with a mean annual temperature of 18°C. As shown in Fig. 1, Al-Bireh city, about 12 km north of Jerusalem in the West Bank, is located at a mean altitude of approximately 725 m above sea level with a population of 25 000 people in 1995 [14], where agriculture and industry are the main economic activities.

Unlike other Palestinian communities, Al-Bireh city has had a mechanical wastewater treatment plant since the early sixties. Currently, it is served by an urban sewage works, which has been put into operation in early 2000. The major aim of AWWTP was to improve public health and protect the limited available water resources, where the reuse of the treated effluent in agricultural irrigation near Deir Debwan town is one component of the wastewater treatment facility.

According to recent estimations, about 85% of the population is served by a central sewerage network, collecting municipal sewage from Al-Bireh city and neighboring refugee camps including an Israeli colony. The latter, was connected by the Israeli force else no political decision was possible to establish AWWTP. The municipal wastewater collected entails about 7% industrial origin with additional co-septage treatment from suburb areas [11].

The Israeli-Palestinian interim agreement – Annex III (www.mfa.gov.il/MFA/) [15] entails Article 40, which regulates the water and wastewater aspects in the Palestinian communities. The technical and civil administrative permits for the erection of AWWTP were obtained by a joint decision made within the Joint Water Committee (JWC). As per Article 40, the JWC is responsible for issues related to water and sanitation facilities in the Palestinian communities. The JWC approved the erection of AWWTP with treatment processes that should meet the Israel's rule for a treated effluent with a BOD_5 (20 mg/L) and total suspended solid (TSS) (30 mg/L) in 75 and 80% of monthly grab samples analyzed, respectively. The Israeli's effluent rule coincides very well with the local prescribed Palestinian quality standards [16] for treated wastewater destined for agricultural irrigation.

2.2 Design and construction of Al-Bireh wastewater treatment plant

Reports on feasible options for wastewater management in Al-Bireh city were made in 1985, while the detailed plans for the erection of a central wastewater treatment plant for Al-Bireh city were initiated between 1992 and1995, however, never seen implementation due to political constraints. The basic design data from previous reports were verified, new design criteria were established based on wastewater volume and characteristics as well as data gained from the pilot-scale treatment systems. Detailed design plans with tender documents for the erection of AWWTP were first made with the German financial and technical assistance during the period between 1996 and 1999, where the current AWWTP is in operation since early 2000.

The wastewater is mainly domestic and delivered by two main sewer lines (gravity and forced) from Al-Bireh city. Figure 2 illustrates schematically (not to scale) the planning concept for AWWTP layout entailing two erection stages (first phase serves 50 000 PE), while the

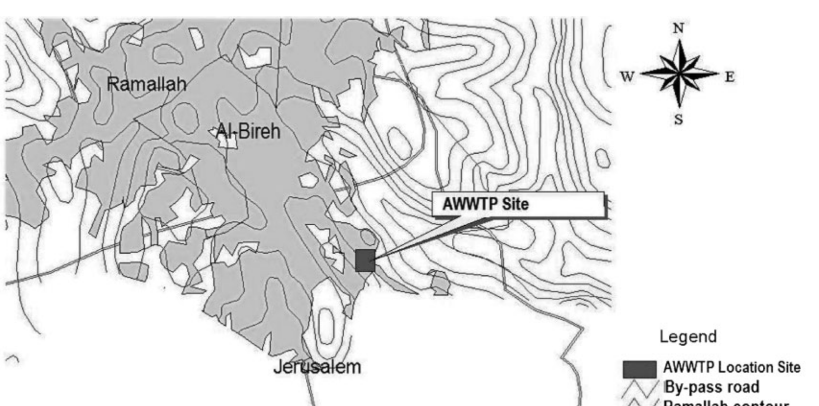

Figure 1. Site location of Al-Bireh wastewater treatment plant (AWWTP).

