Locally Made Small Scale Activated Sludge Wastewater Treatment Plants: "An Alternative Solution to the Problem of Untreated Domestic Wastewater"

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Abstract

Despite the fact that wastewater is a major source of pollution it is considered a sustainable and valuable resource that should be collected, treated to acceptable standards and reused not only to preserve the environment and groundwater aquifers, but also to conserve and augment the water resources. The reuse of treated wastewater, mainly for agricultural irrigation, would promote water conservation through replacement of fresh water reallocated for domestic use from the Palestinian agricultural sector. This would also result in guaranteed regular supplies of fresh water to the citizens. The dispersed pattern of houses in the rural Palestinian localities and remote areas makes it economically unfeasible to construct wastewater collection networks and centralized wastewater treatment plants. On-Site small scale wastewater treatment plants, respond to the needs and conditions of rural localities. They can solve the wastewater collection and disposal problems in such communities, along with the benefit of generating a water resource that can be utilized for irrigation purposes. Despite the several advantages that the utilization of small scale On-Site wastewater treatment units can provide, introducing of such technology in the Palestinian rural areas has been a hard task; due to several reasons among those reasons is the high cost of such imported plants, with no locally made real alternatives. This encouraged the Applied Research Institute – Jerusalem (ARIJ) to work in finding alternative solutions to the faced challenges. In August 2005, engineers of the Water and Environment Research Unit (WERU) at (ARIJ) managed to transform the theoretical knowledge to a real application. In this application, a small scale wastewater treatment plant was constructed based on the activated sludge Technology[1] (Ref. 1), which includes a cylindrical bioreactor having as its main body a plastic tank with a total volume of 2500 liter, partitioned into four hydraulically independent zones. These are the mechanical debris collection basket, the de-nitrification zone, the activation / nitrification zone and the separation zone. The idea was to accommodate all the treatment process in a local available plastic tank.

Keywords: Wastewater, Reuse of Treated Wastewater, Small Scale Onsite Wastewater Treatment Plant, Activated Sludge.

[1]In general, the activated sludge process is a continuous or semi continuous (fill and draw) aerobic method for biological wastewater treatment, including carbonaceous oxidation and nitrification. This process is based on the aeration of wastewater with flocculating biological growth, followed by separation of treated wastewater from this growth. Part of this growth is then wasted, and the remainder is returned to the system. Usually, the separation of the growth from the treated wastewater is performed by settling (gravity separation) but it may also be done by flotation and other methods.

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Nomenclature

(BOD_5): Biological Oxygen Demand.
(COD): Chemical Oxygen Demand.
(TSS): Total Suspended Solids.
($N\text{-}NH_4$): Ammonium Nitrogen.
(TP): Total Phosphorus.

1. INTRODUCTION

In reference to the Palestinian Environmental Strategy, wastewater management has been identified as the most urgent element that must be effectively tackled in order to alleviate the environmental and health problems associated with the existing management, (Ref. 2).

Wastewater management, at all stages of collection, treatment and disposal, has been neglected throughout the West Bank Territory. The existing practices for managing domestic wastewater are limited to the collection of the generated wastewater by sewage networks and / or cesspits, and final discharge into the sea (as the case of the Gaza strip) and open areas (as the case of the West Bank). Sewage collection networks are limited to major cities and refugee camps. However, the coverage of households' connections to networks is still partial in some places. The existing sewage networks serve approximately 43 % of the West Bank and Gaza population (Ref. 3).

Most of the networks are poorly designed and old, thus leakage and flooding of wastewater is common. In areas where sewage networks do not exist, mainly rural localities, the residents use cesspits for wastewater collection. Most of these cesspits are left without a cement basement of liner and infiltrate the wastewater directly into the earth layers. Such situation endangers the quality of groundwater especially in areas overlying the highly permeable recharge areas of the West Bank Aquifer. The sarcastic nature of this limestone aquifer, which is characterized by fractures, allows quick movement of wastewater and leads to the contamination of groundwater which is the major source of drinking water (Ref. 1).

