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DELIVERING WATER, SANITATION AND HYGIENE SERVICES
IN AN UNCERTAIN ENVIRONMENT

Using reed-bed system for wastewater treatment and reuse in urban semi/urban community in Gaza- Palestine

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The paper presents the outcomes of a study of a reed bed system for decentralized wastewater treatment in an urban community within the in Gaza Strip, Palestine. The study demonstrated the appropriateness of the system for small communities or single households in remote areas, and a BOD removal efficiency of close to 80%. Reed bed units have been shown to be a cost-effective system for disposal and treatment of wastewater, providing opportunity for effluent reuse. The biological complexity of the system within the root zone of the reed bed results in powerful water cleansing capability which is often much less constrained than in many chemical or mechanical treatment systems.

Background

The Gaza Strip is a densely populated area, with approximately 1,700,000 inhabitants within 365 Km2. The environmental situation has deteriorated since closure due to limited access to natural resources and over-population (PWA, 2011). The three wastewater treatment plants which serve the population are overloaded and poorly managed. Only 52% of the population are connected to sewage networks, with the remainder reliant on cesspits and septic tanks (PCBS, 2011). Identifying cost-effective solutions for wastewater management within this context remains challenging, particularly within areas without access to communal sewage networks. The use of Reed Bed systems for wastewater and sludge treatment is an innovative process (Nassar, et al 2006), combining traditional septic tanks and with natural wetlands. It is widely used throughout Europe, Asia, and Australia, and in more than 50 locations in the United States (Nassar, et al 2009). Reed Bed technology requires low construction costs and minimal costs for day-to-day operation and maintenance (Keefer, 2000). The system reduces wastewater contaminants, reduces solids, and provides sufficient storage time for stabilization of bio-solids prior to disposal.

Reeds act in many ways to alter the character of organic solids present in the wastewater (Afifi, 2003). Firstly, their root system provides oxygen, which boosts the population and activity of naturally occurring microorganisms, which, accelerate the biodegradation of organic material. Secondly, the plants grow rapidly in this nutrient-rich medium and absorb mineral contaminants (Nassar, et al 2009). Thirdly, roots extend from the reed stems into the bio solids which create a system of channels in the bio solids, allowing for continuous drainage and preventing the formation of a semi-impermeable layer, which is typical in unplanted beds (Mellstorm, 1994).

The paper presents the results of a pilot project in Bani Suheila, in the Gaza Strip, which tested decentralized reed bed systems for wastewater disposal and treatment within communities excluded from municipal sewage networks. In total, five units were constructed under the pilot. Each treatment unit served three to four households, producing up to 4 cubic meter of wastewater daily. The units are connected to septic tanks and reed beds, and use treated effluent water from the reed-bed for agricultural purposes or for recharge to the aquifer where agricultural use of effluent water is not possible.

The work was undertaken with the active participation of the beneficiary community, who played a significant role in the design of each system – supported through the leadership of the Palestinian NGO, Palestinian Environmental Friends (PEF). The project was overseen by Oxfam GB, who provided funding for and overall management of the study.

Treatment system design

Five decentralized units were constructed under the pilot. Figure 1 presents the layout of the treatment system, which consists of three parts as follows:

1. Septic Tank consisting of two chambers for the removal of suspended solids.
2. Vertical Flow Reed Bed unit for biological treatment of wastewater.
3. Outlet facility for reuse of effluent in agriculture or groundwater recharge.

