Selection and Evaluation of Appropriate Sanitation Systems in Rural Egypt.
Case Study in Sohag Governorate, Upper Egypt

Hisham S. A.Halim[1], Walid Abdel-Halim[2*], and M.Nazih[2]
E-mail: hishama.halim@access.com.eg
[1] Cairo University, Faculty of Engineering. [2] Housing and Building Research Center, Cairo, Egypt.
* Currently: Institute of Water Quality and Waste Management, Hannover Uni., Germany

Abstract

Maintaining social justice for every one in Egypt is one of the most important duties of the government, and in this thought maintaining health and well being for individuals has been considered in Egypt's Basic Legislation. Wastewater is one of the greatest environmental problems in Egypt, where more than 3000 local villages and sub-villages with a total population of about 25 millions have no facilities of wastewater treatment and/or wastewater collection. To provide these villages with the required facilities of wastewater collection, treatment and disposal, some of evaluation and selection tools must be done starting with selection of villages with high priority, selection of suitable sanitation system and ending to the implementation of the most eligible system in terms of technical and economical eligibility. Governorate of Sohag GOS was selected to be a case study of this study. It is located in Upper Egypt, 467 km south of Cairo, consists of 11 central units, 10 cities, 51 local units, 270 mother villages and 1217 small villages. Total population is 3,113,012 capita, 78% of them live in rural areas, and 67% of them need sanitation facilities and suffering from lack of infrastructure utilities and economic plans.
The main objective of this study is producing of selection tool as well as a simplified computer program to assist in choosing suitable sanitation systems for different villages depending on a technology selection leading to a single or group of options for the sanitation technologies as well as economical comparison between the selected options to get the most economical option. The selection of sanitation options was based on the state-of-art technologies for different components of the system. Moreover, this study assists in determination of the preference factors to get the villages' priorities for implementation. The proposed selection tool and the developed software was tested for a group of villages in GOS and proved successful and simple applicability.

Keywords

rural sanitation; wastewater treatment and disposal; on-site systems; sewerage systems; drainage; Egypt.

1- Introduction

The selection of a sanitation system for specific community in rural and semi-urban areas became a hard task for the decision makers in Egypt. Considering the major change in the community pattern and continuos shift from rural to semi-urban and to urban patterm makes the selection of the most suitable system for the wastewarter collection, treatment and disposal a dynamic process. This justifies to a great extend the importance of having a simple and flexible tool for selection of such sanitation system. Accordingly, it is worth to mention that the selection tool developed in this study is not for rural sanitation or on-site-sanitation rather than a tool able to deal with different patterns of communities covering rural, semi-urban, or small towns. The following paragraphs will present some litrature related to the topic of the paper. This would be a step ahead to the presentation of the methodology and results of this research.

An increasing proportion of surface and ground water resources in Egypt is polluted mainly due to inappropriate disposal of municipal wastewater, infiltration from onsite sanitation facilities, and excessive use of fertilizers and pesticides in agriculture. Due to the shortages in agricultural water, reuse of wastewater has become unavoidable. Community wastewater management services in Egypt evolved in three phases. During the first phase, wastewater services were provided to large cities and urban centers. In the second phase, currently underway, wastewater collections services and some treatment works were provided to secondary towns. The third phase, now being considered, will provide wastewater services to smaller towns and communities.

It has been argued that water supply and sanitation in Egypt have a considerable effect on child mortality. For instance Ali et al. (1990) find that access to clean water and adequate sanitation decreases child mortality. According to the World Bank (2002) there is an annual average loss (cost) of 0.8 percent of Egypt's Gross Domestic Product (GDP) due to diseases and mortality primarily affecting children, caused by lack of access to safe water and sanitation.

More than 95% of the Egyptian rural-areas are not provided with wastewater collection and treatment facilities. There are about 4000 Egyptian rural-areas with a population ranging from 1000 to 20000 capita. The wastewater produced from houses in these rural areas is mainly treated in septic tanks. Communities without municipal water range between 23 and 36 percent. As concerns the lack of sanitation, the coverage is between 6 and 17 percent. The former communities rely on unimproved water supplies (e.g., wells, rivers, ponds, canals and unprotected springs) and the latter on unimproved sanitation facilities as holes in the ground, bushes and other places where human waste is not contained to prevent it from contaminating the environment. Communities with improved water and sanitation do not all have the same services. It should be noted that the

functioning or the improvements in sanitation facilities also depends on its connection to a sewer system. However, only some of the urban households have access to sewer systems.

