WATER QUALITY PROTECTION IN RURAL AREAS OF EGYPT

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ABSTRACT

Egypt has limited water resources; it depends mainly on the Nile, which is considered the Egyptian life blood for the domestic, industrial and irrigation uses. The rapid increase in population and urbanization is a big challenge to the country in facing water scarcity. The economic development also puts a lot of stress on water demands since it affects water quality especially in rural areas. These areas are not included in the current plans of the country for wastewater treatment due to the lack of funds and availability of low cost wastewater treatment plants modules. This puts a lot of pressure on water resources from untreated or partially treated wastewater, which vigorously encourages not only the government but also the civil society to have wastewater collection and treatment facilities in one package that can be funded, operated and maintained by the beneficiaries themselves to ensure sustainable development.

Wastewater characteristics and flow vary greatly from urban to rural areas and even from small to big rural areas. This work investigates the raw wastewater characteristics and the performance of low cost wastewater treatment plants in rural areas. Field data collection on population census and activity, water supply, sewage system and water and wastewater samples from water bodies, sewage network outlet and septic tank is available from a field survey. The data is being analyzed using statistical methods to evaluate wastewater characteristics for the design of low cost wastewater treatment plants.

The results show the average wastewater characteristics and the performance of the low cost wastewater treatment plants, which proved to vary greatly in rural areas and depend mainly on the behavior of the society. It is thus recommended to have aside specific data for the design of low cost wastewater treatments plants for water quality protection.

Keywords: Rural areas, Wastewater flow, Low cost, Wastewater treatment plants, Water quality, Egypt

1. INTRODUCTION

Despite the fact that wastewater is a major source of pollution to the water courses it is considered a sustainable and valuable resource that should be collected, treated and reused in a proper way not only to preserve the environment and water bodies but also to conserve the water resources. The per capita share of Nile fresh water is about 700 m^3/year which is already below the water poverty level. In addition to water scarcity, the water courses suffer from domestic wastewater pollution especially in rural areas. These areas unfortunately have not included yet in the governmental plan and until now there is no institutional form for sanitary drainage in rural areas. Rehabilitation and construction of sewage systems has not kept pace with the increase in rural water supply networks.

Wastewater treatment in the Egyptian rural areas lags far behind potable water supply. The vast majority of the Egyptian population receives piped potable water, however only urban areas and some larger rural villages possess wastewater treatment facilities. Economics of conventional wastewater treatment make the cost prohibitive in small dispersed rural settlements. Untreated wastewater is typically discharged water bodies. This practice has contributed to widespread degradation of water quality and affects the policy reuse of drainage water plans in Egypt.

Although the enforcement and the legislative framework, the sanitary drainage in each household is connected to unsealed septic tank and the sewage is regularly evacuated by trucks and dumped in water bodies. Dumping wastewater in water courses costs from (4 – 10) USD in rural areas depending on the water table level and the septic tank condition which is costly to the household owner.

10 percent of the total burden disease worldwide could be prevented by improvements related to drinking water, sanitation, and hygiene and water resources management. Eighty-eight percent of cases of diarrhea worldwide are attributable to unsafe water, inadequate sanitation or insufficient hygiene. In Egypt, the total burden diseases that can be alleviated by improving drinking water, sanitation, hygiene is 25.1 percent (WHO [10]).

Nowadays, there is a strong intention to build sewage networks and small wastewater treatments plants (WWTP) in rural areas not only from the government side but also from the civil society. Wastewater characteristics in small localities strongly differ from those in densely populated areas. Wastewater in rural areas is also different from one region to other (Becares, et al, [3]). Also, the flow of wastewater varies greatly from urban to rural areas and even from small rural to big rural areas, which depending on many factors like the density of population , the activities, the water supply and the sewage network efficiency.

Raw wastewater characteristics for the studied rural areas showed interesting difference in comparison with those found in the bibliography (Ferrer and et al [4]) Frequently, the management of WWTP in small urban areas is not adequate, which can be deduced from the poor results achieved by many of them, especially those which are run directly by local town council (Salas [8]).

