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SUSTAINABILITY OF OXIDATION AND MECHANIZED AERATED PONDS FOR DOMESTIC AND MUNICIPAL WASTEWATER TREATMENT IN PALESTINE

Rashed Al-Sa`ed

Institute for Water Studies, Birzeit University
P.O. Box 14, Birzeit, Palestine
Telefax: +972-2-298 21 20, E-mail: rsaed@birzeit.edu

SUMMARY

Palestinian rural and urban communities face a significant challenge resulting from rapid urbanization and population growth. Low average per capita freshwater resources and inadequate water and sanitation services compound an increasing water pollution problem. The use of natural and mechanized treatment processes is attracting increasing interest for the removal of organic pollutants and nutrients from domestic and urban wastewater. The treatment efficiency of these processes strongly depends on the reactor design, process monitoring and operating conditions. This article examines examples of applied low-cost treatment processes and technologies in Palestine: natural purification systems (waste stabilization ponds, algae- and duckweed-based ponds, and aerated lagoons. The effects of various design and operating parameters on the efficacy of these treatment processes with special emphasis on nitrogen removal are discussed. Sustainability of these treatment facilities is threatened by numerous institutional, technical, attitudinal and political factors, where the availability of financial aids from donor agencies alone is no guarantee of success.

1. INTRODUCTION

Palestine faces significant water and sanitation challenges resulting from both rapid urbanization development and population growth. Low average per capita freshwater resources and inadequate water and sanitation services exacerbate increasing water pollution problems. The use of natural and mechanized treatment processes is attracting increasing interest for the removal of organic pollutants and nutrients from domestic and urban wastewater. Among many wastewater treatment alternatives, waste stabilization ponds (WSP) including algae and duckweed ponds as well as aerated lagoons have become popular in both rural and urban communities worldwide. Several national and international experts and professional agencies recommended the application of these treatment technologies in the Middle East region [1-3].

The treatment efficiency of natural purification and mechanized treatment processes strongly depends on the reactor design, process monitoring and operating conditions. However, design data and technical information on practical experience as well as process performance of these treatment technologies under Mediterranean climatic conditions in Middle East, and particularly in Palestine, are still lacking. The design of wastewater collection, treatment and disposal systems in Palestine is usually based on assumed design parameters and imported as ready-made treatment schemes from international engineering firms abroad. In the absence of local data, foreign planners and sewage works designers, tend to adopt their own classical parameter values gained to design local wastewater treatment facilities. The common result is the either over-sizing of the treatment systems or sometimes under-designing the treatment unit operations, in both cases bringing the system to failure, when put into operation [4,5]. According to [6] the characteristics of wastewater in Palestine have not been subjected to good analysis, and hence, no enough reliable data are available. Furthermore, the selection of a given treatment technology and retrofing of an overloaded sewage treatment works are governed by the characteristics of the wastewater under question [7].

This study will contribute to increasing knowledge on basic design and operational data in the field of wastewater treatment using natural treatment and oxidation ponds. The results of this research study will benefit rural, educational and environmental sectors in the Palestinian society, where rural and urban sewage treatment facilities are still lacking. This study evaluates the performance and process optimization of the WSP system at Talita Kumi School in Beit Jala City, Palestine, the pilot scale algal and duckweed pond system at Birzeit University campus, and Ramallah oxidation ponds. Major design and operational parameters are discussed and the effects of wastewater characteristics, operation and maintenance of these treatment systems will also be presented.

In laboratory-scale batch experiments [8,9] have monitored the efficiency of duckweed (*Limna gibba*)-based and algae-based wastewater containers under different concentration of total nitrogen (50 and 100 mg-N/l). They realized that nitrogen loss, probably due to denitrification and ammonia volatilization, represents 40% of the total nitrogen content of algae-based and duckweed-based containers. However, in duckweed-based containers only 28% of N-loss was observed in containers with higher initial N-content. In another experiment, a pilot plant experiment was carried out to assess differences in environmental conditions and treatment performance in two systems for wastewater treatment: algae-based ponds (ABP) and duckweed-based (*Lemna gibba*) ponds (DBP). During the summer period, the average removal rate in total nitrogen was more in ABP (80%) compared with DBP (55%). However, lower values were measured during the winter period. Seasonal nitrogen reductions in DBP were significantly different, where about 33% and 15% of the total nitrogen was incorporated by duckweed biomass and removed from the system via duckweed harvesting during the summer and winter period, respectively. A plausible scientific explanation on why no more significant nitrogen removal in latter ponds for both systems was not given, also the impact of C:N ratio on the stability of denitrification capacity in both systems was not explored. No concrete design guidelines with regard to optimal design parameters to achieve adequate nitrification and denitrification rates, or feasibility of these natural ponds as a sustainable low-cost treatment option were made.

This aim of this study was to assess the sustainability of wastewater handling in terms of the treatment efficiency of natural treatment processes and aerated lagoons applied in Palestine. Special emphasis were made on design parameters, nitrogen removal rates and wastewater characteristics (C:N ratio) on nitrification and denitrification rates. The view of the author as to the factors behind sustainability of these treatment options will also be presented.