It is important to note that not all collected wastewater receives treatment. The centralized wastewater treatment plant that is operating at a high efficiency rate exists in Al Bireh in Ramallah Governorate. The other plants are either not functioning at all, or operating at low efficiency rates. Moreover, wastewater pumped out of filled cesspits using vacuum tankers is discharged raw into open areas in valleys. About 90 % of the generated wastewater in the West Bank is currently discharged untreated into the environment (Ref. 4). Accordingly, the improper disposal of untreated wastewater has added more pressure on the environment and contributed in the occurrence of several environmental problems. These include the deterioration of groundwater quality, deterioration of nature and biodiversity, landscape and aesthetic distortion of the visual environment. The use of contaminated water by wastewater results in the spread of waterborne diseases including hepatitis, diarrhea and amoeba, among others (Ref. 1).

Despite the fact that wastewater is a major source of pollution it is considered a sustainable and valuable resource that should be collected, treated to acceptable standards and reused not only to preserve the environment and groundwater aquifers, but also to conserve and augment resources. The reuse of treated wastewater, mainly for agricultural irrigation, would promote water conservation through replacement of fresh water reallocated for domestic use from the Palestinian agricultural sector. This would also result in guaranteed regular supplies of fresh water to all citizens. The dispersed pattern of houses in rural localities and remote areas makes it economically unfeasible to construct wastewater collection networks and centralized wastewater treatment plants. On-Site small scale wastewater treatment plants, which can serve a single house or a cluster of houses, respond to the needs and conditions in rural localities. They can solve the wastewater collection and disposal problems in such communities, along with the benefit of generating a water resource that can be utilized for irrigation purposes as land and agriculture are available. This can relieve pressure on precious fresh water resources in the Occupied Palestinian Territory and, thus contributing to solving the water crisis in the area.

2. METHODOLOGY

2.1 System Description

The materials used in the construction of the facility were carefully selected to assure a proper and a reliable unit. The first idea was to use fiber glass materials but due to the elevation costs of imported fiber materials and to the lack of local sources, it was preceded trying other market available alternatives. Plastic was an available and appropriate option due to a combination of reasons, including its corrosion control abilities, its light weight, its low cost, its strength-to-weight ratio, and other unique properties. Polyethylene and aluminum were available too. At the implementation stage, the plant was constructed with a combination of the aforementioned materials. A plastic cylindrical water tank was used to form the main body of the wastewater treatment

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plant. This tank was attached to a metal frame that was painted with a corrosion protective coating and consisted of three rings linked together by three parallel profiles that were perpendicular to the three rings and fixed with a displacement between each other of 120 degrees from the center of the rings, as shown in (**Figure 1)**. Later on, Polyethylene rigid high density polyethylene-HPPE sheets were added to form the divisions between the different zones of the wastewater treatment reactor.

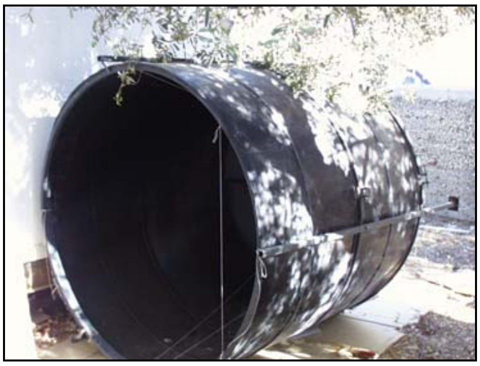

Figure 1: The Main Body of the Plant with the Attached Metal Frame

Once the Construction of the wastewater treatment plant was concluded, it was preceded with its installation on the site. The exact location of the wastewater treatment facility was defined by the existing drainage network requirements , the last wastewater collecting manhole which is the lowest was the key factor in the determination of the recommended location for the facility ; the level of the output pipe of that manhole, determined the depth of the pit needed to be excavated .As important to mention the plant was leveled properly during its installation to guarantee the objectives of the partitions in the main wastewater treatment reactor.