The use of low cost technologies for small communities in the Arab region is still at demonstration or experimental scale. Small-scale anaerobic low cost technology in a form of two- stage UASB reactor has proven to be 70 percent efficient in treating wastewater under arid condition; these results were concluded from a long –term research program carried out in Jordan, Egypt and the West Bank (UNEP [9]).

Setting the appropriate wastewater characteristics and flow for the design of the sewage collection and low cost wastewater treatment in rural areas is an important issue for the system economy and sustainability.

This work assesses and investigates the domestic wastewater characteristics in the rural areas for the design of low cost wastewater treatment plant in addition to the performance of these plants.

2. MATERIALS AND METHODS:

2.1 STUDY AREA:

The characterization of the wastewater in rural areas is based on data collection from two villages in the Upper Egypt, one village from Lower Egypt, one village from Eastern Delta, three villages from the Middle of Delta and one village Western of Delta (Fig.1).

Figure 1 Study Areas

The distribution of rural areas in the governorates is explained in Table 1. The data were collected under the support of environmental services for improving water quality management program in Egypt (El Gammal [4]).

Table 1 Regions of Rural Areas

Region	Village	District	Governorate	No of Villages
Upper Egypt	El Toad	Luxor	Luxor	2
	El Odessa			
Lower Egypt	Abdel Kareem Elisa	Sinurus	Fayoum	1
Eastern Delta	Ezbet El Khady	Zagazig	Sharkiya	1
Middle Delta	Senbo	Zefta	Gharbiya	3
	Damanhour El Wahsh	Zefta		
	Subrakas	Santa		
Western Delta	Sharaf El Din	Damanhour	Behira	1
Total Number of Study Villages				8

The following approach is used to gather the data:

- Collect general information about the villages, including location, access, population, non-governmental organizations (NGOs) operating in the area, administrative entities, and business activities related to the wastewater treatment issue.
- Collecting information about the quantity of wastewater through:
  a. Direct field measurement from sewage networks or sewage trucks
  b. Estimation of the actual consumption of potable water and population
- Collecting information on quality of wastewater through:
  a. Collecting wastewater samples from outlets of the sewage network or from sewage trucks
  b. Analyzing samples
  c. Identifying sources of pollution such as animal manures or industries

After data collection, two types of wastewater treatments plants were installed in the rural areas of Egypt. The aerobic system is used in Upper Egypt and in the Middle of Nile Delta while anaerobic system is installed in middle of Egypt and in the Eastern and Western of Nile Delta.

Wastewater treatment Historically accounts for about 25% of a municipality's total energy use. Within the wastewater plant, energy costs are the second largest operations and maintenance expense after labor. Biological processes account for 55% to 70% of this energy use, depending on plant design. This excludes energy and other costs for biosolids dewatering and disposal.

Anaerobic system has been considered as a promising method for the treatment of high, medium and low concentration wastewaters, due to the economy of the process, and the low generation of surplus sludge as well as winning of the biogas as an alternative source of energy. Developing countries occupy regions where the climate is warm most of the time. Even in subtropical areas, low temperatures don't persist for long periods. This is the main factor that makes the use of anaerobic technology applicable and less expensive in those countries (Foresti [6]). Different anaerobic technologies have been applied to the treatment of domestic wastewater.

Based on the past experiences and learned lessons in the municipal wastewater treatment, the anaerobic technology proved a very good performance and efficiencies due to its positive advantages against aerobic ones (Abdel Shafi et al [2]).

The anaerobic wastewater treatment can be regarded as the core method of a sustainable wastewater management strategy, due to its benefits and enormous potentials such as: (i) little use of mineral resources and energy; (ii) enabling production of resources (energy from wastes); (iii) pairing high efficiency with long term of lives; (iv) applicability at any place and at any scale; (v) easiness in construction, operation and maintenance. Moreover, although conventional aerobic treatment systems generally provide excellent treatment efficiency, they do not fully meet the criteria needed for a sustainable wastewater management strategy (Lettinga, et al [7]).