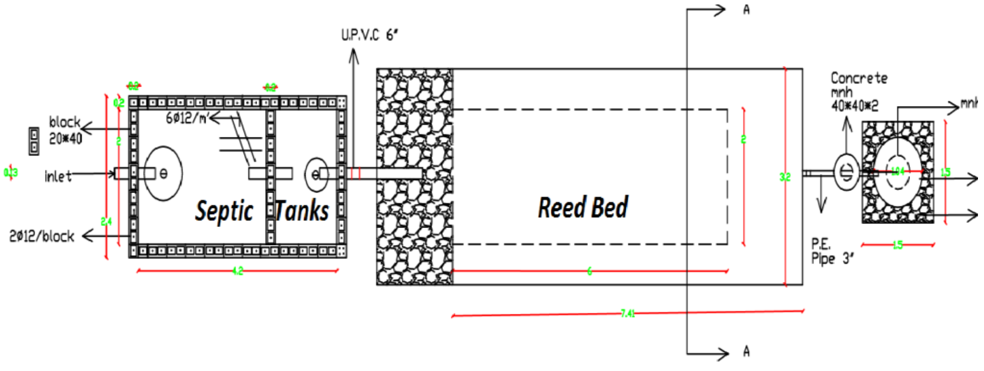

Figure 1. General lay out diagram of used reed bed treatment system - Plan view

Septic tank

A typical tank measures 4 × 2 × 2 meters, with a total volume of 16 m^3. Tanks consist of two chambers: the first chamber comprising of 2/3 of the total volume, with a detention time of two days; and the second chamber of 1/3 of the total volume with a detention time 1 day. In some cases, minor modification to these specifications was required to allow for available space onsite. Anaerobic digestion of settled organic material reduces the accumulated sludge, and thus the frequency of sludge removal.

Reed bed

The most important design criteria for the reed bed unit is the amount of time wastewater is retained in the bed. A typical bed measures 9 × 2 × 1.5 meters, with a total volume of around 27 m^3. As with the septic tanks, in some cases minor deviations from these dimensions were made to allow for space constraints at site. The design offers a relatively high detention time of up to two days, enabling greater opportunity for water treatment. The settled wastewater from the septic tank is introduced on the top layer of the bed as evenly as possible into a gravel layer. It is important to prevent effluent from surfacing, and minimise odour, as such, the inlet pipe covered with construction aggregate, with large (7-9cm) diameter rocks placed around the inlet and outlet pipes to allow the effluent to disperse easily and quickly, to minimize clogging and to make checking for root intrusion easier.

The reed basin is lined with a plastic sheet cover made of geo-membrane and filed with a range of aggregate:

Table 1.

Layer	Depth	Medium	Specifications
I (bottom)	45 cm	Gravel	3-4 cm diameter
II	25 cm	Gravel	2.5-3 cm diameter
III	25 cm	Kurkar (Eolianite)	
IV	55 cm	Sandy clay soil	
V	Top soil	Locally available Reeds (*Phragmites Communis*)	25 per m^2

Outlet facility

Where agricultural land was available, a flexible reuse system was added to the outlet of each unit, enabling use of the treated wastewater for irrigation. Where such land was not available, the treated effluent was recharged to Ground Water (GW) through approximately 1 m^3 of gravel system as presented in Figure 2.

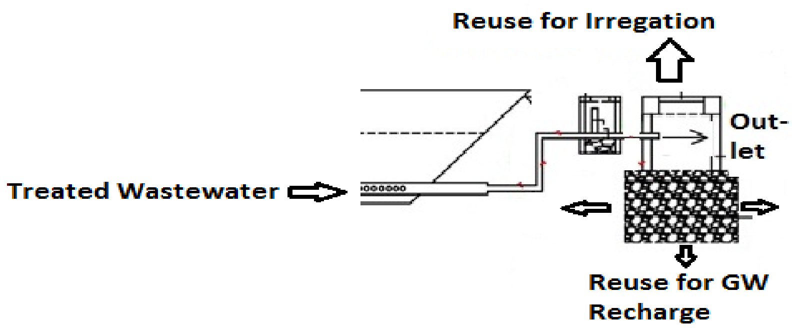

Figure 2. Flexible Reuse Out Let System For Irrigation or GW Recharge

Selection of beneficiaries and final unit design

Prior to selection of final beneficiaries, a field survey was conducted to select sites and communities for the units, taking into consideration the sustainability, accountability, transparency and community participation. Beneficiaries of the project were selected according to the following criteria:

