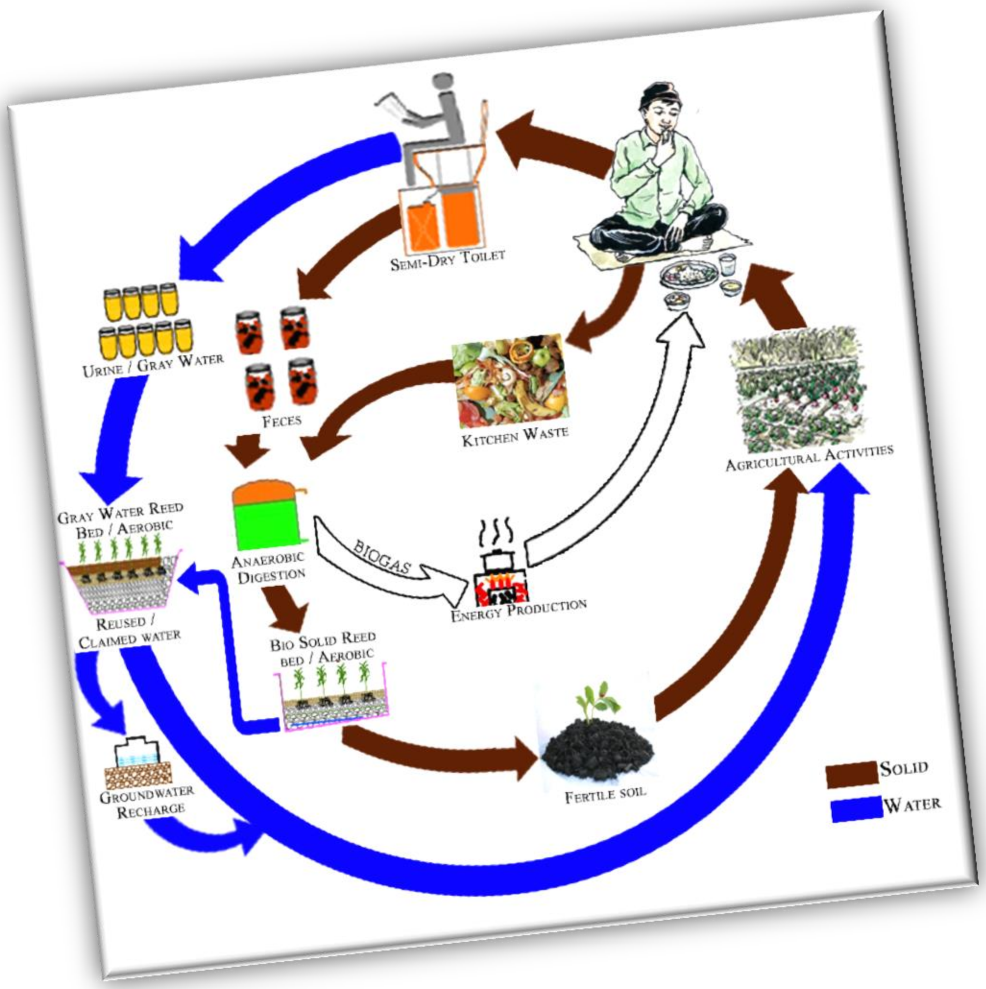
Developing An Integrated Sustainable Sanitation System For Urban Areas: Gaza Strip Case Study

Prepared for: ***GCSM Competition***
Prepared by: ***Samir Alnahhal***
Date: ***2014***



1 Abstract

Nowadays, it is estimated that there are 2.7 billion people without access to basic sanitation. Yet, worldwide, more than 90% of the wastewater does not receive any treatment at all, thus contaminate a large amount of fresh water [1]. As a consequence, it is estimated that every 20 seconds, a child dies globally due to diarrhea, cholera and other enteric diseases as a result of poor sanitation [2].

In Gaza Strip, about 30 % of more than 1.7 million people have no access to sewage facilities which varies from areas. The total annual wastewater production is estimated to be 40 million m3 annually, of which 24 million m3 passes into sewerage networks [3]. Due to reduced capacity overloaded, and partially functioning of the four existing wastewater treatment plants, this sewage is either untreated or partially treated, and finally released into the Mediterranean Sea [4]. The rest of daily produced wastewater (42%) is directly infiltrated to the ground without any further treatment through cesspools or pit latrines [5]. As a result of sewage infiltration and overexploitation, 95 % of the coastal aquifer, the sole source of fresh water available for Palestinians in the Gaza Strip, is polluted with dangerous levels of nitrates and chlorides way above the standards recommended by WHO [6]. In Gaza strip, the waterborne sanitation systems are conventional and have its drawbacks regarding the water use, cost, and the health risks. In this system about 50 to 100 liters of freshwater is consumed to evacuate daily production of 1 to 1.5 liters of excreta [5].

Through this work, a vertical flow constructed wetland using reed bed was used for the treatment of bio-solid and gray water/ settled wastewater. The results present a positive performance in treating the bio solids and the well-stabilized accumulated organic material in the bed formed fertile (black) soil. In other hand, using vertical flow reed bed of liquid waste treatment showed removal of around 70% of organic matter indicator Biological Oxygen Demand (BOD5) and Chemical Oxygen Demand (COD). The Fecal Coliform (FC) removal was around 2 logs (99.9%) with a retention time of less than two days. The effluent can be used in agriculture or groundwater recharge. A semi-dry toilet followed by anaerobic/aerobic units is in planning to be coupled with an existing system. The system mainly depended on separating of the human excreta from the urine and gray water.