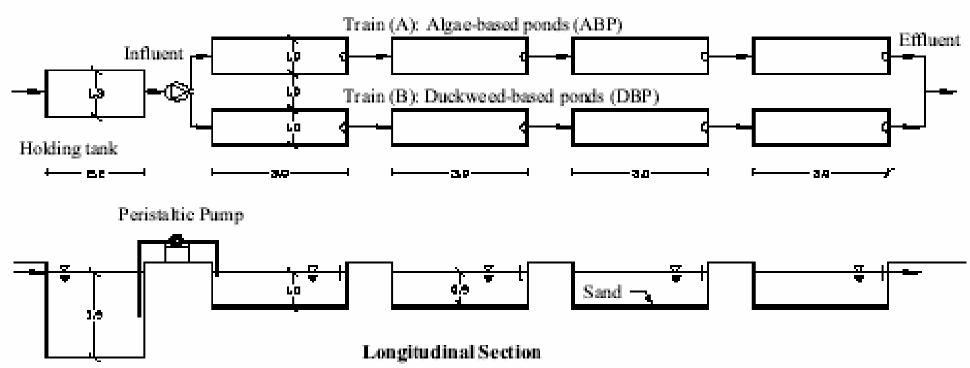
2. MATERIALS AND METHODS

2.1. STUDY SITES

Four wastewater treatment facilities; waste stabilization pond (WSP), algae- and duckweed-based ponds (ABP and DBP respectively) and one mechanized municipal aerated ponds, were studied, all located in the West Bank, Palestine. Sites were selected because of well established institutional and historically taken as adequate for research purposes. Furthermore, the aerated ponds represent oldest type of treatment technologies applied and one third of all installed urban sewage works in the West Bank.

Talitha Kumi Waste stabilization ponds (WSPs): The treatment system consists of a series of 10 rectangular reinforced concrete ponds; the first is an anaerobic pond (LxWxD: 15x1.5x 2m) followed by seven facultative ponds (LxWxD: 15x1.5x1.5m), where as the last two ponds act as polishing lagoons (LxWxD: 15x1.5x1m). A fixed precast concrete mixing partition with 0.5m depth below surface water is constructed in the middle of each pond to enhance the hydraulic mixing. Talitha Kumi WSPs were monitored during three intervals. The first run phase, ten weeks following the commissioning date (11 March- 25 May 2000), weekly visits to the plant were performed to monitor the start-up phase. The second sampling interval (phase 2) was during the summer time at the beginning of the school semester during September. Similar methodology was followed in the winter season (third phase) during January 2001. The treatment capacity is designed to serve 800 students with 36 boarding school students and 100 beds guesthouse. The maximum hydraulic dry weather flow rate is estimated to reach about 45 m^3/d. With the measured average daily flow rate of 38 m^3/d the hydraulic retention time (HRT) prevailed in the anaerobic pond, facultative and polishing ponds was around 1.2, 4.4 and 1.2 days respectively.

Pilot Scale Algae- and Duckweed-Based Ponds (ABP and DBP): The pilot scale pond system is located Birzeit University (BZU) campus since 1998. The pilot plant was built using reinforced concrete walls to ensure water tightness. It entails of a septic tank (2.2 m length, 1.3 m width and 1.9 m depth) followed by two parallel systems: algae-based ponds (ABP) and duckweed-based ponds (DBP). Each system consisted of a sequence of 4 equal ponds (3 m length, 1m width and 0.9 m depth) in series (Figure 1). The pilot plant was monitored for 30 days between May-June, 2001, where about 0.8 m3 of sewage was pumped daily to the septic tank from an aerated equalization basin, which is part of the central BZU activated sludge plant (4000 students and staff members) applying the contact stabilization process. A peristaltic pump pumped the wastewater from the holding tank at equal rates (0.4 m^3/d to each system) to the ABP and DBP. The total hydraulic retention time (HRT) in the entire ponds was 28 days, while it was only 3 days for the septic tank. Duckweed-based ponds were started with *Lemna gibba* species at a density of 600 g fresh weight/m^2.



FIGERE 1. Schematic flow diagram of the pilot plant at BZU campus (dimension: in meter)

The overall nitrification and denitrification rates were measured for the whole water body and sediment layer in all ponds (ABPs and DBPs). Two batch reactors consisted of PVC plastic tubes of 0.1 m diameter and 1.0 m length were used. Under continuous flow mode of operation, about 7.1 m3 of liquid and sediment portions were incubated for 24 hours in each reactor, where a nitrification inhibitor was added in one of them to measure the actual nitrification rate. After mixing both water and sediment in each batch reactor, duplicate samples of 100 ml were taken and analyzed for ammonium, nitrite and nitrate. The nitrification and denitrification rates were determined as described by [10].