2.2 WATER QUALITY PARAMETERS

The basic wastewater parameters are monitored before and after the construction of the wastewater treatment plants, i.e. pH, TDS, T, BOD, COD, TSS and TFC according to the standard method (Table 2). Listed acronyms are defined in the next dedicated paragraphs.

Table 2 Sampling, Analysis, and Measured Frequency for Water quality Parameters (2007-2009)

Measured parameters	Abbreviation	Unit	Wastewater		Measured Frequency
			Influent	Effluent	
Temperature	T	°C	x	x	Quarterly
Acidity & alkalinity	pH	-	x	x	Quarterly
Total Dissolved Solids	TDS	mg/l	x	x	Quarterly
Chemical Oxygen Demand	COD	mg/l	x	x	Quarterly
Biological Oxygen Demand	BOD5	mg/l	x	x	Quarterly
Total Suspended Solids	TSS	mg/l	x	x	Quarterly
Total Fecal Coliform	TFC	mg/l	x	x	Quarterly

3. RESULTS AND DISCUSSION

3.1 RAW WASTEWATER CHARACTERISTICS

3.1.1 ACIDITY & ALKALINITY (pH):

The pH values for the raw domestic wastewater range from 7.1 to 7.6 with an average value of 7.3 which is normal and close to the neutral water. The standard deviation of the whole measured values in the upper, lower, and Nile Delta of rural areas of Egypt is 0.2 units which expresses the data consistency and the normal distribution of the pH measured parameter.

3.1.2 TOTAL DISSOLVED SOLIDS (TDS):

The TDS values of the raw domestic wastewater vary between 980 to 2600 mg/l with an average value of 1600 mg/l. The data from the different regions of the rural areas shows a big variation as it clear from the value of the standard deviation of 760 mg/l.

The average TDS of raw wastewater of the rural areas of the Nile Delta is 1050 mg/l while in the upper and lower region of the Nile valley is 2420 mg/l. This wide variation in the TDS values may be explained by the variations in the family traditions and habits in the food system in the rural areas.

3.1.3 BIOLOGICAL OXYGEN DEMAND (BOD5):

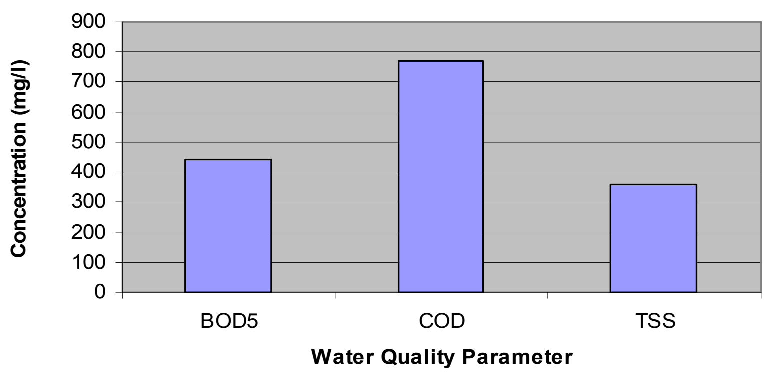

Figure 2 Average Raw Wastewater Concentration in Rural Area

The BOD5 of the raw domestic wastewater ranges from 160 to 760 mg/l with an average value of 450 mg/l with a standard deviation of 190 mg/l (Fig. 2). The data shows a big variation especially in the lower region of the Nile valley from 150 to 500 mg/l with an average value of 340 mg/l.

3.1.4 CHEMICAL OXYGEN DEMAND (COD):

The COD values of the raw domestic wastewater vary between 260 and 1650 mg/l with an average value of 770 mg/l. The large variation in the values results from the high variation in COD in middle of Nile Delta rural areas where some local industrials discharge directly to the sewerage networks like chemical and metal industries. The COD values in the middle Nile Delta rural areas range from 400 to 1650 mg/l with an average value of 860 mg/l. The average COD in the upper and lower region of the Nile Delta valley is 550 mg/l which is complying with similar results of raw domestic water (Abdel-Halim et al, [1])

3.1.5 TOTAL SUSPENDED SOLIDS (TSS):

The TSS values of the rural domestic wastewater range from 150 to 1200 mg/l with an average value of 360 mg/l. The data show a big variation from one region to another in the rural areas with no clear trend. The mean TSS value in the upper and lower region of the Nile Valley is 700 mg/l, while in the Nile Delta region is 400 mg/l.