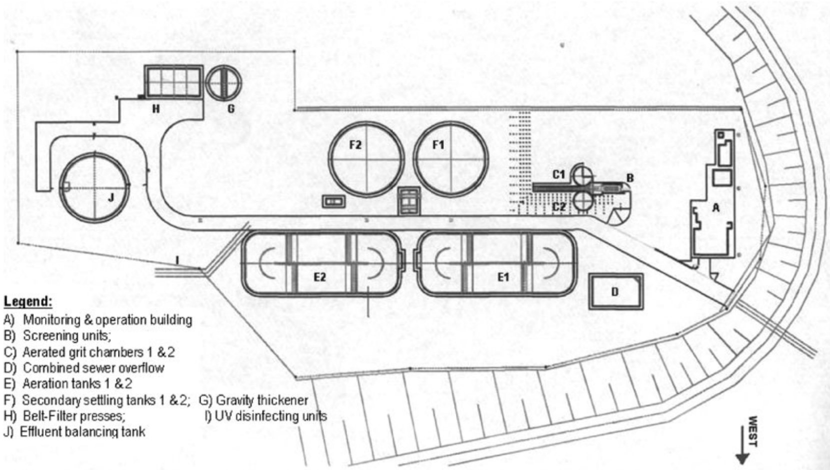

Figure 2. Layout of Al-Bireh wastewater treatment plant (not to scale).

final stage will ultimately serve about 100 000 PE. The treatment system of Al-Bireh city includes a preliminary treatment stage (screening and aerated grit chambers), secondary and tertiary units (two surface aerated activated sludge units with two secondary settling tanks), UV-disinfection units and an effluent balancing tank (Fig. 2). The biosolids line entails a gravity thickener for excess sludge and two filter presses for biosolids dewatering before final landfill disposal. AWWTP is designed as a single stage activated sludge system with simultaneous nitrification–denitrification processes. The biosolids (excess sludge) is aerobically stabilized at high sludge age (>25 days) using Passavant surface rotors (surface aerators). Both nitrogen removal and sludge stabilization were dimensioned according to the German working sheet ATV-A 131 [17]. The ATV-A 131 as a design procedure is widely accepted for the conceptual planning and detailed design of activated sludge systems, not only by the German water authorities but also worldwide. The ATV-A 131 design procedure entails main design equations based mainly on empirical data and extensive practical experience in operation and extensive applied research on full-scale wastewater treatment plants. The technical design data for unit process operations for the oxidation ditch and secondary settling tanks are summarized in Tab. 1. These technical data were taken from the final design report [18] and modified for the purpose of this paper.

2.3 Sampling and analysis

During the 6-year operation, grab water samples were collected from the influent and effluent of AWWTP and analyzed for potable temperature and pH electrodes. ISO standardized procedures were followed using DR 2800 ECO Spectrophotometer for the analysis of BOD_5, COD, TN, and ortho-phosphate (PO_4-P) at different intervals [19]. Since the erection of AWWTP was technically and legally approved on lab analysis of monthly grab samples [15], no attempt was made to arrange for flow proportional sampling programs. In this study, grab samples were taken at two points along the treatment system, before the screening units (inlet) and from the UV disinfection channel, effluent of the secondary settling tanks (outlet). COD, BOD_5, pH, and SS were measured two to three times per week from July 2000 to April 2007. TN and ortho-P were analyzed twice per month from January 2001 to December 2004. Total coliform and fecal coliform were measured three times in May 2003. The pH and dissolved oxygen were monitored online and recorded on paper strips automatically in the operation panel. Both COD and BOD_5 parameters, as a quality control on HACH method, were occasionally analyzed using the potassium dichromate-boiling method and incubation method, respectively [20].