Ramallah Wastewater Treatment Plant (RWWTP): Detailed data on description, design of the treatment units of RWWTP (two aerated lagoons and two polishing ponds) and technical plans for process upgrading can be found in the technical report on possible upgrading alternatives [11]. RWWTP was designed in 1973 and put into operation in 1975 to serve a population of about 13000 inhabitants (50% sewer connected), where the ultimate planning horizon was 1993 and the maximum population to be served was estimated at 22000 capita (70% sewer connected). RWWTP consists of a preliminary treatment stage consisting of a comminutor (defect since years) and a manual bar rack, Parshall flume, two aerated lagoons with surface aerators, two polishing ponds and a chlorinating unit, which has been never put into operation, due to non-technical reasons (Fig. 2 and Fig. 3a and b). It was envisaged to use the treated effluent for agricultural purposes, but this has not been practiced due to both technical and non-technical reasons.

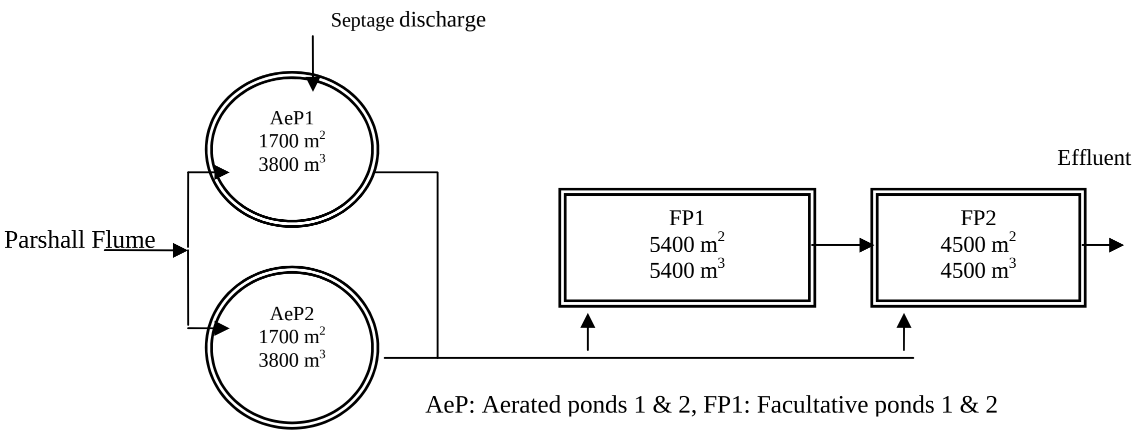


FIGURE 2. A schematic flow diagram of Ramallah wastewater treatment plant (RWWTP).

The treatment efficiency of the aerated ponds was investigated by [12], however he made no analysis on design parameters, operation and maintenance of the treatment scheme. The impacts of wastewater characteristics on the treatment efficiency of the aerated lagoons will be discussed.

FIGURE 3a. Operation room and tow aerated ponds (aerator out of operation in background) of RWWTP

FIGURE 3b. Two polishing ponds (chlorinating unit and a by-pass road of an Israeli colony, background)

2.2. MONITORED PARAMETERS

Water sampling in all sites was conducted on a weekly basis. Wastewater temperature and pH were measured onsite using alcohol thermometer and using an EC10 pH meter (Hach) respectively. Total suspended solids (TSS), Kjeldahl nitrogen (TKN), ammonium (NH_4-N), nitrite (NO_2-N), nitrate, total PO_4, ortho-and PO_4-P, were all determined according to standard methods [13]. Raw samples analyzed for measuring total COD, were filtered using 4.4 mm folded papers (Schleicher and Schuell 5951/2, Germany).

3. RESULTS AND DISCUSSION

3.1. CHARACTERISTICS OF DOMESTIC AND MUNICIPAL WASTEWATER

Wastewater classification

The average values of all parameters analyzed for Palestinian raw sewage are presented in Table 1. According to the wastewater classification suggested by [14], the data presented in the table reflect high strength domestic and municipal wastewaters [4,7,9].

TABLE 1. Characterization of Palestinian raw domestic and municipal sewage [a]

Parameter	**Domestic sewage (Talitha Kumi Shool)[b]**	**Domestic sewage (Birzeit Campus) [c]**	**Municipal sewage (Ramallah city) [d]**
BOD_5	467 (261)	167 (3.0)	872 (351)
T_{water} (^oC), annual	17.7 (4.8)	19.0 (3.0)	19.3 (6.6)
pH (-)	7.7 (0.33)	7.7 (0.2)	7.45 (0.39)
COD	657 (267)	302 (56)	2180 (663)
Total-P	24.8 (7.3)	4.3 (0.3)	12.8 (2.2)
PO_4-P	(-)	(-)	12.4 (3.8)
TSS	2282 (1914)	230 (66)	729 (127)
NH_4-N	56 (16.2)	60 (6.0)	58 (8.5)
NO_3-N	17.9 (11.3)	0.2 (0.2)	0.49 (0.48)
Total coliform (CFU/100 ml)	$15\text{x}10^5$	(-)	4.8×10^8
Fecal coliform (CFU/100 ml)	$2.4\text{x}10^5$	$2.24\text{x}10^4$	(-)

[a] All parameters are measured in duplicates and their units are in mg/l otherwise stated, data are means (standard errors), [b] n = 17, [c] n = 8, [d] n = 10, (-) no data available, CFU = Colony forming unit

3.2. UNIT OPERATIONS DESIGN AND TECHNOLOGY SELECTION

Talitha Kumi WSP

The original design of the unit operations of the WSP was not based on real data of wastewater analysis but assumed values. The actual design data obtained after commissioning the treatment facility revealed that the anaerobic, facultative and polishing ponds were overloaded. This was clear after applying the design equations for WSP design as suggested by [3]. Based on the results obtained from the monitoring phase of the WSP, Table 2 illustrates the design and actual design data for an adequately treated effluent.