The two separated fractions will be treated in vertical flow reed bed to produce organic fertilizer and reclaimed water for reuse. The designed and planned system integrated environmental and technical sound approaches with socio- economical aspects. In addition, the designed system implemented the idea of a natural and closed circle of water and nutrients “from food to food”.

2 Introduction

The way to sustainable management of natural resources is one of the greatest challenges of present time. The societies´ sustainability depends essentially on secured water resources, food supply and an intelligent management of wastes. Sustainable sanitation aims to overcome the conventional sanitation systems drawbacks. It is not a certain technology, but an approach with certain underlying principles. There are number of technologies that can be used to make sanitation and wastewater management more sustainable. Therefore, the main objective of any sustainable sanitation system is to protect and promote human health by providing a clean environment and breaking the cycle of disease. In order to be sustainable, a sanitation system has to be not only economically viable, socially acceptable, and technically and institutionally appropriate, it should also protect the environment and the natural resources [8].

Any sanitation systems need to be evaluated carefully with regard to all dimensions of sustainability. Since there is no one-for-all sanitation solution, which fulfills the sustainability criteria in different circumstances to the same extent, this system evaluation will depend on the local framework and has to take into consideration existing environmental, technical, sociocultural and economic conditions. There is no “one-fits-all” approach; rather, the most adequate solution has to be found from case to case, considering climate and water availability, agricultural practices, socio-cultural preferences, affordability, safety, and technical prerequisites [9, 10]. Taking into consideration these entire range of sustainability criteria, Semi Dry Toilet System (SDTS) arises as a sustainable sanitation alternative to conventional sanitation systems, which can improve several social and ecological issues in rural and urban regions as well. The SDTS cope with essential minimal use of water to meet hygienic and socio-cultural needs and integrate reuse of emitted water and bio-solid.

3 Work Scope and System Description

The main scope of this work is to apply the SDTS approach under the local circumstances of Gaza strip and similar regions worldwide through source separation of the human excreta “bio-solid” and urine “liquid waste”. The two separated fractions will be treated in vertical flow reed beds. Reeds act in many ways to alter the character of organic solids present in the wastewater [4]. 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 some of the minerals. 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 [11].

The main concept of SDTS is to implement the idea of a close natural circulation system of water and nutrients “from food to food”. The basic principle of the system is to collect excreta (Bio-Solid) separately from urine and gray water (liquid waste). The human excreta and bio kitchen waste will be treated using anaerobic digestion to produce Biogas (Energy) and to stabilize the fresh human excreta. The further treatment of bio-solid followed by vertical-flow reed bed (aerobic), which will generate an odor and pathogen free highly fertile soil. The separated urine and gray water will be treated in a second vertical flow reed bed. The treated water can be reused directly in agriculture or indirectly for groundwater recharge. The outcomes of the system ultimately ensure the production of new food and closing the loop of human nutrition as presented in Figure (1).

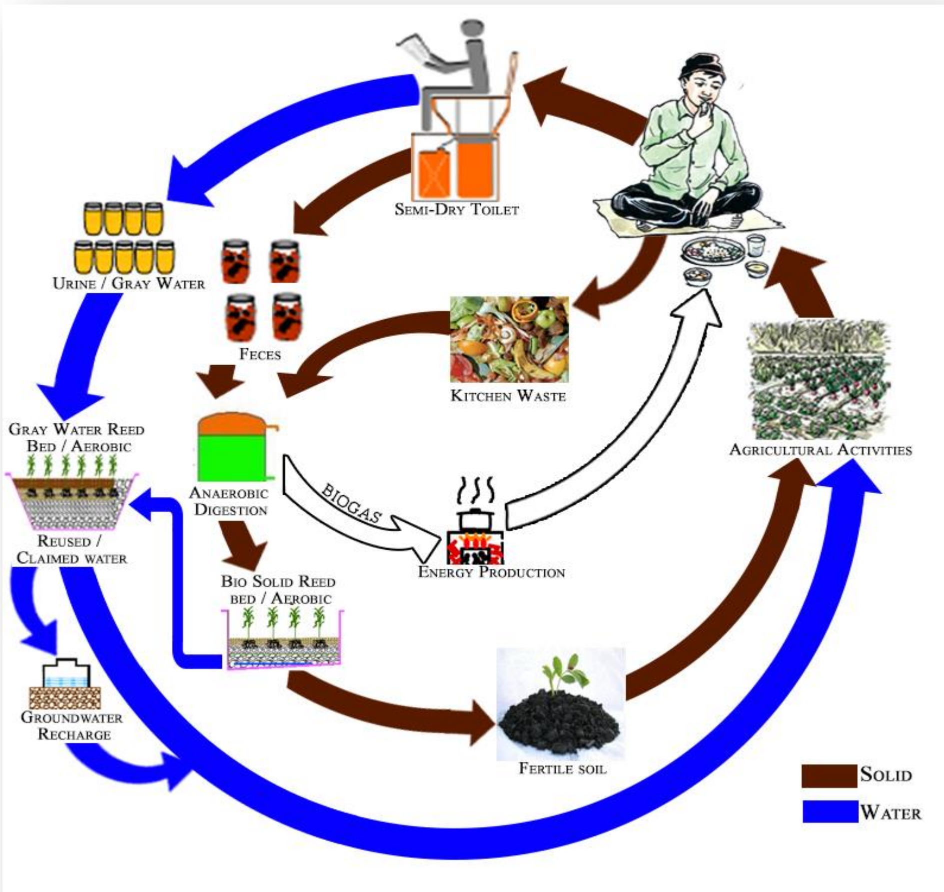


Figure 1: Integrated sustainable sanitation system for urban areas

Since many years, Gaza strip went through many sanitation systems in fragmented ways. Many researches and pilot projects were implemented to treat the bio-solid alone using different biological and environmental approaches. In addition, the liquid waste was also targeted in old and new researches.