- Lack of access to adequate sewage disposal and treatment facilities,
- Suffering from negative impacts of existing facilities,
- Available land for units,
- Presence of sloping ground to facilitate movement of processed water,

Monitoring and follow up

Operation of the units began in August, 2012, taking around one month for each unit to build up enough effluent in the system for outflow into the reed bed unit. A monitoring protocol was established for the influent and effluent at specifics locations throughout the system (see figure 3), with samples collected at two week intervals. The three sampling points were identified as follows:

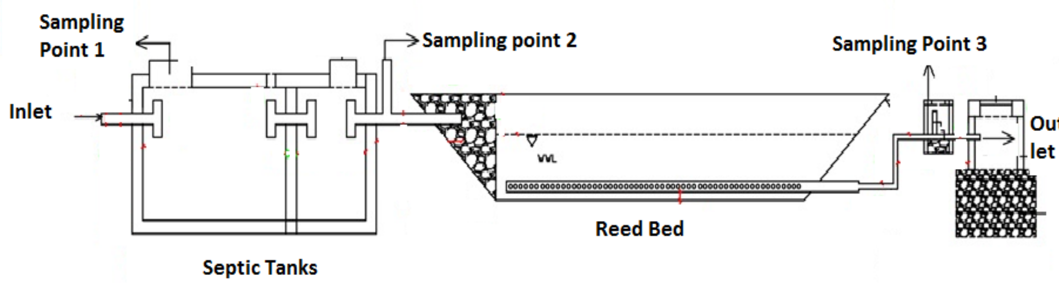

Figure 3. Different sampling point locations for monitoring

- Point 1: Raw wastewater coming from residencies to septic tanks, providing baseline reference for the effectiveness of the system,
- Point 2: Out let from septic tank (to reed bed), indicating efficiency of suspended solid removal from septic tank,
- Point 3: Reed bed out let, indicating treatment efficiency of the whole system,

The monitoring program included key parameters, including chemical, biological and physical parameters to assess the system's overall performance.

Results and discussion

The following is an analysis of results from one of the treatment units, based upon measurements taken between September and November 2012. Table 2 presents the average values of the tested parameters in the three locations.

Table 2. Average values of tested parameters in the three locations of sampling

Parameters	Sampling point 1	Sampling point 2	Sampling point 3	Removal %
pH value	6.8	6.9	7.1	-
Electrical conductivity m/	2100	2100	2007	-
Biochemical Oxygen Demand (BOD) mg/l	1050	497	222	78.8
Chemical Oxygen Demand (COD) mg/l	2207	883	415	81.2
Fecal Coliform (FC) u/100ml	..109	..107	..105	99.9 (4 logs)
Imhoff (settlable solids) ml/l	27.8	0.5	0.08	99.7
Total Slid (TS) mg/l	1800	1500	1450	19.5
Total Suspended Solids (TSS) mg/l	352	300	177	49,7
TKN mg/l	110	85	50	54.5

Initial results of the monitoring showed very promising treatment efficiency, with average BOD and COD removal through the septic tank and reed bed unit at more than 78% and 81% respectively. It is expected that the efficiency will be increased with time as the plant (Phragmites) grows and develops its root system. The removal efficiency of most municipal wastewater treatment plants in Gaza Strip stands at around 60% (PWA, 2012).

The Fecal Coliform (FC) removal is significant, at around 4 logs (99%). The level of FC in the effluent is expected to further improve with time as the plants grow. According to FAO guidelines, at this level water is suitable for reuse in agriculture (FAO, 1992).

Reed bed treatment systems are able to remove more than 50% of the nitrogen load, with TKN (Total Kejeldahl Nitrogen) seen present mostly within the septic tank. A reduction of around 50% in Total Suspended Solids (TSS) was also observed.