3 Results and discussion

This study addressed the long-term treatment performance (October 2000–April 2007) during the last 6 full years of operation AWWTP, as a large-scale extended aeration system (a modified activated sludge process) in Palestine. Results from the study demonstrated that AWWTP could effectively absorb the high pollution loads received at the onset of its operation in the year 2000. Table 1 and Fig. 3 illustrate this finding, where the development of population served

Table 1. Summary of major technical design data for Al-Bireh WWTP

Design data	Unit	Design (D) (I)	Design (D) (II)	Currently (C)	Ration (C/D)
Population served	PE	50 000	25 000	49 000	1.96
Biological units		2	1	1	0.50
Aeration tank volume (V_{AT})	m^3	13 846	6923	6923	0.50
Hydraulic loads					
Average daily flow	m^3/day	5750	2875	4177	1.45
Daily pollution loads					
COD	kg/day	6000	3000	4674	1.56
BOD	kg/day	3000	1500	2189	1.46
TSS	kg/day	3185	1593	2320	1.46
Total N (as total nitrogen)	kg/day	418	209	388	1.86
PO_4-P	kg/day	253	127	67	0.53

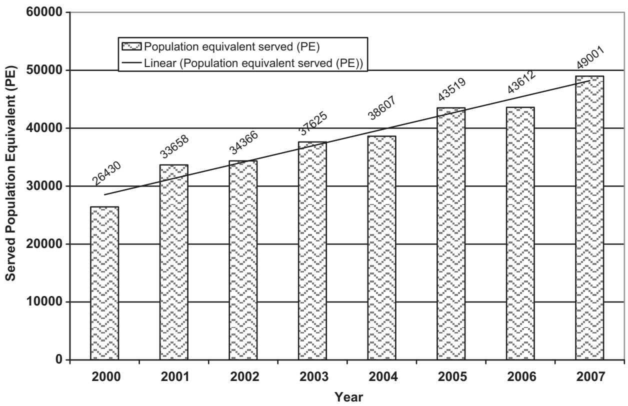

Figure 3. Annual development of population equivalent (PE) served by AWWTP.

during the last 6 full years of operation is depicted. It is obvious from this figure that by the year 2007, the pollution load has almost doubled (49 000 PE) with only one surface aerated biological tank in operation.

However, the annual removal efficiency for the pollution reduction in the effluent with COD remained stable (91.0%), BOD (97.7%) until 2006 (Fig. 4). The annual average concentrations of COD and BOD were 98 and 12 mg/l in the effluent, respectively. The removal efficacy for COD and BOD declined by the year 2007, and the effluent of COD and BOD reached 171 and 45 mg/L, respectively. The removals of nutrients, however, were not as good as those of COD and BOD.

Similarly, until the end of 2006, the treatment level achieved and averaged effluent concentrations in total-N and ortho-P were 27.9 and 9.4 mg/L, giving reduction efficiencies of 71.8% for total-N and 47.1% for ortho-phosphorus (Fig. 5).

During the first 6 years of operation, AWWTP showed a stable process performance with reliable effluent quality suitable for agricultural irrigation. The effluent quality compiled with those national prescribed guidelines for effluent reuse in restricted crops irrigation. However, as the population served increased while operation only one aeration tank, the sludge age decreased and several operational problems were encountered, mainly excessive sludge bulking and foaming (results not shown). Despite overloading, AWWTP accomplished reliable COD and BOD removal due

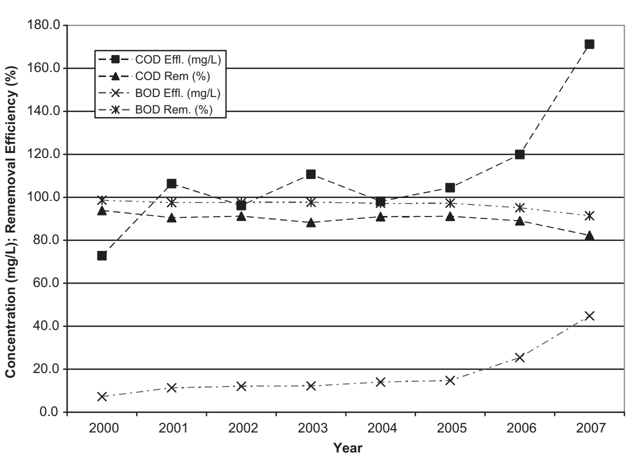

Figure 4. Annual removal efficiency of AWWTP for BOD and COD.