As the polishing ponds would have no role in the overall treatment efficiency of WSP systems, the design of these units were not rechecked. From Table 2, it is obvious that the WSP would not properly function as designed for. The author was aware of the fact that the design of the unit operations of the WSP was made by a non-experienced engineering office and the implementing agency did not make an accurate budget for a well-engineered design.

TABLE 2. Theoretical and actual design data for Talitha Kumi WSP

Design Parameter	Unit	Anaerobic Pond (AnP)		Facultative Ponds (FP)	
		Design	Actual	Design	Actual
Dry weather flow rate	(m^3/d)	38			
Surface area (A)	(m^2)	22.5		157.5	
Water depth (WD)	(m)	2		1.1	
Hydraulic retention time (HRT)	(d)	2	1.2	11	4.5
Volumetric organic loading rate	(g BOD/m^3.d)	186	307		
Surface organic loading rate	(kg BOD/ha.d)			167	540

The outcome is clear, cost savings by the design would never pay off in real operation and compliance of prescribed national standards. An upgrading scheme for the WSP suggested by [4], where a fixed film technology in some facultative ponds applied to create additional surface area without extra civil works or further financial investments.

Algae- and Duckweed-Based Ponds

The treatment train as depicted in Figure 1 revealed that the pollution load reaching the main biological units has actually experienced partial reductions. These reductions were encountered due to partial aeration in the equalization basin of BZU central treatment plant and to a pro-longed hydraulic retention time in the holding tanks preceding the septic tank. This is reflected by the unbalanced C:N ratios (less than 3) in the facultative ponds, where no further improvement in the nitrogen removal rates in both ABP and DBP series (ABP4 and DBP4) was achievable. Also, it is not clear if the autotrophic denitrifiers are behind the nitrate reduction in the DBP series (DBP2 to DBP4), as the required C:N ratio for heterotrophic denitrifiers was below then 3 and no attempts were made to clarify this hypothesis. The design of the ABP and DBP was made to serve about 5 inhabitants. The design parameters for the ABP and DBP are summarized in Table 3.

TABLE 3. Design parameters for pilot scale ABP and DBP systems at Birzeit University

Design parameter	**Unit**	**ABP1**	**DBP1**	**ABP2**	**DBP2**	**ABP3**	**DBP3**	**ABP4**	**DBP4**
Water temperature	(^{o}C)	20.8	19.7	21.7	20.5	23.6	22.7	22.9	22.7
pH	(-)	8.3	7.8	8.5	7.9	8.6	8.0	8.8	8.1
Specific surface area	(m^2/capita)	2.3	2.4	3.7	4.5	6.1	6.9	7.4	7.0
BOD Surface loading rate	(g BOD/m^2.d)	26.1	25.3	16.3	13.4	9.8	8.7	8.1	8.1
NH_4-N Surface loading rate	(g NH_4-N/m^2.d)	8.0	8.9	6.3	7.1	3.7	5.7	2.6	4.5
C:N ratio	(-)	3.3	2.9	2.6	1.9	2.6	1.5	3.2	1.8
Nitrification rate	(mg NH_4-N/m^2.d)	343	284	459	303	549	366	500	400
Nitrification efficiency	(%)	4.3	3.2	7.3	4.3	14.7	6.5	19.4	8.9
Denitrification rate	(mg NO_3-N/m^2.d)	352	302	432	312	513	348	446	364
Denitrification efficiency	(%)	4.4	3.4	6.9	4.4	13.8	6.2	17.3	8.1

Ramallah WWTP

In addition to the untreated and uncontrolled industrial discharge RWWTP also receives about 100 m^3 of domestic and industrial septage daily. The wastewater characteristics of Ramallah city can be classified as of high strength sewage, due to high COD and BOD content. The main technical design data are listed in Table 4. The ratio between COD:BOD (3.0-2.6) is also very high, reflecting to a high percentage of industrial discharges. The study made by [11] revealed that the oxidation ponds were already overloaded. The overall removal efficiency of was only about 57.7% in BOD pollution load. The aerated ponds removed about 43.3% of the BOD load, whereas the facultative ponds removed only 26.2% of the load. Attempts of the municipality to upgrade the treatment system failed because of both technical and non-technical issues.

