World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:3, No:5, 2009

Photovoltaic Small-Scale Wastewater Treatment Project for Rural and New-Cultivated Areas in Egypt

Fadia M. A. Ghali

Open Science Index, Environmental and Ecological Engineering Vol:3, No:5, 2009 publications.waset.org/9943/pdf

***Abstract*—**The problem of wastewater treatment in Egypt is a two-fold problem; the first part concerning the existing rural areas, the second one dealing with new industrial/domestic areas. In Egypt several agricultural projects have been initiated by the government and the private sector as well, in order to change its infrastructure. As a reliable energy source, photovoltaic pumping systems have contributed to supply water for local rural communities worldwide; they can also be implemented to solve the problem "wastewater environment pollution". The solution of this problem can be categorised as recycle process. In addition, because of regional conditions past technologies are being reexamined to select a small-scale treatment system requiring low construction and maintenance costs. This paper gives the design guidelines of a Photovoltaic Small-Scale Wastewater Treatment Plant (PVSSWTP) based on technologies that can be transferred.

***Keywords*—**Renewable energy sources, Photovoltaic, small-scale projects, wastewater treatment.

I. Introduction

IN the developing countries the wastewater treatment field, which is an important sector of public health, has been left stationary while major upgrading projects improved the water supply systems in many countries and provinces. This trend basically ignored the downstream effect of improved water supply, that of increased discharges into rivers or aquifers. Two reasons appear to be the major cause for that: firstly, wastewater collection and treatment is costly and their benefit often hard to show; and secondly, even if low cost solutions are being implemented many projects fail to deliver the expected outcome. Without introducing the complexity of wastewater treatment projects, three principal reasons may be held accountable for the non-delivery problems [1]:

- The technology was not appropriate,
- The beneficiary was not involved and consulted sufficiently, and
- The responsibilities within government were not resolved to ensure the necessary support.

There is a trend in industrial/domestic wastewater treatment in which large city areas are accommodated more readily than medium and small city areas, or rural communities. Because the population density in rural areas is less compared with large city areas, a small-scale dispersed treatment system is sought for areas with smaller populations. The conventional activated sludge process that is widely popular for domestic wastewater treatment in large cities is a stable treatment system, but the process is sometimes not suitable for a small-scale treatment system, so other systems are being selected. The issue of domestic wastewater treatment has been shifting from large-scale intensive systems for large cities, to small-scale systems necessary for small city areas, and rural communities. In addition, "locally suitable technology" that is adaptable to local social and economic conditions should be sought in developing countries.

Author is with Electronics Research Institute, Cairo, Egypt (e-mail: fadia@eri.sci.eg).

II. The Need for Small-Scale Wastewater Treatment Plants- the Egyptian Case Study

The problem of wastewater treatment in Egypt is a two-fold problem; the first part concerning the existing rural areas, the second one dealing with new industrial/domestic areas. During the last years many rural areas were provided with some kind of water supply systems. These systems mainly discharge the wastewater either directly into the porous underground or into simple holes. At the same time, other villages are still out of developing schemes getting their water supply from shallow wells, which are often located in the direct neighbourhoods of the discharge locations. Even if landowners consider the possible contamination of their wells through their own discharge points and locate them far apart, they can not avoid the location of their neighbour's discharge close to their well. A similar risk of water body contamination occurs where villages situated on the banks of a small lagoon, discharge their wastewater without treatment.

The second fold is allocated where new communities and agricultural projects have been initiated by the government and the private sector as well, in order to change Egypt's infrastructure. It is known that the Egyptian population is concentrated on the banks and Delta of the River Nile occupying only 5% of the total area of Egypt. In the new cultivated areas, the population is faced with the severe problem of water shortage aggravated with the lack or high prices of electric power. The water shortage problem has been partly solved by the erection of several water canals. Moreover, agricultural projects near the new positioned industrial cities have started to suffer the unforeseen sequences of environment pollution due to wastewater that has been discharged neighbour to them without treatment.

Open Science Index, Environmental and Ecological Engineering Vol:3, No:5, 2009 publications.waset.org/9943/pdf

On the other hand, in areas far from the electric network, new and renewable energy sources proved to be an attractive option to supply various electrical demands. As a reliable energy source, photovoltaic pumping systems have contributed to supply water for local rural communities; they can also be implemented to solve the problem "wastewater environment pollution". The solution of this problem can be categorised as recycle process. Meeting the international standards, treated water can be used again in irrigation.[2] Production of crops, with water supplied by photovoltaic wastewater treatment systems, might then become a good alternative in terms of local economic activities.[3] It is expected that Photovoltaic Small-Scale Wastewater Treatment Plants (PVSSWTP), under certain circumstances, are the solution for these problems. More specifically the PVSSWTP technology could be applied where,

- conventional sewage is simply too costly,
- environmental conditions require a high effluent quality,
- conventional on-site treatment proved to be of low community acceptance.