3.1.6 TOTAL NITROGEN (TN):

The TN values range from 30 to 70 mg/l with an average value of 50 mg/l (Fig.3). The high values come from discharging the manure of the animals in farmer's households to the sewerage network. The TN values vary from one region to another based on the tradition and habits of farmers in the rural areas.

3.1.7 AMMONIA- NITROGEN (NH_3-N):

The values of NH_3 range from 26 to 36 with an average value of 30 mg/l. The NH_3 values vary from one region to another, with no clear trend from the southern region of Nile Valley to the Nile Delta region.

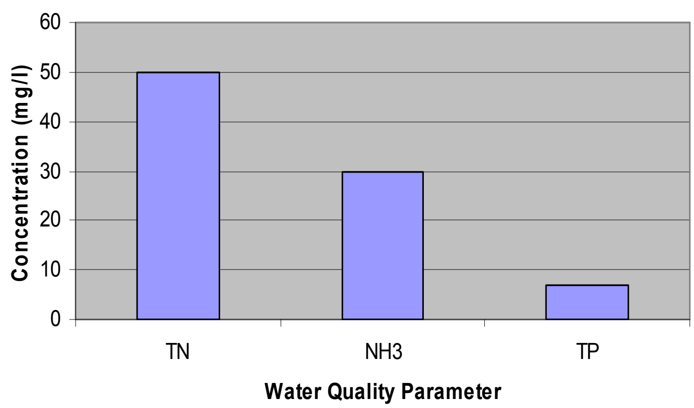

Figure 3 Average Raw Wastewater Nutrient Concentrations in Rural Area

3.1.8 TOTAL PHOSPHATE (TP):

The TP values range from 2 to 15 mg/l with an average value 7 mg/l. The data show a big variation from one region to another. The TP are higher in the Nile Delta region than those in the lower and upper region of Nile Valley due to the overuse of the detergents.

3.1.9 TOTAL FECAL COLIFORM (TFC):

The TFC values vary from 1.3 x 106 to 24 x108 with an average value of 2 x 108 MPN/100 ml. The measured values show a large variation in all regions of the rural areas with no clear trend. The variability of data is due to the nature and method of the measurements depending on personal counting.

4. PERFORMANCE OF WASTEWATER TREATMENTS PLANTS

The process performance was measured by monitoring the influent and effluent concentrations of BOD5, COD, TSS, and TFC of the aerobic and anaerobic wastewater treatments in the rural areas of upper and lower regions of Nile Valley and in the Nile Delta. The aerobic and anaerobic systems in the upper and lower region of Nile Valley are the same as with the ones in the Nile Delta.

4.1 BOD REMOVAL

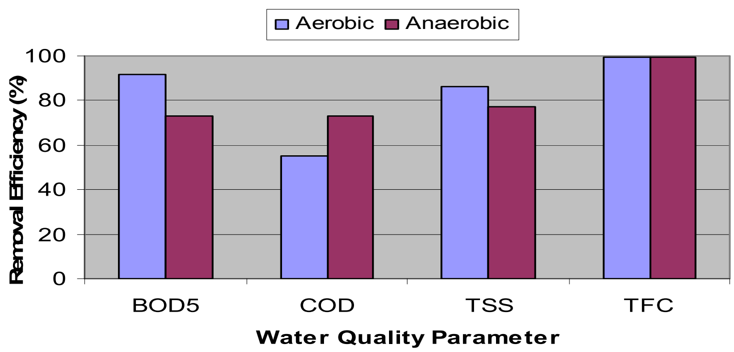

Figure 4 Average Removal Efficiency of Aerobic and Anaerobic Wastewater Treatment Plants

The BOD removal values range from 62 to 99 percent with an average value of 92 percent for the aerobic wastewater treatment plants in the rural areas while these values vary between 26 and 88 percent with an average value of 73 percent for the anaerobic wastewater treatment plants. The results of anaerobic system are in accordance with the results of UASB in Egypt and Jordan.