Depending upon the current sanitation systems that mainly fulfill the requirements and steps of the SDTS, this work tried to incorporate up-to-date results with future planned development as shown in Figure (2). Such results and tests could help in integrating all current and needed systems with the advanced innovative technologies of reducing water consumption system and circulation for nutrients. Such integration finally need to accomplish the concept of SDTS to make the source separation of the both bio solid and liquid waste and implement the full recycle of the waste elements: bio-solid, energy, liquid, and nutrients. The Gaza team implemented successfully the bio solid and gray water treatments in vertical flow reed beds. The adopted innovative technology for the source separation and design of semi dry toilets to be integrated with up to date results. Such toilets will be designed to separate the human excreta from the urine. The excreta will be transformed through special ducts; or directly transformed to the anaerobic treatment units. The bio-solid becomes more stabilized, the bad odor is reduced, and biogas is created to produce the energy. The reed bed treatment unit would be used to finally treat of bio-solid and to create the fertile black soil.

The separated urine" liquid waste" is collected and mixed with the other generated gray water from the different domestic sources at the household level such as the shower, kitchen, washbasin, and laundry. The mixed gray water is finally transformed through the gray water network to the aerobic biological treatment unit (vertical flow reed bed), in which, the reclaimed water is transformed to the final outlet facility for reuse in agriculture or/and groundwater aquifer recharge. The following schematic diagram in Figure (2) summarizes the scope of the work and methodology.

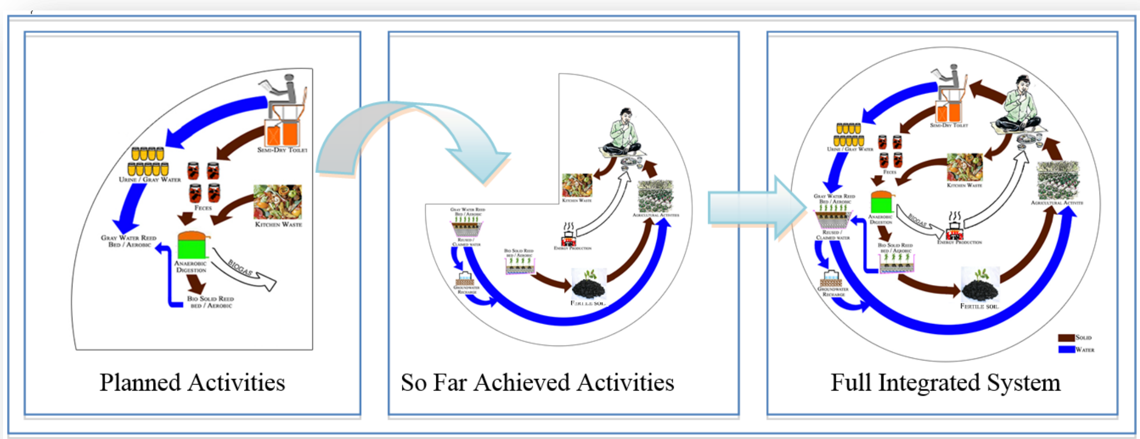


Figure 2: Schematic diagram for the scope of the work and methodology

In the following point, the so far achieved result of using vertical flow reed bed system for liquid and bio solid waste treatment will be presented.

4 So Far Achieved Activities and Designs

4.1 Bio-Solid Waste Treatment:

In Gaza Strip, the human excreta are commonly accumulated in onsite sanitation systems such as septic tanks and cesspools where no sewage networks are available. The random discharge of this material resulting in degradation of environment and serious public health risks [4, 12] such as groundwater pollution and transmission of enteric related diseases [13] . Accumulated human excreta “septage” must be properly treated before disposal. However, the septage contains essential nutrients (nitrogen and phosphorus) and is potentially beneficial as fertilizers for plants. The organic carbon in the septage, once stabilized, is also desirable as a soil conditioner, because it provides improved soil structure for plant root [14].

The Vertical flow constructed wetland was planted using reed bed for bio-solid waste handle and disposal as low-cost and environmentally sound technique. In such system, both dewatering and organic matter decomposition by aerobic biological activity achieved and helped in final formation of organic materials in fertile black soil. Several factors influenced vertical flow constructed wetland efficiency such as sludge quality, climate, loading rates, and feeding frequencies [13].

For more details about the results and discussion regarding the adopted and used bio-solid waste treatment system, see appendix 7.1: Results of Bio-Solid Waste Treatment

The main dimensions of used vertical flow reed bed for treating the bio-solids waste was; 3m length * 1.5m width * 1.3m depth with total volume of about 6 cu. m. The bed was constructed using painted galvanized steel to reduce the heat absorption. The bed depth was filled with different types of gravels and soils as following (from bottom to top):

- Bottom layer was filled with gravel size (25 – 40 mm) of 15 cm thick.
- The next upper layer was filled with gravel size (10 – 25 mm) of 15 cm thick.
- The top layer of 10 cm thickness was filled with silty sand (fine sand)
- A free board layer of 70 cm thickness was arranged for accumulating the bio-solids
- The bed was planted using local reeds (Phragmites Australis) at the top layer.
- A perforated PVC pipe was installed above the bottom layer by 15cm to act as a drainage system and to collect infiltrated water as in Figure (3). The perforated pipe could be connected with storage tank to store the percolated water.