TABLE 4. Technical design data of RWWTP (start up 1973 and planned horizon, 1993)

Design Parameter	Unit	Aerated Ponds (AeP)		Polishing Ponds (PP)	
		1973	1993	1973	1993
Dry weather flow rate	(m^3/d)	390	1217	390	1217
Surface area (A)	(m^2)	34000		5400	
Water depth (WD)	(m)	4.5		1.2	
Hydraulic retention time (HRT)	(d)	19.5	6.2	30.5	9.8
Organic surface loading rate	(g BOD/m^2.d)	21	39	15	67

3.3. EFFICACY AND STABILITY OF TREATMENT PROCESSES

Talitha Kumi WSP

During the monitoring period, the anaerobic pond with a short hydraulic retention time of 1.2 days was able to achieve a reduction of 38% and 45% in both total BOD and filtered BOD respectively. A removal rate of 41% was also recorded for both total and filtered COD. Figure 4 shows that at higher temperatures (start-up phase1 and 2) the COD effluent values were lower than those during the winter period (phase 3).

In the same range, removal rates of nutrients were noticed. For ammonium, nitrate and total phosphate, reduction rate of 42%, 46% and 9% were achieved respectively, whereas only 39% of the TSS was achieved in the anaerobic pond. The effluent quality of the facultative and maturation ponds was very poor. There was an increase in total BOD, total COD and filtered COD concentrations in the effluent. The removal rate for phosphorus and ammonium were 30% and 12% respectively. It was noticed that there was a slight increase in the nitrate concentration. Finally, an increase in the TSS concentration was also noticed. The obtained results from this research study showed that the performances of the anaerobic pond, facultative and maturation ponds were not satisfactory. The reasons behind the unsatisfactory results can be summarized as follows:

- All the ponds were connected in series with a very short hydraulic retention time (1.6 days per pond).
- The ponds arrangement failed to absorb the maximum allowable surface organic loading rate. According to Oliveria and Mara (1996), each pond in a series of facultative ponds should be able to undertake the maximum allowable BOD surface loading.

- Ponds were anaerobic during the whole investigation, where also algal biomass was washed out causing and increase of total suspended solids in the effluent.

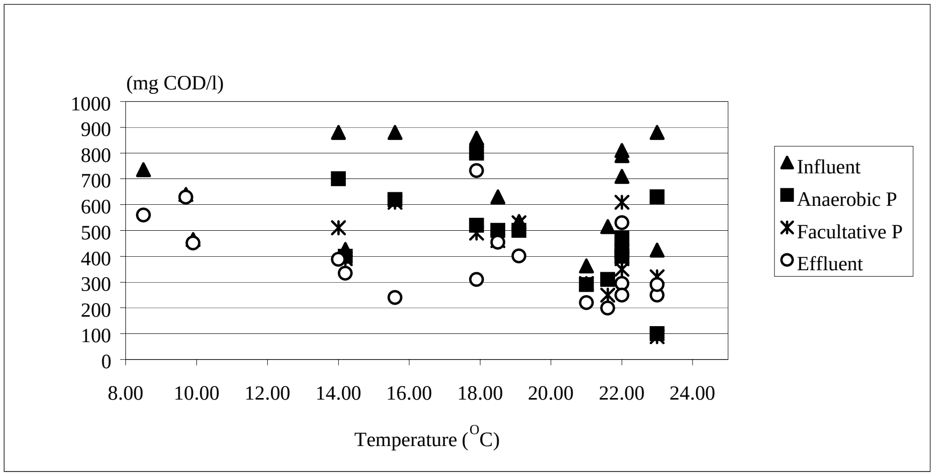


FIGURE 4. Efficiency of COD removal during various study periods (phases 1, 2 and 3)

Boring holes in the baffle in the second pond to increase flow velocity and to utilize this pond as an anaerobic pond. A total volume for the anaerobic pond should be around 78 m^3 instead of actual 45 m^3. This will result in a reasonable organic loading rate of about 180 g/(m^3.d) at 14 ºC. The newly hydraulic retention time in both ponds is about 2 days. Installment of additional surface area in the first 5 facultative ponds will provide a total liquid volume of about 113 m^3. By a selected average surface organic loading rate of 15 g/(m^2.d) and liquid waste temperature of about 14 ºC, almost an additional surface area of 350 m^2 must be provided. Without additional civil works and large investment costs, this can be achieved via installment of plastic boxes filled with coarse and medium size gravels and stones (4 m^3). The specific surface area of such fixed bed material is between 80 and 100 m^2/m^3. This will make about 6-8 boxes, which can be distributed within the first two facultative ponds. The total hydraulic retention time in these ponds will be about 3 days.

Ramallah Aerated Ponds (RWWTP)

The investigation made by [12] on the operational design parameters of the RWWTP, revealed that the volumetric organic loading rate for the aerobic ponds was 470 g BOD_5/m^3.d and the average hydraulic retention time for each one was 2-3 days. He designated the function of the aerobic ponds as if they were anaerobic lagoons. This is actually justified, as [3] suggested a range for the design of anaerobic ponds between 100-400 g BOD/ m^3.d to avoid odor problems. As the ponds system is organically overloaded, the removal mechanisms proceed through settling and subsequent anaerobic mineralization. The COD removal efficiency was about 33% while the overall removal did not exceed 45% of the initial COD pollution load. The facultative ponds were also overloaded and as a result the dissolved oxygen within the top 10 cm water column had never exceeded 0.6 mg/l, due to weak algal photosynthesis and high turbidity within the water body of the ponds. Actually the effective water volume is largely decreased due to the high depth of the sludge layer (65 cm). The measured hydraulic retention time ranged between 1.5 and 2.5 days.