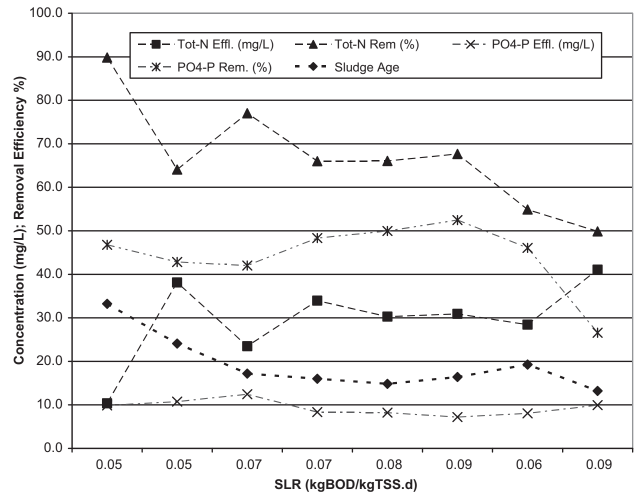

Figure 5. Impact of sludge loading rate (SLR) on the removal of nitrogen and phosphorus.

to a good cooperation between daily operation strategies (sludge removal rates/sludge age, septage disposal) and microbial mechanisms [11, 21]. There are three important features possessed by AWWTP that make the one extended aeration lane powerful in removing COD and BOD. First, owing to the wide range of sludge loading rate (SLR, variable sludge age), through variable sludge wasting program, the organic pollutants (COD and BOD) could be utilized by the microbial community at long sludge ages as indicated in Fig. 5. Second, the strategy of sludge wastage adopted was beneficial not only to overcome poor sludge settling properties of biomass within the secondary settling tank, but also enhanced the proliferation of heterotrophs other than filamentous bacteria. Third, anoxic conditions were easily established due to automatic operation and control of aeration and mixers installed within the denitrification zone, which increased the organic biodegradation under anoxic conditions under a wide range of SLRs [22–25].

Negligible seasonal influences on BOD and COD were detected in the operation of AWWTP during winter (December–March 02) and summer periods (April–November 02) along the first 6 years of process control and monitoring. Taking the operational year 2002 as an example, Tab. 2 lists the mean BOD and COD percent reductions, where 1% less efficient in winter compared to summer. Such reductions in efficiency were expected. The low seasonal variations in BOD and COD removal efficiency were possibly due to stable average wastewater temperature differences between winter (16.4°C) and summer season (24.6°C). Also, the slight monthly differences of BOD and COD inlet concentrations and inflow loads among seasons may be partly attributable to low effluent differences (Tab. 2).

Compared with summer season, the efficiency in nitrogen removal during winter period showed a value of less than 10%, where the effluent concentration reached an average monthly value of 24.4 mg/L, compared with 23 mg/L for summer period. This also reflects stable nitrification–denitrification processes within AWWTP, due to a stable annual sludge age (17 days) and low SLRs (0.07 kg BOD/kg TSS d). Samples analysis showed that water samples collected in rainy days often had lower organic matter and nutrient outlet concentrations compared to those in the ordinary course of events during the 2000 operation, but the variations are minor and no more than 5% (as of space, data not shown).

Table 2. Monthly average data during the operational year 2002 (taken as example) of AWWTP