Testing showed an overall improvement in key indicators over time, supporting the hypothesis that as the reed root network develops, as does the effectiveness of the system. Figure 4 presents BOD levels in the three sampling locations over the monitoring period. BOD removal (the ratio between BOD at source and after each stage of treatment) was limited at the beginning of the operation, but improved remarkably after around one month of operation. It is expected that the efficiency of the system will continue increase in the first year of plant growth. Similar trends – as presented in Figure 5 **–** can also be seen for COD**.**

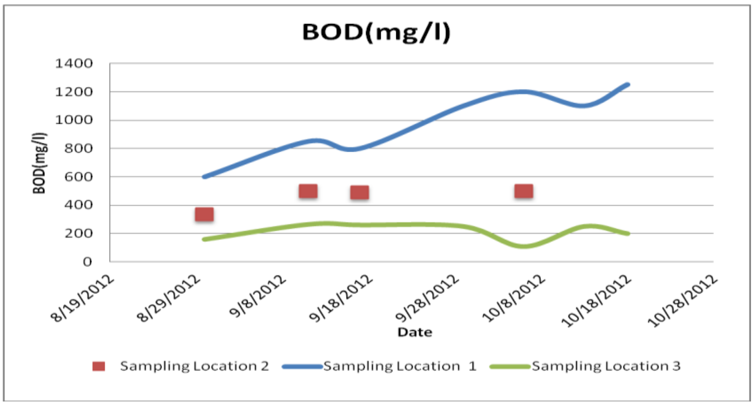

Figure 4. BOD Level in the Three Sampling Location in Monitoring Period

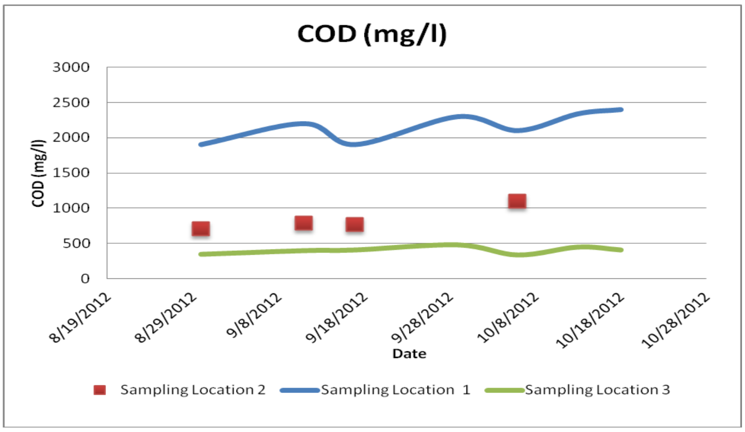

Figure 5. COD level in the three sampling location in the monitoring period

A field survey of beneficiaries conducted after start up of system operation showed that their monthly cost of sewage disposal reduced on average from around USD 20 to less than USD 4. In addition, the negative impacts from the previous system have been removed. Moreover, the majority of beneficiaries are now reusing the effluent for olive plant irrigation.

Conclusions

The main objective of the pilot was to provide effective wastewater treatment and reuse systems in areas without access to sewage systems in urban/peri-urban areas of the Gaza Strip. Throughout the project the following observations can be concluded:

- Reed bed systems are appropriate practice for small communities or single households in remote areas lacking access to communal sewerage systems, and are often a good complement to a septic tank.
- The systems are highly effective in removing biological, chemical and physical contaminants from effluent.
- Reed beds are a highly cost-efficient system for disposal and treatment of wastewater in urban peri/urban communities, and provide additional benefits in terms of effluent reuse.
- Participation of beneficiaries in the design process is a guarantee for sustainability, ensuring interest and enthusiasm in operation and maintenance of the system.
- The complexity of microbial life forms and the reactions within the root zone of the reed bed result in a powerful water cleaning capability which is often much less constrained than in many chemical or physical treatment systems.

Keywords:
Wastewater Treatment, Urban Semi/urban Community, Gaza Strip, Palestine, Reed Bed

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