Aerobic lagoons normally contain dissolved oxygen throughout the water depth and act essentially as carbon conversion systems. Aerobic heterotrophic bacteria degrade influent waste organic matter and the resulting carbon dioxide (or bicarbonate) and algal cells to photosynthesize, use nutrients. Oxygen released by algae in this process is the major source of oxygen required to satisfy the demand in the aerobic bacterial biodegradation process. The combined and mutually beneficial action of algae and bacteria in this process is termed algal-bacterial symbiosis (Figure 5, top layer of water column only). There is no net loss of influent carbon in the system, just the transformation of waste organic matter into living cells, mainly algae and bacteria [1,3]. About 80 to 95% of the soluble BOD could be removed in this system.

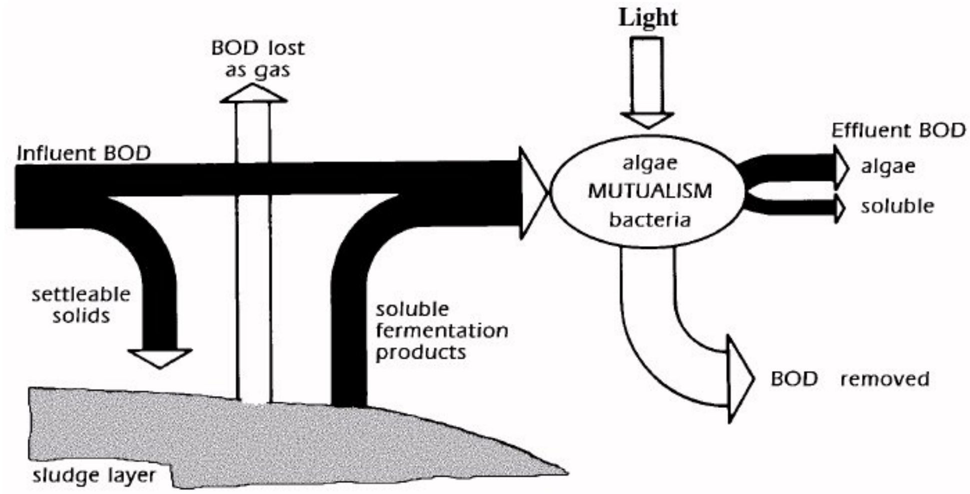


FIGURE 5. Principles of treatment processes in a lagoon system [3]

Recent results published by [15] revealed that algae-bacterial flocs in a lab-scale reactor might be enhanced via mixing and return sludge flow, where removal efficiencies of 93%, 46% and 25% for COD, total nitrogen and total phosphorus respectively. This innovative technology can be applied as an upgrading option for RWWTP, provided that a desludging process of biosolids from both facultative ponds is practiced. Also a return sludge pump and mixing devices should be installed to secure healthy flocs of algal-heterotrophic bacterial biomass. However, the very high algal concentration in the unfiltered effluent could result in a very high BOD concentration. Therefore, to produce a good effluent, the algae need to be removed. Removal of algae is not easy, as they won't settle and as the alternative, flotation is an expensive unit process, this is not normally done before discharge [16].

Algae- and Duckweed Based Ponds

The aesthetic quality of pond effluents may be lower than that produced by other secondary processes, because algae contribute high concentrations of both suspended solids and BOD. However, natural oxidation ponds can be effective in nutrient removal as nitrogen and phosphorus, if they are preceded by a well-designed enhanced primary treatment stage like the UASB technology.

Based on the results obtained from this research study, a conventional one-compartment septic tank would achieve reasonable nitrogen removal efficiencies in algae- and duckweed-based ponds systems. As illustrated in Figure 6, the efficiency of the nitrification process in ABPs and DBPs has increased with a decrease tendency in surface organic loading rates.