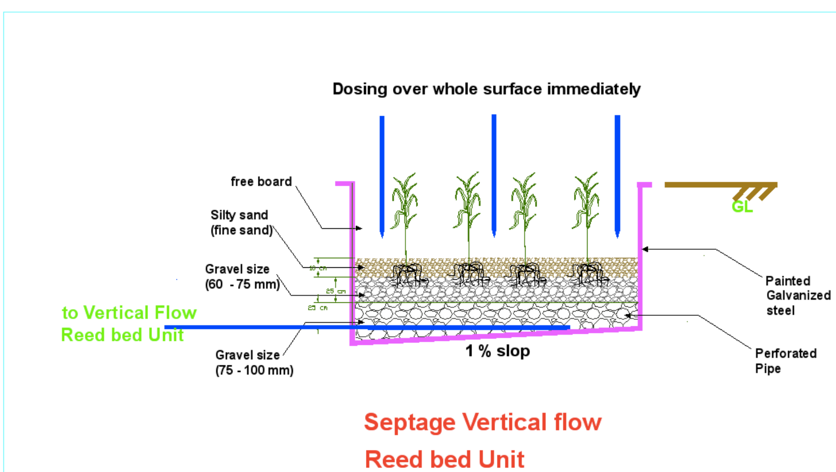


Figure 3: Septage vertical flow reed bed unit

4.2 Gray water/ settled wastewater treatment and reuse

A reed bed is essentially a channel, lined with an impermeable membrane, that is filled with gravel and planted with local reeds and used to treat wastewater.
A vertical flow (reed bed) wetland was used to treat gray water or (settled wastewater) effluent from septic tank, which used to trap the bio-solid and some of the suspended solids before flowing to the reed bed.

Wastewater, black or gray, is passed through the root zone of the reeds where it undergoes treatment. Inlet and outlet pipes are positioned below the gravel surface, so that the water always remains below the gravel surface, thus excluding human exposure to the wastewater, mosquito breeding and unpleasant odors.

i. System Design and Operation

The residence time is the main design criteria for the biological treatment in constructed wetland (reed beds). This residence time aids with the treatment by allowing sufficient time for the settling and filtering of suspended solids, nitrification/De-nitrification to occur, fixation onto the substrate, breakdown of organic matter and nutrient removal via microorganisms and plant uptake. Retention time is generally governed by the surface area and depth of the reed bed. The residence time was calculated based on the function:

Residence time = Reed Bed Volume X Porosity/Daily Wastewater Generation

The gray water enters the reed bed via the inlet pipe positioned at a height greater than the outlet pipe, and disperses the wastewater as evenly as possible into the gravel. It is important to prevent surfacing of effluent and the escape of odors. Therefore, the inlet pipe should be covered with aggregate. Larger diameter aggregates must be placed around the inlet and outlet pipes to allow the effluent to disperse easily and quickly, to minimize clogging and make checking for root intrusion easier. Reed beds dimensions should have a length to width ratio between 3:1 and 1:1.

The outlet facility was designed and constructed to double benefit of reusing the effluent. The effluent could be managed to be reused in irrigating the backyard farms if available and/or to be reused in recharging the groundwater aquifer. Moreover, the facility could be arranged to restore the claimed wastewater for time need and reuse. The groundwater recharging facility could be arranged with larger gravel size to make the effluent quickly and smoothly infiltration.

For more details about the results and discussion regarding the adopted and used gray water/ settled wastewater treatment and reuse, see appendix 7.2: Results of gray water/ settled wastewater treatment and reuse.

ii. Design Criteria

The following are the main design criteria of the used vertical flow (reed bed) constructed wetland and the reused outlet facility as shown in figures (5) and (6):

- The average daily water consumption is 70 liter/person based on EWASH fact sheet 2011 [7]
- The average of household size in Gaza strip is 6.3 based in PCBS 2011.
- The average daily wastewater consumption is 80% of the water consumption of about 3.5 cu. m.
- The bed was designed to serve more than 50 persons in 8 households living in multistory buildings
- The general dimension was (7.4*2.6*1.5 m) of a total volume 29 cu. m.
- A residence time of about 3 days, which offered better treatment opportunity, was achieved.
- The system enabled the vertical flow of the settled wastewater / gray water influent with settling the bio- mass on the top layer of the bed and as evenly as possible into a gravel layer. In order to prevent surfacing of effluent and bad odors, the inlet pipe covered with relatively larger aggregate of (75 mm- 100 mm) diameter size as well as outlet pipe. Using the relatively larger aggregate allow quick and smooth flow, minimize clogging, and ensure easier root intrusion.
- The bed was lined with plastic sheet made of Poly Ethylene.
- The bed was filled and lied with different aggregates sizes as following (from bottom to top):
  - The thickness of bottom layer was 45 cm and gravel size (75 mm – 100 mm)
  - The next layer thickness was 25 cm and gravel size (60 mm – 75 mm)
  - The second next layer was silty-sand soil of 25 cm thick
  - The upper layer was cutoff soil of 55 cm thick
- The top layer was planted with local reed 25 seedlings for each square meter
- The reuse outlet facility mainly consisted of the following:
  - Storage water tank of 250 liters capacity connected directly with the reed bed effluent pipeline in order to restore the reclaimed wastewater and reuse in appropriate times.
  - The storage tank was arranged with water pump of 1.0 horsepower capacity to pump stored reclaimed wastewater in irrigation.
  - The storage tank was also connected with the groundwater recharging facility
  - The groundwater recharging facility was arranged with recharging manhole and larger size aggregate below the recharging manhole.
  - The recharging manhole was open bottom end concrete manhole of 80 cm diameter and 100 cm depth.
  - Below the recharging manhole, the local soil was replaced with larger gravels of (75- 100 cm) diameter size for 100 cm deep.