III. What is Wastewater Treatment?

The term treatment means separation of solids and stabilization of pollutants. In turn, stabilization means the degradation of organic matter until the point at which chemical or biological reactions stop. Treatment can also mean the removal of toxic or other dangerous substances (for e.g. heavy metals or phosphorous) which are likely to distort sustainable biological cycles, even after stabilization of the organic matter [4] [5].

A. General Parameters to Measure Organic Pollution

COD (Chemical Oxygen Demand) is said to be the most general parameter to measure organic pollution. COD describes how much oxygen is required to oxidize all organic and inorganic matter found in the wastewater sample. BOD (Biological Oxygen Demand) describes what can be oxidized biologically, with the help of bacteria and is always a fraction of COD. Usually BOD is measured as BOD5; it describes the amount of oxygen consumed over a five-day measurement period. It is a direct measurement of the amount of oxygen consumed by organisms removing the organic matter in the waste. SS (Suspended Solids) describes how much of the organic or inorganic matter is not dissolved in water and contains settled solids that sink to the bottom in a short time and non-settled suspended solids. It is an important parameter because SS causes turbidity in the water causing clogging of filters. The mentioned parameters are measured in 'mg/l'. Fig. 1 shows the wastewater decomposition and the relative percentage of the three main elements; water, dissolved and suspended solids.

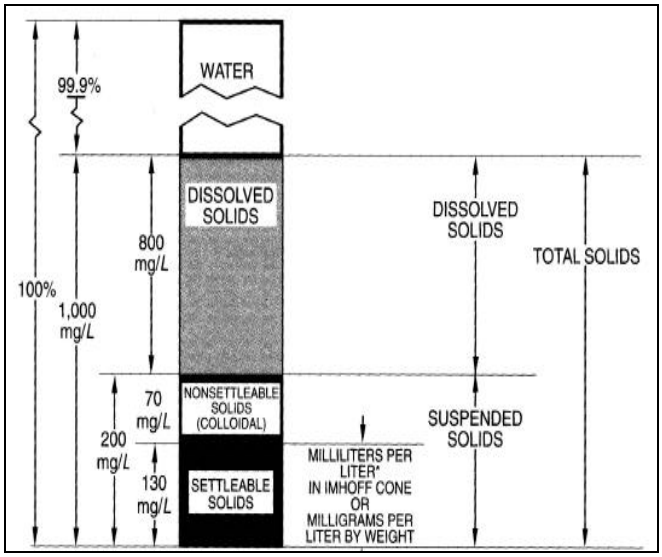


Fig. 1 Composition of solids in wastewater

B. Levels of Wastewater Treatment

Wastewater treatment options may be classified into groups of processes according to the function they perform and their complexity, Fig. 2:

1. Preliminary Treatment: includes simple processes that deal with solid material. The purpose of preliminary treatment is to remove those easily separable components. This is usually performed by screening (usually by bar screens) and grit removal. Their removal is important in order to increase the effectiveness of the later treatment processes and prevent damages to the pipes, pumps and fittings.

2. Primary Treatment: is mainly the removal of solids by settlement. Simple settlement of the solid material in sewage can reduce the polluting load by significant amounts. It can reduce BOD by up to 40%. Some examples of primary treatment are septic tanks and septic tanks with up-flow filters.

3. Secondary Treatment: at this stage the organic material that remains in the wastewater is reduced biologically. Secondary treatment actually involves harnessing and accelerating the natural process of waste disposal whereby bacteria convert organic matter to stable forms. Both aerobic and anaerobic processes are employed in secondary treatment. Some examples of secondary treatment are reed bed systems, trickling filters and stabilization ponds.

4. Tertiary Treatment: is the polishing process whereby treated effluent is further purified to acceptable levels for discharge. It is usually for the removal of specific pollutants e.g. nitrogen or phosphorus or specific industrial pollutants. Tertiary treatment processes are generally specialized processes. Some examples of tertiary treatment are bank's clarifiers and grass plots.