Variable			TSS			COD			BOD_5			Total-N			PO_4-P			MLSS		tTS
Year (2002)	Month	Inflow rate (m3/day)	Influent WWTP (mg/L)	Effluent WWTP (mg/L)	Removal rate (%)	Influent WWTP (mg/L)	Effluent WWTP (mg/L)	Removal rate (%)	Influent WWTP (mg/L)	Effluent guideline (<20 mg/L)	Removal rate (%)	Influent WWTP (mg/L)	Effluent WWTP (mg/L)	Removal rate (%)	Influent WWTP (mg/L)	Effluent WWTP (mg/L)	Removal rate (%)	Aeration tank (g/L)	Sludge volume index (mL/g)	Sludge age (day)
Monthly Averages	Jan-02	6938	656	5.8	99.1	1014	85.6	91.5	446.8	9.9	97.8	114.2	38.2	67.4	16.3	7.6	51.7	5.3	98	17
	Feb-02	5183	602	4.3	99.3	1100	82.9	92.4	470.2	10.7	97.7	98.9	21.1	78.7	13.3	6.0	55.9	5.4	108	19
	Mar-02	3134	653	6.5	99.0	1075	81.6	92.4	445.5	11.1	97.4	111.0	20.1	82.1	16.1	7.1	55.7	5.1	114	18
	Apr-02	3142	645	10.8	98.3	1032	84.9	91.7	368.5	12.8	96.4	91.7	25.4	72.8	20.7	44.7	33.7	4.8	158	17
	May-02	3318	541	9.3	98.3	1087	83.8	92.2	493.7	13.8	97.1	98.8	23.6	76.1	17.9	10.9	39.2	5.0	115	28
	Jun-02	3309	826	4.7	99.4	1130	112.1	90.0	532.0	12.8	97.6	107.5	20.8	80.6	17.0	8.3	51.1	4.1	110	19
	Jul-02	3131	671	13.1	98.0	1163	93.2	91.9	508.0	11.5	97.7	100.7	26.7	73.6	16.4	9.3	43.2	7.2	115	29
	Aug-02	2926	580	6.8	98.8	1196	103.5	91.3	580.0	12.0	97.9	98.4	26.3	73.3	17.1	10.0	39.3	6.6	133	19
	Sep-02	3225	895	4.2	99.5	1157	101.6	91.2	540.0	13.0	97.6	104.9	18.9	82.0	17.3	11.7	34.0	5.3	160	18
	Oct-02	3079	655	14	97.9	1239	106.7	91.4	533.3	12.0	97.7	101.8	19.4	81.0	16.7	11.9	28.8	5.0	148	21
	Nov-02	3096	601	12	98.0	1064	108.2	89.5	536.0	12.0	97.8	102.8	23.3	77.2	17.8	12.6	30.8	4.7	146	21
	Dec-02	3995	624	10	98.4	1095	109.5	89.7	560.5	13.0	97.6	91.7	18.3	79.6	15.0	9.6	41.0	3.8	122	12
Annual average		3706	662	8.4	98.7	1113	96.1	91.3	501.2	12.0	97.5	101.9	23.5	77.0	16.8	12.5	42.0	5.2	127	20

One of the most common features in extended aeration systems, AWWTP is non-exception, dimensioned for nutrient removal (N and P removal) is the frequent reappearance of excessive growth of sludge bulking/foaming microorganisms [26, 27]. Figure 6 shows the seasonal variations in AWWTP during the whole study period (July 00–April 07). During Autumn/Spring seasons high sludge volume index (SVI) caused by filamentous bacteria are obvious, where the severe decline of sludge settleability and/or of foaming has caused effluent quality deterioration (COD and Tot-N). Since its start in operation, AWWTP showed a clear decreasing tendency in the nitrification–denitrification capacity (decline in Tot-N removal percentage) as depicted in Fig. 6. Published results [13, 27] indicated that *Microthrix parvicella* is usually dominating the spectrum of filamentous organisms causing operational problems. Improper aeration using surface aeration (Passavant rotors) with 5 m water depth in the aeration tanks is one of the major causes for unsatisfactory performance of AWWTP with regard to TN removal. The attempts to achieve an almost complete nitrogen removal and save energy using only one aeration tank was behind the hesitance of past and current key decision makers at municipality. However, frequent operation on the long term with unusually long anoxic periods in the denitrification zone and low aeration levels within the nitrification zone might have enhanced the growth of *M. parvicella*.