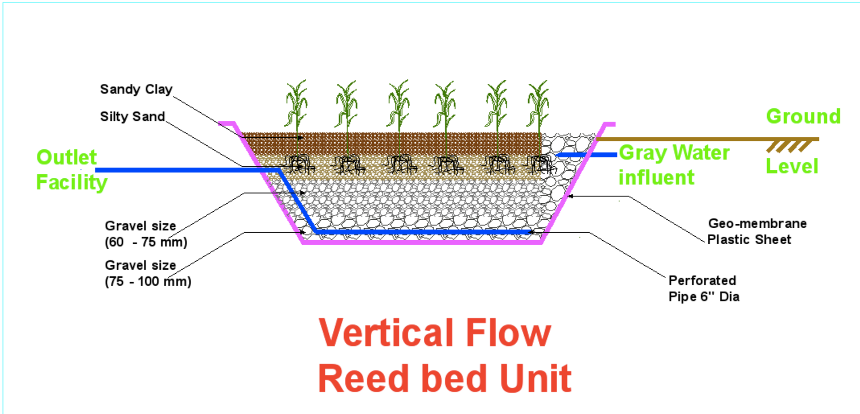


Figure 4: Schematic diagram for the Gray water vertical flow (reed bed) constructed wetland

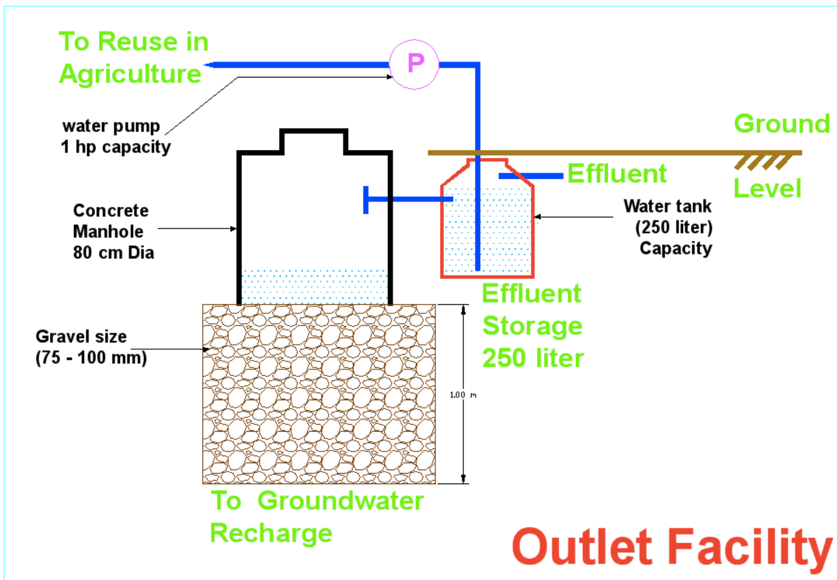


Figure 5: Schematic diagram for the gray water vertical flow (reed bed) constructed wetland

For more details about the drawings and design regarding the adopted and used gray water/ settled wastewater treatment and reuse, see appendix 7.3: design drawings for the gray water/ settled wastewater treatment and reuse and the AutoCAD attached file.

iii. Manufacturing process

The manufacturing process of the gray water vertical flow (reed bed) constructed wetland is a construction process. Main steps of the construction process are as following:

1. Selecting the proper location for constructing the bed based upon the level and depth of the household gray water outlet. The outlet will be below the surface of the bed as early mentioned. During the construction, the raw gray water effluent is recommended to flow under gravity in the wetland.

2. Excavating the local soil of the bed taking in consideration designed dimensions and selected location. Safety measures need to be considered during the excavation.
3. Lining the plastic sheet in the excavated bed. The plastic sheet should cover the outer upper edges of the bed with reasonable distance. The plastic sheet should be lined carefully to avoid any rupture and deteriorations. The purpose of the plastic sheet is to contain the gray water or settled wastewater for the treatment purposes besides all needed and filled gravels.
4. Filling the bottom layer using larger gravels of size (75 mm to 100 mm) for 15 cm thickness.
5. Installing the perforated 6” PVC pipe above the 15 cm large size gravel layer. One end is closed which is near the influent side. The other end will be open to connect the effluent P.E. pipe 3” dia.
6. Fitting the effluent P.E. pipe of 3” at the effluent end of the perforated PVC pipe. The other end of the P.E. pipe should be fitted outside the bed at a level of 20cm from the bed edge.
7. Continue filling the bottom layer till reaching the 45 cm thickness using the same gravel size.
8. Filling the next layer of 25 cm thick using gravel size (60 mm – 75 mm). However, the inlet side of the bed should be filled from bottom to top using larger gravels (75 mm to 100 mm)
9. Filling the next layer of 25 cm thick using silty sand soil.
10. Installing and fitting the inlet pipe of raw gray water inside the bed by 100 cm.
11. Filling the upper layer of 55 cm thick using the cutoff soil. The rest of cutoff soil could be removed from the construction site.
12. Planting the reeds seedlings in the upper layer. 4 reed seedlings are planted in every 100 sq. cm in the bed top surface area.
13. Excavating the local soil for installing the storage tank and the groundwater recharging facility.
14. Installing the storage tank and fitting the effluent pipe from bed and the pipe connected to the recharging manhole. The reuse pipe and 1.0 horsepower water pump will be fitted.
15. Filling the recharging gravel of general dimensions (100 X 150 X 150) cm below the recharging manhole. The recharging gravels used will be larger size (75 mm – 100 mm).
16. Installing the recharging manhole of 80 cm diameter and 100 cm depth above the recharging gravel. All pipes and fittings will be fitted correctly and effluent flow under gravity should be maintained.