The constructed wastewater treatment plant served a family of 6 persons, with a variable wastewater generated volume raging between 0.6 and 1 cubic meter per day. The locally constructed wastewater treatment system includes a cylindrical bioreactor having as its main body a plastic tank with a total volume of 2500 liter. It is partitioned into four hydraulically independent zones. These are:

(1) the mechanical debris collection basket,
(2) the de-nitrification / anoxic zone,
(3) the activation/nitrification zone and
(4) the separation zone.

The plant zone sizing started by, assuming the standard dimensions of a market available plastic tank as the maximum available space for the treatment process. The effective volume for the treatment process was approximately 85% of the total tank volume. The zones volume is summarized in Table 1.

Table1. Zones volume of the treatment system (Ref. 5)

Zone	Lit	Percent (%)
Screen	85	3.4
Activation/nitrification zone	1062.5	42.5
De-nitrification / anoxic zone	523	20.92
Separation	450.5	18.02
Empty part at top of WWTP	301.35	12.05
Interior walls and others	77.65	3.11
Total volume	2500	100

Source: Applied Research Institute – Jerusalem (ARIJ) - 2005

2.2 Process Description

The treatment process starts with the screening of certain suspended solids present in the wastewater; these suspended solids are filtered by the use of a removable screen basket with filtering slots 5-8 mm. The recycled activated sludge is brought just underneath the basket from the separation zone, and where is mixed with the incoming wastewater. After the screening the de-nitrification and Activation/Nitrification process take place. In the de-nitrification zone, oxygen is removed from nitrate and nitrite to form nitrogen gas and water. From the de-nitrification zone, wastewater overflows into the aeration (nitrification/activation) zone, which is the largest zone and provides a space where the bacterial mass is aerated and maintained for the longest period of time. This allows for the maximum utilization of nutrients and conversion of the contaminants in the raw sewage into less harmful compounds; carbon oxide and water in the process of oxidation, and nitrite and nitrate in the process of nitrification.

The aeration system goal was to maintain the dissolved oxygen at 2-3 mg/l, maintain of solids in suspension and ensure proper recirculation of the activated sludge. Air was diffused from the bottom of the aeration zone. It is important to mention that the typical wastewater does not contain nitrate that means that no de-nitrification can occur unless a nitrification was preceded and due to that, the de-nitrification of the treatment plant was accomplished through the use of a circulating pipe that returns the flow to the screen and therefore to the de-nitrification compartment assuring by that the de-nitrification process. Then the half conical

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shape of the separation zone ensured that the upward velocity of the sludge flocks decreases as the flocks rise until they form a stationary sludge blanket when gravitational and uplift forces reach equilibrium. Wastewater passes through the sludge blanket, fine suspended solids are retained and the filtered effluent rises above it. The effluent is then discharged out of the system. The growing flocks of the sludge at the bottom of the separation zone are recycled by means of an air lift pump back to the screen and de-nitrification zone of the bioreactor. Also located in the separation zone is a device to skim and remove flocks of sludge occasionally breaking away and floating on the surface of the separation zone by means of an air lift pump. The average volume of air injected to the system during aeration was approximately 1.1 Lit / Sec. The running of the treatment facility was totally automatically controlled, including: steering, recirculation of activated sludge, injected oxygen volumes and treated wastewater pumping. Figure 2 illustrates the Wastewater Treatment Plant Process.

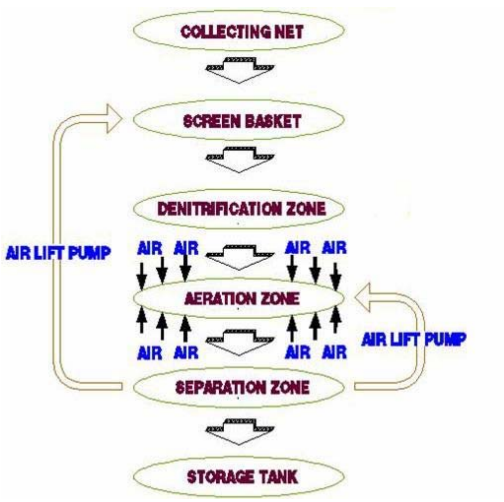

Figure 2: Wastewater Treatment Plant Process Diagram (Ref. 5)

3. RESULTS AND DISCUSION

Selected parameters were analyzed to study the efficiency of the small scale wastewater treatment system, and whether this effluent is suitable for irrigation purposes. These parameters are the Biological Oxygen Demand (BOD_5), the Chemical Oxygen Demand (COD), the Total Suspended Solids (TSS), the Ammonium Nitrogen (N-NH_4), and the Total Phosphorus (TP). The quality parameters of the effluent are given in Table 2.