Lack of fat separator within the grit chamber and high lipids, oil and fat in raw wastewater can also be among the reasons behind excessive sludge bulking/foaming phenomenon at AWWTP. Microscopic investigations by Al-Sa'ed [28] indicated that the operational mode of AWWTP might affect the proliferation of sludge bulking bacteria (*e.g.*, *M. parvicella* and *Nocardia*) during autumn/spring periods reflected by thick scum formation within the secondary settling tanks. Short operational modes changing the return sludge flow and increasing sludge wastage have slight positive impacts on sludge settling properties (low sludge volume index).

The annual increment in population served by AWWTP has impacted the overall treatment efficiency of the system. Annual variation analysis of the extended aeration system in removal of BOD, COD, and TSSs showed that there was a trend of increasing removal efficiency from 2000 to 2005. It is worth mentioning that TSS content in the effluent remained stable [28] during the operation year 2002 (taken as an example). The annual average of TSS in the inlet and outlet reached 662 and 8.4 mg/L, respectively (Tab. 2). This may be due to system process nature of extended aeration systems in their self-adjustment capability as an ecological system during treatment, *i.e.*, wide range of F/M ratio during long period of operation, with a well-established microbial population and adequate sludge age might improve efficiency. However, total-N and ortho-P reduction did significantly change from 2005 to 2007 and began to decrease in 2005 onwards. A possible reason for this is that operation of AWWTP with only one aeration tank has reached its treatment capacity limits, reflected by the doubling of population number connected at the system. The oxygenation capacity of the surface aerators in the aeration tank was monitored online using DO electrodes. At deeper depths (4–5 m) in the aeration tanks, low oxygen concentrations (<0.1 mg O_2/L) were measured. Despite low oxygen content, no nitrite build-up (reflecting incomplete nitrification) was observed [28]. However, process performance including aeration system and nitrogen removal efficacy using redox potential or oxygen uptake rate (OUR) can deliver better data on the actual SLRs and the oxygenation capacity of AWWTP. Also, increased organic and nitrogen loads caused an increase in the SLR and

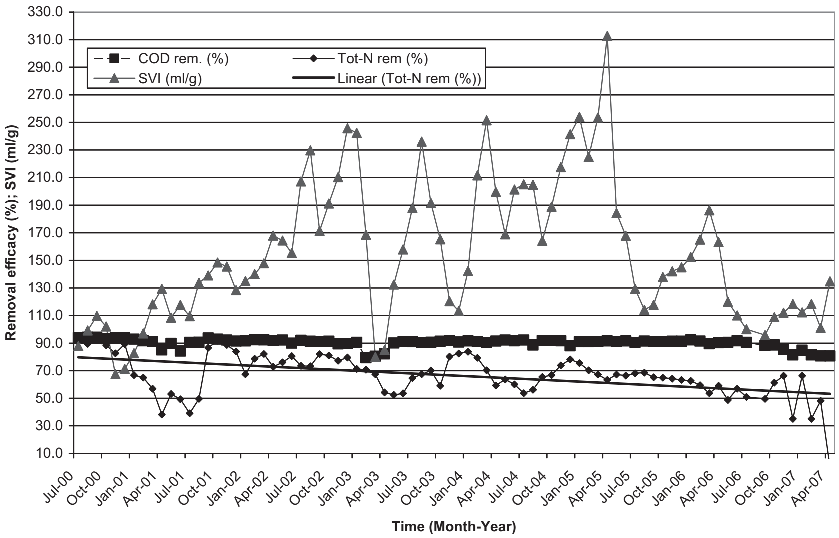

Figure 6. Monthly variations in AWWTP performance from July 2000 to April 2007.

decreased sludge age, which will have negative impacts on the effluent quality. There are other major reasons behind the decreased treatment efficacy of AWWTP, due to space limitations only some of these are listed below:

- Increment of pollution loads from industrial, newly connected sub-rubs, and co-septage treatment at AWWTP [11, 28].
- Annual sludge bulking/foaming phenomenon during autumn/spring seasons with no efforts to implement suggested protective measures [13, 28].
- Poor maintenance and ineffective repair activities during the last 2 years with reduction in number of skilled key operational staff [11, 12, 28].
- Poor understanding of top management staff for the need to put the second aeration tank into operation, maintain the PLC, repair the dewatering filter presses, put UV disinfecting unit into operation [12, 13, 28].
- Insufficient cost recovery, weak wastewater tariff system, and dependence on donor countries financial support [28, 29].
- Lack of enforcement measures to oblige the top management level to invest time and finance in conducting maintenance types (corrective, preventive, and predictive maintenance), that will maintain a sustainable operation strategy [12, 28].