For more details about the bill of quantities and technical specifications of the pilot unit used as a gray water/ settled wastewater treatment and reuse, see the MS Excel file

For more details about the photos of the pilot unit used as avgray water/ settled wastewater treatment and reuse, see the photos folder

5 Future Planned Activities

5.1 Semi Dry Toilet for Human Excreta separation

The semi dry toilet is planed to be designed to separate the human excreta and urine. Semi dry toilet as planned is innovative equipment suitable for daily basic sanitation needs and effective for source separation of the human excreta and urine. The idea of this toilet depends upon closing the natural cycle of the nutrients and from food to food cycle, moreover, to reduce the water consumption.

The main structure of the proposed toilet consists of two main basins. The first basin will be used for the urine separation, collection and transformation. The design surface area of the urine basin will be approximately 2/3 the toilet surface area. The basin structure will be designed with reasonable slopes for quick and hygiene release of the urine. The basin at the bottom will be connected to the house level gray water network in order to let the urine transfer and easly connect to the different sources of gray water such as washbasins, showers, and kitchen basins, etc. The gray water will be finally connected to the vertical flow (reed bed) constructed wetland for the treatment and reuse.

While as, the second toilet basin will be designed for the feces separation, collection, and transformation for treatment and reuse. The feces transformation will be through using either special ducts or directly flow under gravity to the anaerobic digestion and aerobic treatment units. A mixer or mangetic stirrer to mix the feaces in a very little quantities of water; and to make the feaces be in liquid phase and to be more homogenous. Using such mixing mechanisim will make the transformation of the feaces more easily, cost-effective, and more haygine.

The main design criteria for the semi dry toilet will be as following:

- The system efficiency will ensure the minimization of the loss of carbon and nutrients and water.
- The system will be in a reasonable total life cycle cost, including production, installation, maintenance and operation costs.
- The system will be technically and sociologically adapted to the targeted culture.
- The system will be robust enough for the minimal deviation of the system operation.
- The system will be safely and hygienic handle of the human excreta and urine.

A spray bidet can be added to the toilet for many reasons as following:

1. To promotes practical dual-hygienic cleansing of both genitals and anal area with a single toilet unit.
2. To consume the water use during cleaning the toilet unit.
3. It is not expensive as compared to separate bidet units and saves toilet paper.
4. It does not require extra space in your bathroom for a separate unit.
5. It is easy to install

5.2 Human Excreta anaerobic biological treatment

The human excreta will be treated anaerobically before the direct apply (aerobic) treatment in order to double the benefit in reusing the excreta. The anaerobic treatment will be used to produce biogas, while the aerobic treatment followed with the anaerobic treatment will be used to form the fertile soil.

From source in the semi dry toilet, the seperated human excreta (bio-solid) will be mixed with little water for cleaining, disposal and transfering purposes of the excreta under the gravity. The human excreta will be transferred to the anaerobic digestion unit. In the digestion unit, a bacterial decomposition process occurs and stabilizes the organic wastes of the bio-solid; and produces a mixture of methane and carbon dioxide gas (biogas). The biogas will be reused in producing the energy needed for the human. In addition, through the anaerobic digestion, the bad odor of the fresh bio-solid and the possibilities for growth of bleeding insects will be totally reduced and disappeared.

The anaerobic deignestion unit will be designed and optimized to contain the daily generated quantities of the human excerta and the kitchen organic wastes based on the previous design critera and number of people sarved by the unit. In Gaza strip, the kitchen organic waste is about 55% of the total solid waste. Based on the previous studies, the daily average generated quantities of solid wastes per person is about 700 gm.

The generated well-stabilized bio-solid from the digestion unit will be transferred to the aerobic treatment in the septage vertical flow (reed bed) constructed wetland. In the wetland, the fertile soil will be formed due to continuous accumulation of the decomposed bio-solids with reasonable time in the free board of the wetland.