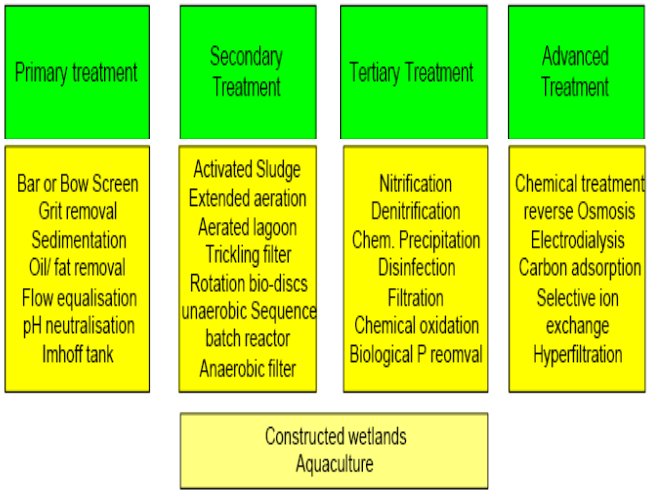


Fig. 2 Wastewater treatment categories and technologies

IV. Design of Small-Scale Wastewater Treatment Plants Units

Fig. 3 gives the general description of a Small-Scale Wastewater Treatment Plant that consists of three main components. The first component is a photovoltaic (PV) module, which supplies the system with the electrical power needed to operate the pumps and the control unit. The second component is the wastewater treatment unit; a detailed description will be given in the following section. A set of electrical pumps is the third component of the plant. According to each site conditions, the sizing of the three main components will be determined. As a common rule for all plants, fixed non-tracking PV-modules will be installed, to avoid mechanical losses and higher installation/maintenance costs. The dimensions of the wastewater treatment unit will be set according the available land space of each location. The pressure of the input fluid to the system will be specified, resulting in setting the required number of pumps to be installed. If the fluid input to the treatment unit is under pressure; fed through pressurized pipes, only one pump controlling the effluent (output) of the plant, should be installed. On the other hand, non-pressurized input fluids will demand the erection of two pumps. To insure sustainability, the selection of the pumps used should be within the local market commercially available types. A control unit will be connected to the system's components to ensure compatible performance. This unit could optionally be equipped with acquisition system to monitor and assess the plant's performance. The plant effluent will be pumped directly in the irrigation network. This proposed simple scheme; no power conditioning unit and no water storage tank are considered; emphasize the project goal of wide scope applicable approach.

V. Wastewater Treatment Unit

A. Primary Process using Septic Tank

Septic tanks are mainly designed for on-site treatment of domestic sewage and are small, rectangular chambers situated just below ground level where sewage is retained for 1-3 days. They usually consist of two compartments with the first larger then the second. Solids settle to the bottom of the tank where they are digested anaerobically, Fig. 4. A thick crust of scum is formed at the surface and helps maintain anaerobic conditions. Some sludge accumulates at the bottom of the tank that needs regular desludging. Biogas is produced in a septic tank as sludge decomposes and gas rises to the surface as bubbles. The gas then accumulates on the surface above the liquid from where it should be allowed to escape into the air. Septic tank effluent is then left to drain away.

1. General Information

Effluent Quality
This is rough primary treatment prior to secondary or tertiary treatment,
25-50% COD removal,
40% BOD reduction of raw sewage,
65% Suspended Solids reduction,
Effluent still contains pathogenic bacteria, cysts and worm eggs.

Water Information
Both greywater and blackwater can be propagated through the system
Not suitable where water supply scarce or unreliable.

O&M
Construction of septic tank requires skilled labour
Little maintenance however requires regular desludging.

2. Advantages

Low cost
Low land space required
Low operational and maintenance requirements
Construction material locally available

3. Disadvantages

Low effluent quality.
Still heavily contaminated with pathogens, cysts and worm eggs.

B. Horizontal Gravel Filter: [6]

Reed bed systems are suitable for domestic and industrial wastewater that has undergone preliminary treatment and that has a COD content not higher than 500mg/l. The reed bed system is 1m deep basin sealed with clay or some other form of lining to prevent percolation into groundwater with the basin itself being filled with soil in which reeds are then planted, Fig. 5. Oxygen is transported through the pores of the plant down to the roots whereby the oxygen content increases the biological activity of the soil. When wastewater runs through the root zone soil organic compounds and other impurities are eliminated by micro-organisms in the soil.

1. General Information

Effluent quality:
84% COD removal rates
86% BOD removal rate

Water Information

Open Science Index, Environmental and Ecological Engineering Vol:3, No:5, 2009 publications.waset.org/9943/pdf