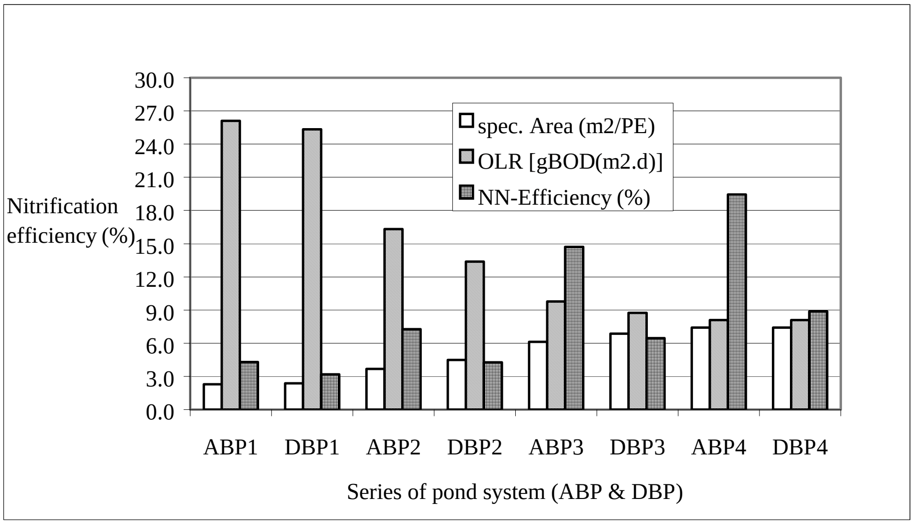


FIGURE 5. Effect of organic surface loading on nitrification efficiency in ABPs & DBPs

Compared with that for DBPs, the nitrification efficiency was higher in ABPs (ABP3 and ABP4) by almost 10%. At a similar surface organic loading rate in both systems, increasing the surface area for the nitrifiers in DBPs had no positive impacts on the overall ammonium oxidation. This can be attributed to less nitrifiers fractions prevailing within the DBPs compared to ABPs, where nitrifiers might be attached to the free swimming algal biomass. In ABPs, nitrification and denitrification rates increased until pond number 3 and then decreased, with higher nitrogen removal efficiencies measured in ABPs compared with DBPs (Fig. 6). The higher denitrification rates in ABPs can be explained by higher average in C:N ratios, which is necessary for the heterotrophic denitrifiers.

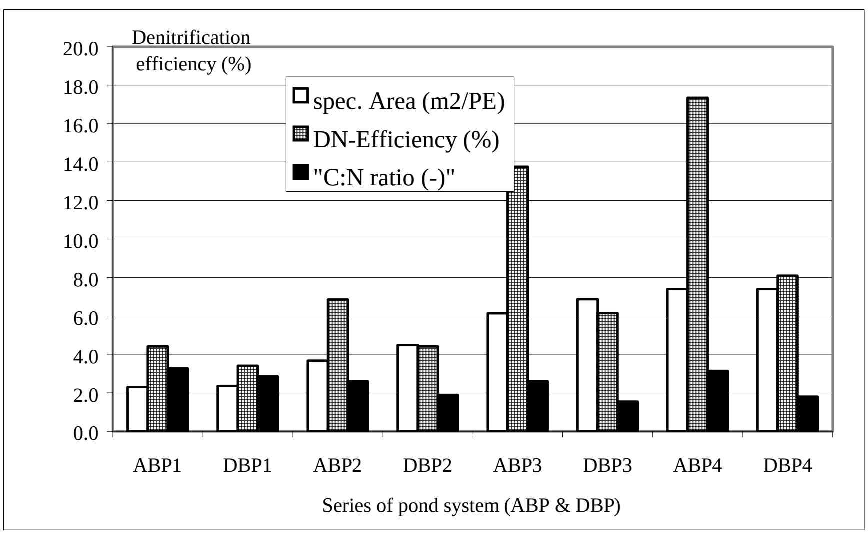


FIGURE 6. C:N ratio and specific surface area effect on denitrification in ABPs & DBPs

Though the denitrification efficiency in DBPs was below 10%, it was not clear what type of microorganisms are responsible for nitrate reduction under C:N ratios below 2. The obtained nitrogen removal efficiencies in ABPs and DBPs are not easy to compare with published literature data as variable environmental and differences in operational design parameters. The measured denitrification rates in ABPs and DBPs ranged between 352-513 mg $N/m^2.d$

and 302-364 mg N/m^2.d correspondingly. Similar values (470 mg N/m2.d) were reported by [17] for denitrifiers' activity in river sediments.

Rural and old urban sanitation facilities in Palestine are inefficient due to high strength wastewaters, inadequate technical design, and lack of proper maintenance and monitoring. Nitrogen removal can be achieved in waste stabilization ponds preceded by enhanced primary treatment, however causing high specific area demand, which is against one of the major positives characterizing these technologies as low-cost treatment options.

4. SUSTAINABILITY OF THE TECHNOLOGIES UNDER STUDY

It is well known, that rural communities rely on lagoons due to their low capital, operation and maintenance costs compared with the more sophisticated processes at the price of some loss in degree of treatment. However, lagoons should be reassessed because: increased sensitivity to produced odors; requirements to comply with prescribed effluent quality guidelines and increased penalties for non-compliance; restrictions on ultimate land disposal of treated wastewater and sludge; and pressure to recycle water requiring higher effluent qualities. In Palestine, where receiving water bodies can assimilate effluent of quality achievable in lagoons, and where land is available, the low cost of lagoon treatment makes it an attractive, flexible and reliable option for domestic wastewater treatment.