Table 2. Effluent quality of locally small scale wastewater treatment system

Effluent sample (mg/l)	pH	TS	TSS	COD	BOD_5	TP	NH_4
Sample 1	7.1	653	173	27	<15	5.08	4.6
Sample 2	7.4	651	171	17	<15	5.23	4.1

Source: the Biological and Chemical Analysis Center of Al-Quds University, 2005

According to the Palestinian Standards Institution for treated wastewater characteristics which is shown in Table 3, result of the effluent parameters show that the quality of treated wastewater of locally small scale wastewater treatment unit is acceptable for irrigation purposes without any hazards impacts. However, the TSS concentrations were generally high. Furthermore, according to the World Health Organization (WHO) standards, the effluent quality is acceptable for irrigation purposes, except for the TSS which is very high and will cause some negative impacts particularly when drip irrigation is used.

This obtained effluent can be further treated by a normal or slow sand filter, and / or disinfected to be reused for irrigation purposes after taking into consideration the local reuse standards and recommendations. Table 3

Table 3:Recommended guidelines by the Palestinian Standards Institute (Ref. 6)

Effluent parameter (mg/l	Fodder irrigation		Gardens	Industrial crops	Groundwater Rechargeable	Land scapes
	Dry	wet	Play grounds			
BOD5	60	45	40	60	40	60
COD	200	150	150	200	150	200
DO	> 0.5	> 0.5	> 0.5	> 0.5	> 1.0	>0.5
TDS	1500	1500	1200	1500	1500	50
TSS	50	40	30	50	50	50
pH	6-9	6-9	6-9	6-9	6-9	6-9
NO3-N	50	50	50	50	15	50

Source: Palestinian standards Institute – 2005

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It was found also that is highly recommended after the determination of the volumes of air needed to be injected to the system according to the aeration system utilized and / or diffuser specifications, to compare between the different air pumps available in the market and that comply with the air flow and head requirements, before the selection of the air pump, specially that there are variations in the power consumption due to differences in pumps efficiencies under different pressures and to changes in pumping volumes due to changes in operation pressures . For that reason to compare different pumps that comply with the required specifications by the use of the pump manufacturer chart with the relation flow / head and the determination of the operation point in the chart curve for each pump on evaluation, is highly recommended before assigning a pump to an aeration system to assure the selection of the less power consumption pump. Locally made diffusers gave low efficiencies, affecting by that the volume of dissolved oxygen volume entering the system.

Tested high quality air diffusers beside to appropriate air pumps could be imported from abroad, to ensure a proper functioning of the locally constructed plants. The obtained effluent can be further treated by a normal or slow sand filter, and disinfected to be reused for irrigation purposes after taking into consideration the local reuse standards and recommendations.

4. CONCLUSIONS

The adoption of such technology in the Palestinian Territory with lack of sanitation services, can lead to many positive impacts on the natural environment by:

1) improving the management of wastewater treatment and reuse
2) protect the surface and groundwater from potential contamination
3) increase the agricultural area by utilizing the reused water for irrigation
4) Limit health hazards as a result of illegal discharges of raw sewage.

The construction of small scale wastewater treatment plants locally, can contribute in solving a big portion of the problem generated by the untreated domestic wastewater in the Occupied Palestinian Territory; this can be achieved by making wastewater treatment technologies accessible for all. Moreover, the construction of such wastewater treatment systems locally can provide a decrease in the construction costs of such systems, contributing by that in the creation of a real alternative that can replace cesspits.

ACKNOWLEDGMENT

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