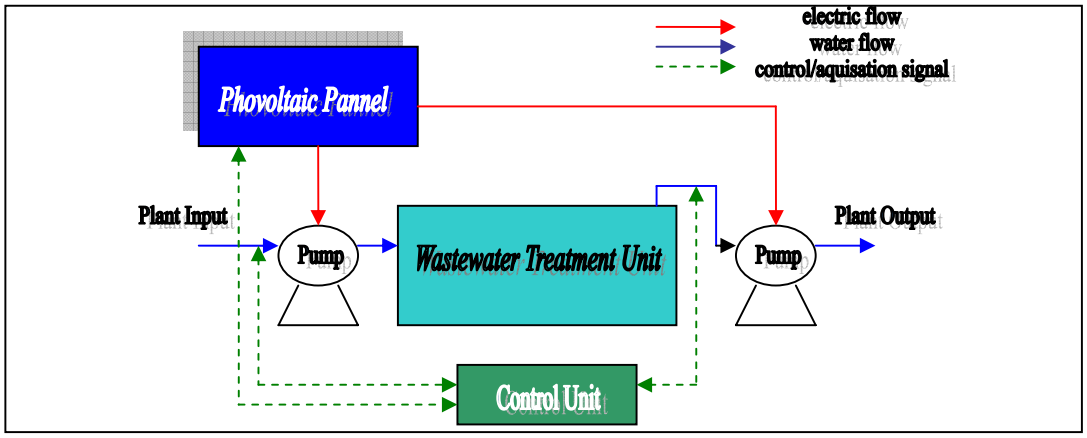


Fig. 3 Small-Scale Wastewater Treatment Plants

Open Science Index, Environmental and Ecological Engineering Vol:3, No:5, 2009 publications.waset.org/9943/pdf

Since it only receives liquid waste, not suitable where water scarce or unreliable.
Requires high volumes of water for transportation to treatment site

O & M
Low operation and maintenance required.
Regular maintenance
Moderate land requirement
Moderate Costs

2. Advantages
Low operation and maintenance
Construction material locally available.
High effluent quality

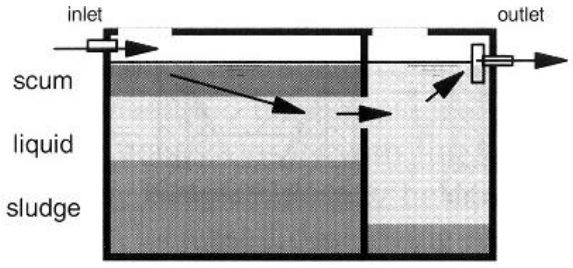


Fig. 4 Septic Tank

Principle of Horizontal Filter Process
Continuous oxygen supply to the upper layers only major role of plants: provide favourable environment for bacteria diversity

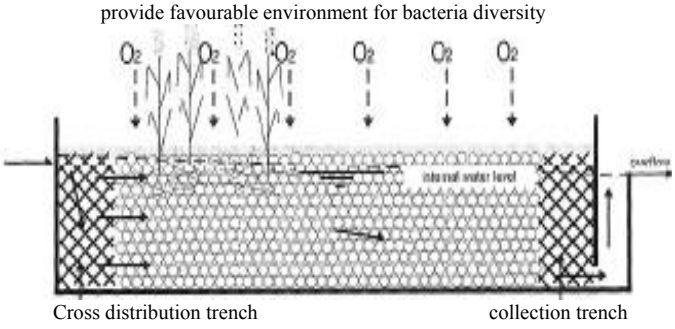


Fig. 5 Horizontal Gravel Filter

VI. Conclusion: Ideal Approach for Technological Transfer

Wastewater treatment technology changes according to social and economic conditions, and must take the most suitable form for a society that uses that technology, apart from its basic elements. Therefore, when the technology is transferred to another society, it is necessary to examine its adaptability from various aspects. The difficulty in transferring advanced technology to developing countries without modification is widely known. However, in recent years, there has been an urgent need to provide wastewater treatment facilities in regional areas without so much population. Processes requiring low construction and maintenance costs, that were used 25 to 30 years ago, can be considered leading-edge technology that takes into account the current social conditions because of financial difficulties. Therefore, in order to consider future technological transfer, it is necessary to not only consider current technology but also to look into previously developed or adopted technology, and to evaluate it from current technological or economic standpoint of view. In addition, because technology is not stationary, but constantly transforms, it is possible to select technology more suited to each individual site, and develop new technology through additional examination of technological development cases. Therefore, "locally suitable technology" should be selected according to the current situation of each region where the technology is adopted, which also must ensure future sustainability. As this project still in preparation phase, the field experience and assessment will be published in subsequent papers.

References

[1] Small-Scale Domestic Wastewater Treatment Technology in Japan, and the Possibility of Technological Transfer, Motoyuki Mizuochi, Asian Environment Research Group National Institute for Environmental Studies, Japan.
[2] Irrigation Water Quality, LennTech web site.
[3] Resource-Conserving Irrigation with Photovoltaic Pumping Systems in Chile; GTZ, Eschborn, September 2002.
[4] Small Scale Wastewater Treatment Plant Project, Report on Project Criteria, Guidelines and Technologies, July 1999 SOPAC Technical Report 288.
[5] Wastewater treatment technologies, technical description, www.oas.org.
[6] Principle of the Horizontal Filter, Ludwig, S. 1998.