6 References

1. *WHO.10 facts on sanitation. World Health Organization. March 2011.*
2. *Corcoran E, Nellemann C, Baker E, Bos R, Osborn D, Savelli (eds) H. Sick water; The central role of waste- water management in sustainable development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal. www.grida.no. 2010.*
3. *PCBS. Press conference on the preliminary findings of agriculture census-2010. Palestinian Central Bureau of Statistics. Palestine. 2011.*
4. *Afifi, S. Septage treatment in a vertical flow reed bed system. International Conference on Engineering and City Development, Gaza – Palestine: September 2003.*
5. *PWA. Assessment of wastewater treatment and reuse. Palestinian Water Authority, Palestinian Authority. April 2011.*
6. *EWAH. Five years of the Blockade: the water and sanitation situation in the Gaza Strip. The Emergency Water, Sanitation and Hygiene Group in the OPT. June 2012.*
7. *B'Tselem. Over 90% of water in Gaza strip unfit for drinking. Gaza strip. The Israeli Information Center for Human Rights in the Occupied Territories. Feburary 2014.*
8. *Langergraber G. Are constructed treatment wetlands sustainable sanitation solutions?. Water Sci Technol. 2013;67(10):2133-40. doi: 10.2166/wst.2013.12.*
9. *SUSANA. Towards more sustainable sanitation solutions. Sustainable sanitation alliance SuSanA. Version 1.1 November 2007*
10. *SSWM. Sustainable Sanitation. Sustainable sanitation and water management SSWM. 2012.*
11. *Afifi S, Bazazew N, Arakelyan K, Nassar A, Wise T. Using reed-bed system for wastewater treatment and reuse in urban semi/urban community in Gaza- Palestine. 36th WEDC International Conference, Nakuru, Kenya, 2013.*
12. *Koottatep T, Surinkul N, Polprasert C, Kamal ASM, Koné D, Montangero A, Heinss U, Strauss M. Treatment of septage in constructed wetlands in tropical climate – Lessons learnt after seven years of operation. Water Science & Technology, Vol. 51 (9) pp 119–126.*
13. *Vincenta J, Mollea P, Wisniewskib C, Liénarda A. Sludge drying reed beds for septage treatment: Towards design and operation recommendations. Bioresource Technology, Volume 102, Issue 17, September 2011, Pages 8327–8330.*
14. PSA. Sanitation Technology Information Sheet: septage treatment. Philippine Sanitation Alliance. January 2008

7 Appendix

7.1 Results of Bio-Solid Waste Treatment

The total solids (TS), Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP) and Fecal Coliform (FC) are the parameters used to evaluate the efficiency of the reed bed system in treating the bio-solid. Table 1, shows the average concentrations of these parameters for the applied bio-solid and percolated water from reed bed unit.

Table 1: The average concentrations of the chemical and biological applied bio-solid and percolated water from reed bed

Parameters	Input (Bio Solid)	Output (Percolate Water)
COD mg/l	14,200.00	600.00
BOD5 mg/l	7,800.00	250.00
TS mg/l	10,186.00	1,000.00
TKN mg/1	2,926.00	56.00
TP mg/1	1,385.00	9.50
FC /100 ml	3.00×10^4	100.00

The BOD_5 and COD concentrations in the percolated water were significantly reduced. The removal percentage of COD and BOD_5 were 95.77% and 96.79% respectively. The removals percentage of TKN and TP were 98.10% and 99.31% respectively. The removals percentages of the biological indicator FC were 99.67%. The results showed high efficiency of the system in treating the percolated water. The treatment effectiveness can be associated with the reed plants biological ability to transfer the Oxygen through their leafs, stems and roots, resulting of high biological activities of available microorganisms in rhizo-sphere layer.

The bio solid treatment efficiency of the reed bed system was checked in removing the total solids in two scenarios: low and high bio solid loadings. The monthly total solids applied quantities in both low and high loadings were 9.37 kg/m2 and 13.16 kg /m2 respectively.

The average percent of the TS removals were 90% and 71% in the low loading and high loading respectively. Figure (4) shows the total monthly bio solids applied, accumulated and removed. The results present a positive

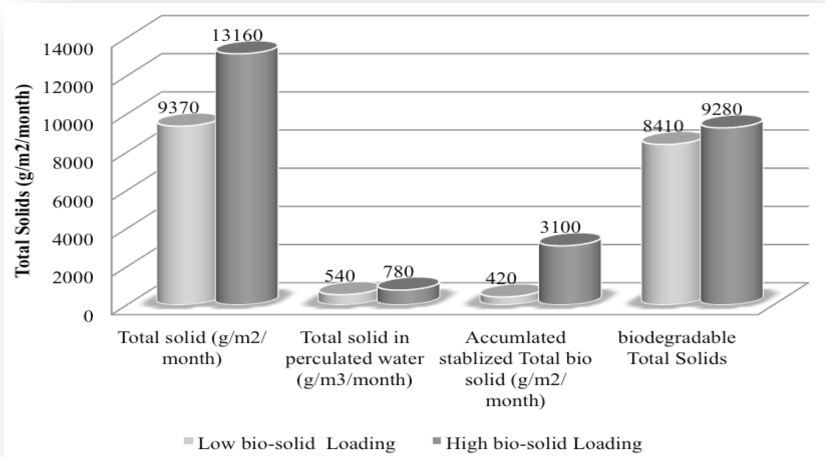


Figure 6: Bio-solid treatment efficiency for reed bed system.

7.2 Results of Gray water/ settled wastewater treatment and reuse

The efficiency of the gray water / settled wastewater reed bed system was check by testing the influent and effluent water. The test of the influent and the effluent consisted the chemical and biological related parameter as presented in table (3).