On the other hand, urban sewage treatment plants were planned and implemented in the past based on reluctant and voluntary approach of the Israeli environmental policy, where water pollution and public health were not taken into consideration. All urban sewage works erected during the Israeli occupation era are unsustainable in terms of adequate sanitation service delivery. Palestinian communities rarely have had sustainable capacities to manage their own infrastructure as un-experienced and un-motivated operational staff and inefficient management at the top level, all this exacerbated the in adequacy of urban and rural sanitation services. These prerequisites for installment of waste stabilization ponds preceded by enhanced primary treatment on a wide scale for rural wastewater treatment are questionable. This is true, as groundwater is sensible to effluent discharges from untreated, partially treated and leaking septic tanks. In addition, lack of large-scale successful case studies based on gained design criteria from pilot-scale studies can be considered as a handicap.

Sound wastewater treatment facilities in Palestine should be based on a clear understanding of the existing problems, the beneficial impacts achievable, and the factors, which determine sustainability. The impacts of Palestinian sanitation programs are limited, and most the existing urban sewage treatment facilities except that of Albireh and Gaza break down, abandoned and are overloaded. Sustainability, in the sense of continued delivery of services based on reasonable technical planning and design, adequate operation and monitoring, is threatened by numerous attitudinal, institutional and political factors, and pumpage of huge foreign financial aids approach alone is no guarantee of successful sanitation programs. The key to sustainability is that all stakeholders involved in use, maintenance, cost recovery, and continuing support perceive it in their best interests to deliver high quality services. In developing countries, several sanitation projects fail to deliver long-term benefits to society as poor understanding of the impacts and sustainability of these projects [18].

Erection of urban wastewater treatment facilities in Palestine results in excessive expenditure of time and financial investments. Old sanitation projects often failed to achieve significant impacts on public health and aquatic environment, and most of these systems are overloaded and broken down. Cost recovery, better technical and useful upgrading plans are crucial for better sanitation services provision. The conventional definition of sustainability as "continues-to-work-over-time" implies steady sate and static conditions, where it might be far from reality. What is required by this definition is a steady state of improved output, continuity of adequate sanitation services, which may be achieved through a balanced relationship between several sustainability factors.

4.1. FACTORS AFFECTING SUSTAINABILITY

Community motivation, involvement and commitment
Although community participation is nowadays an essential foundation stone of sanitation projects in developing countries, this alone is no automatic guarantee of success. Public health education, vesting ownership attitude, and involvement of the community, will usually be necessary to bring about motivation and involvement. Community delivery of high quality sanitation services will also enhance their commitment.

Technical design, process monitoring and maintenance
Sustainable sanitation facilities imply clearly structured, technically and financially resourced, and well-trained maintenance communities, which most of the Palestinian communities are lacking. Ease of implementation of inadequate treatment technology is facilitated by enforcement of already made technical design of sewage works by foreign engineering firms and lack of real local input in technical design or revision. Community-appointed professional committee may have an important role in technical design revision, proper process control and maintenance [19]. Also a reasonable backstopping can be provided through establishment of neighborhood wastewater treatment facilities, regional, or national level organization. Communication between community, professional committees or backstopping agencies needs to be clear, spare parts and tools, and appropriate training programs, must be available.

Cost recovery
Annual maintenance and repair of sanitation facilities including staffing, training, transport, spare parts, materials, tools, energy, disposal of treated effluent, residuals and biosolids, and replacement electromechanical parts all cost communities money. During the Israeli occupation, taxes were collected from the Palestinian communities; however, these were not utilized in maintenance and repair of sewage facilities, despite the fact that these communities were financially under-resourced. The present practice of calculating wastewater tariffs is by fare against sustainable achievement of any sanitation facility, as donated financial aids are not included in the annual depreciation rates. Hence, the level of payment, including donated foreign financial loans, the basis of payment (by volume, capita per year), and the means of administering and accounting for wastewater tariffs, all have to be decided by the community.

Continuing technical and financial support
Experience gained from old urban sewage works, makes it clear that the enthusiasm of Palestinian communities for pollution reduction and adopting improved hygiene practices, and continuing maintenance and repair has diminished within one year after construction. It is crucial that the supporting Government, NGO or donor countries maintain responsibility and commitment for a reasonable follow-up. This is a long-term endeavor, implying continuity until there is a critical mass of good practice within a given community. The evidence from the German financial and technical support in the erection of wastewater treatment facilities in Albireh city shows that continuity in support enhances the chances of sustainability. The achievement of sustainability implies incentives for all stakeholders involved in use,

maintenance, financing, and continuing support of sanitation services. For those providing services, these incentives should be financial. Long-term management strategies built on clear relationships between strengthened support institutions and private sector participants, and communities are crucial for sustainability.

Regional political stability and cooperation
As no treatment technology by *de facto* is sustainable, the analysis of the community local context is one of the core issues that must be taken into consideration while planning the framework of a sustainable wastewater treatment option [20]. In this regard, the major factors affecting sustainability of Palestinian sanitation facilities are the prevailing unstable political situation and lack of regional cooperation. Evolved from having one environment and shared water resources makes political stability, reasonable cooperation and equitable rights of management crucial elements for the sustainability of not only future and wastewater treatment facilities but also regional stormwater infrastructures. Any delay in the approval of Palestinian sanitation projects would harm public health and environment.

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