Despite all published data from local research made on suggestions pertinent to optimization of AWWTP, the current management of AWWTP was urged to put the second aeration tank newly into operation. This was achieved based on the findings of consultancy reports financed by the German KfW and technical support of the GTZ, Agency for Technical Cooperation [28]. These reports entailed major recommendations, among of which was to increase the treatment capacity of AWWTP by putting the second extended aeration tank into operation. Though the findings reported [29] were erratic in some technical data, most of these recommendations were already made in previous studies and reports made by local experts [11, 12, 28]. The authors have no clue pertinent to the reluctance of the past and current top management level at the municipality in following up the recommendations made earlier in the past years. This is not unique for Palestine, but Friedler and Pisanty [30] reported similar results on how the government policy might impact the sustainability of wastewater infrastructures and indirectly negatively affect the public interests.

Since May 2007, the authors were denied free access to the monitoring reports, thus no solid technical statement can be made on the current performance of AWWTP. In addition, one of the co-authors acted as chief operator for AWWTP during the study period (until April 2007) and submitted daily reports to the previous and current top management levels. Mayors have scarce financial resources and lack official commitment to take informed decisions that will lead to improvement of AWWTP operation. Understanding the relationship between top management commitment and the overall treatment performance of AWWTP will have implications on public health and environmental risks as well as the future policy of wastewater reuse in Palestine. Authors' ongoing research will shed lights on these issues.

4 Conclusions and recommendations

Database analysis of the full-scale WWTP in Al-Bireh city indicates that extended aeration system can greatly advance water quality by significant reduction in pollution loads. In this study, the overall annual mean percent reductions of pollutants over the 6 years process monitoring were 91.0% for COD, 97.7% for BOD, 66.9% for TN, and 44.4% for ortho-P. During the first 5 years of operation, the effluent COD, BOD, and total-N did consistently meet the WHO and Palestinian guidelines for restricted agricultural irrigation.

All monitored parameters most frequently failed to meet the Palestinian guidelines since January 2005 probably because of process hydraulic and organic loading. TN and TP met the WHO and Palestinian guidelines at all times during this period probably because of constant inlet concentrations, sufficient sludge age with no major temperature variations. There is a non-significant seasonal component to this extended aeration system for BOD, COD, total-N, and ortho-P when measured on a monthly percentage reduction basis. The BOD, COD, total-N, and TP removal efficiencies displayed seasonal variations with the mean BOD and COD removals being 1% less efficient in winter compared to those in summer. TN removal was lower than 10% less efficient in winter when compared to summer periods during the operational year 2002, as an example. Annual variation analysis indicates that COD, BOD, and TN removal efficiencies showed steady state conditions from 2000 to 2004. In contrast, the overall performance efficiency did change significantly and began to decrease from 2005 onwards.

The poor performance of current urban treatment facilities and resulting potential health and environmental risks highlight the urgent need to optimize operation and maintenance of these facilities. Therefore, adequate financial resources from effective cost recovery system and raising the understanding and enhance the commitment of top management level and key decision makers are key elements to ensure functional wastewater treatment facilities. Properly treated and reclaimed effluent will be secured for any planned wastewater reuse scheme that will have direct positive impacts on the environmental and public health issues. Ongoing research studies will explore the links between management and performance of wastewater treatment facilities and how these issues impact the policy and the future investment in Palestinian sanitation sector. Finally, the impacts of sludge age, oxygenation capacity, and online monitoring of unit operations on the liquid and biosolids lines of AWWTP are not fully explored and require further research.

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