4.2 COD REMOVAL

The COD removal values range from 40 to 79 percent with an average value of 55 for the aerobic system while these values range from 20 to 88 percent with an average value of 73 percent for the anaerobic wastewater treatments plants in the rural areas. These values of removal efficiencies of anaerobic systems comply with other studies (Abdel-Halim et al, [1]).

4.3 TSS REMOVAL

The TSS removal values range from 63 to 97 percent with an average value of 86 percent for the aerobic system while for the anaerobic systems the TSS values vary between 53 and 95 percent with an average value of 77 percent. The removal efficiency for the anaerobic system gives quiet good results but for the aerobic system is low. This discrepancy is due to the frequent blockage of the sand filter after the final settling tank which needs regular backwashing in the aerobic system.

4.4 TOTAL FECAL COLIFORM REMOVAL (TFC)

The TFC removal values range from 97 to 100 percent with an average value of 99.5 percent for the aerobic system while for the anaerobic these values vary between 98.5 and 100 percent with an average value 99.5 percent. Although the removal efficiencies are high, the effluent quality does not comply with the discharge permit discharge to the agricultural drainage system according to law 48 article 66.

4.5 ACIDITY & ALKALINITY REMOVAL

The values of pH ranges from 7.1 to 7.6 with an average value of 7.2 for the influent and effluent wastewater for the aerobic and anaerobic wastewater treatment plants in the rural areas. There is no significant change between the influent and the effluent pH values.

5. CONCLUSIONS AND RECOMMENDATIONS

This work investigates and assesses the characteristics of the raw domestic wastewater in the rural areas of Egypt for the design of low cost wastewater treatment plants. Different villages has been chosen in the upper and lower region in the Nile Valley and in the Middle, Eastern, and North of the Nile Delta. Two types of WWTP are built in the selected areas, one is aerobic and the other is anaerobic. The water quality data are collected before and after installation of the WWTP in the rural areas.

For the raw domestic wastewater, the pH values do not show a wide variation from one region to another, its average value is 7.2. The TDS values show wide variation from one region to another. The average value of TDS is 1600 mg/l. The average raw domestic wastewater values of BOD5, COD, and TSS are 450, 770, 360 mg/l respectively. The average values of TN, NH3-N, TP are 50, 30, 7 mg/l respectively. The TFC values of the raw domestic wastewater show a big variation from one region to another and even within the same village in the rural areas. The average value of TFC of raw is 2 x 108 MPN/100 ml.

Generally, the analysis of the results concludes that the removal efficiency of aerobic WWTP is higher than the anaerobic ones except the COD removal. The average removal efficiency values for the aerobic WWTP for the BOD, COD, TSS are 92, 55, 86 percent respectively. For the anaerobic WWTP, the average values of the removal efficiency are 73, 73, and 77 percent respectively. The average values of TFC removal efficiency for aerobic and anaerobic are 99.5 percent which are equal. Although the removal efficiencies for TFC are high but still the effluent quality do not comply with the permit discharge to the agricultural drainage system according to law 48 article 66.

The study shows a wide variation of the raw domestic wastewater characteristics from one region to another in the rural areas. So, it is recommended to have a site specific measured water quality parameters data for the design of low cost WWTP in the rural areas and use the bibliography as a guide. Although the removal efficiency of the anaerobic WWTP is less than the aerobic ones and the effluent does not comply with the permit discharge, it is considered a promising technology for the rural areas in Egypt. The anaerobic WWTP are cheaper than aerobic ones in terms of operation and maintenance, labor, energy cost. A further study is recommended to investigate the availability of post treatment for the anaerobic treatment to comply with the permit discharge.

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