Table 2: The average values of measured chemical and biological parameter

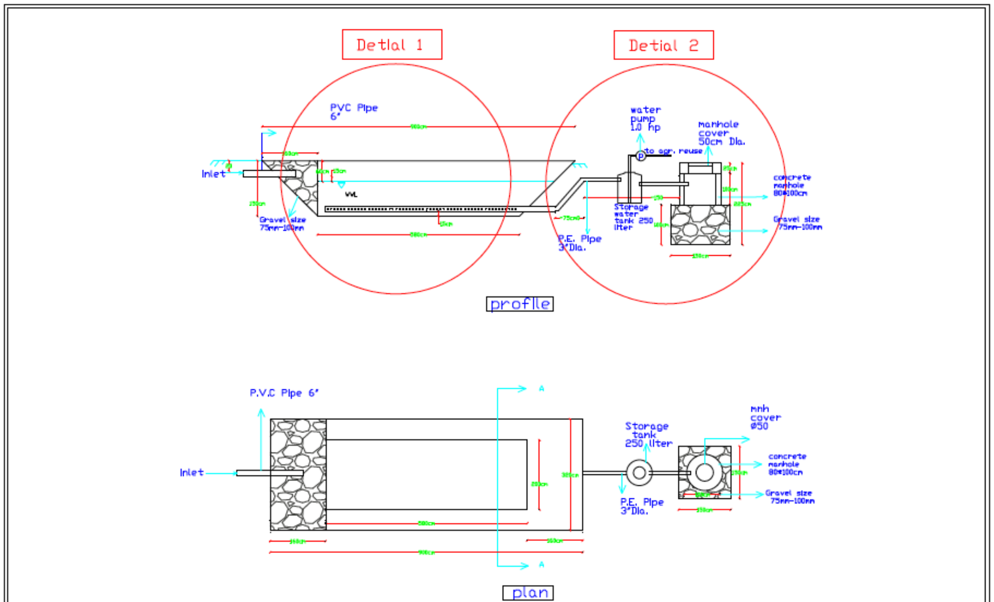
Parameters	Influent (Gray water / settled wastewater)	Effluent (Reclaimed water)	Removal %
BOD5 mg/l	397	122	69.3
COD5 mg/l	683	215	68.5
FC u/100ml	..10^5	..10^3	99.9 (2 logs)
Imhoff (settlable solids) ml/l	0.5	0.08	84
Total Slid (TS) mg/l	1500	1250	19.5
Total Suspended Solids (TSS) mg/l	300	177	41
TKN mg/l	85	50	54.5

The related chemical and biological parameters was tested in the first 3 months of the system after operation. Such initial results represent good potentials for the treatment efficiency of used system. It is expected that the efficiency will be increased with time as reed plant will grow up and their roots net will be enhanced and increased to perform better transfer of the Oxygen needed for the biological activities of the available microorganisms in Future Planned Activity rhizo-sphere layer.

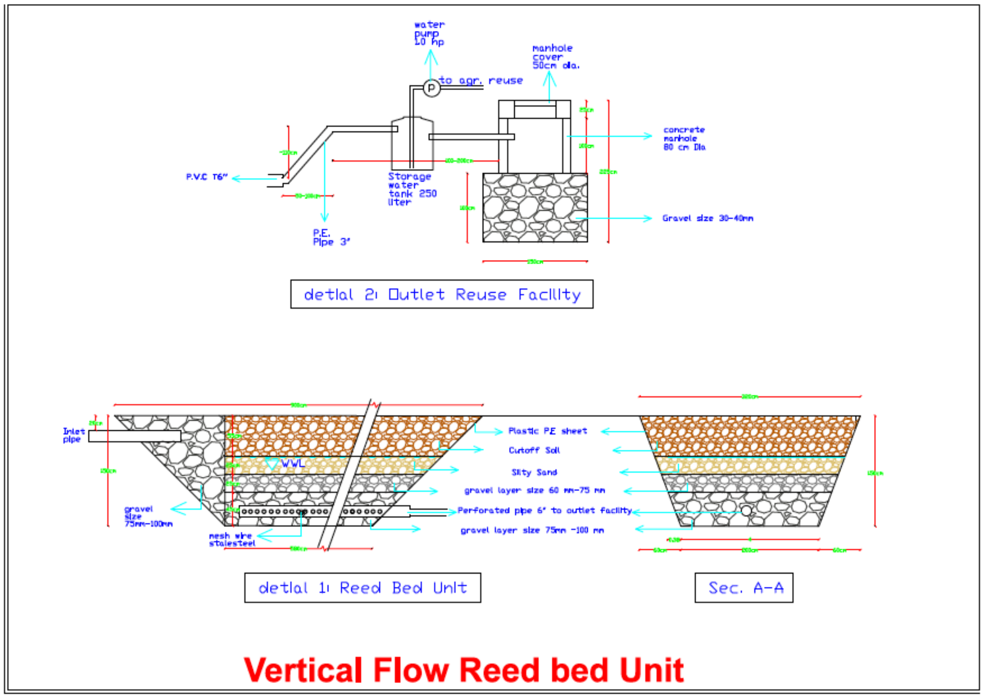
The average removals of the measures BOD5 and COD in reed bed unit were about 69% and 68% respectively. The fecal coliform (FC) removal is the biological indicator for the significant efficiency of the reed bed system, which was around 2 logs (99.9%) with a retention time around less than 2 days. While, the normal level of FC removal in Stabilization Bond System with retention time around 20 days reaches 4 logs. This is very significant indicator for the effectiveness of the reed bed treatment system. This level of (FC) removal is suitable for reuse in agricultural activities based on the FAO guidelines.

7.3 Design drawings for the gray water/ settled wastewater treatment and reuse

The design drawings are prepared in AutoCAD software as attached



Vertical Flow Reed bed Unit



Vertical Flow Reed bed Unit

8 Attachments

1. Design Drawings
2. Bill of Quantities with market costs
3. Photos / pictures
4. Video summerizing our contribution
5. Business model canvas