To meet the demands for water and wastewater services in the next decade, Egypt will have to invest 5-7 billion US$, which is well above the available national resources (USAID, 2002). Providing rural areas in Egypt with water supply (more than 98% of rural areas in Egypt have water supply) has resulted in an increase of wastewater production, which increases the urgent need for proper facilities for wastewater collection and treatment.

1.1 Strategy

1.1.1 Problem and the objectives

Domestic water use in small communities increased due to the general rise in the standards of living. Accordingly, waste generation increased. There is a need for re-evaluation of the environment scenarios, water resource and wastewater drainage systems with a view to the totality of the system and with proper analysis of the flow of water and wastewater. The role of the engineer is to make available to society as many technical options as possible – and to put these options into the proper perspective in relation to the objectives Planners and decision makers typically favor conventional wastewater management systems which are water intensive and especially costly when applied to small communities. Commonly used onsite wastewater disposal systems (cesspits or percolation pits) fail to protect the water resources and environment because of their poor design, lack of maintenance and increased loading and development densities. Application of holistic but decentralized management approach and the use of low cost sewerage are more suited to the socio-cultural and environmental circumstance in small and semi-urban communities.

1.1.2 The Guiding Principles

Adequate and effective wastewater services for small communities in small communities must be developed within the following principles in order to meet the intended benefits:

1. Solutions should be tailored to the social, cultural, and economic circumstances and application of simple blue prints should be avoided. The household and community environments must be protected. Solutions must be cost effective and affordable to the community and national economies.
2. Wastewater is part of the total water cycle and it should be managed within the integrated water resources management processes. Management of wastewater must be holistic and should be based on careful consideration of waste generation, transportation, treatment, and reintegration.
3. Pollution must be contained and the domain in which wastewater is managed should be kept to the minimum practicable size (household, community, town, city, catchments) and wastes diluted as little as possible.

For the development of sustainable wastewater concepts, the prediction of additional environmental impacts, of social and economic aspects must be integrated into the decision-making process. Most of the investigations were focused on the comparison of specific technologies and the determination of the best alternative for one single site, not necessarily being the optimal solution for the whole area or governorate. Therefore, a methodology for the assessment of wastewater management strategies on a governorate level is important to be developed. From that perspective, all the benefits as well as the negative effects may be included in the comparative assessment of different alternatives.

2. Wastewater System Alternatives

Most Urban growth is taking place in informal settlements where government is unwilling or unable to provide wastewater services. Effective wastewater treatment is so expensive that is rarely achieved in practice, particularly in the fast urban centers of developing countries. The sewerage system must be effectible and adequate enough to receive different types of wastewater discharges. In the following dome of sewerage systems techniques:

2.1 Improving onsite wastewater system:

Onsite wastewater disposal systems present a sound method of household wastewater systems in communities where the development density is low, land is available for system construction, and where soil and groundwater conditions permit system use. Onsite systems must be designed for pollution control and recovery of resources. Improved design, construction, operation and maintenance of onsite systems are essential. Reuse of treated gray water in non-potable water uses such as household landscaping, gardening, and toilet flushing is now promoted in many of developing countries.

2.2 Conventional centralized wastewater system:

Conventional sewerage is expensive and water intensive and therefore its application for small communities cannot be justified. Conventional sewerage cost 80-90% of the entire wastewater collection and treatment (Otis R., 1996). Wastewater management can be made affordable only if significant reduction in wastewater collection can be achieved. The conventional sewerage system and treatment works can be provided to the highly developed and densely populated commercial and residential centre of the community.
A World Bank review of sewerage investment in 8 capital cities in developing countries found that costs range between US$ 600-4000 per capita (1980 prices) with a total household annual cost of US$ 150-650 (Mara D., 1996). The conventional sewerage systems are more costly in small communities. Because of their size and layout, small communities do not enjoy the economies of building large systems. Moreover, the per household cost of sewers in a town of 500 is three times the cost for a city of 100,000 (USEPA, 1992a). Conventional sewerage systems are designed as waste transportation

systems in which water is used as the transportation medium. Reliable water supply and a consumption of 100 l/c/d are basic requirements for problem free operation of conventional sewerage systems. Conventional sewerage is not appropriate for small communities where water supply is intermittent and only limited amounts of water are available. Conventional sewerage dilutes fecal matter and spreads pollution to a larger environmental domain.

2.3 The Decentralized System:

Decentralized wastewater system implies managing wastewater as close as practical to where it is generated and to where its potential beneficial reuse is located. The wastewater management system for a community may comprise several smaller subsystems for collection, treatment and reuse. The size of each subsystem is determined by the administrative, drainage boundaries, and other prevailing social and economic conditions. Decentralization is receiving increased attention from wastewater professionals and researchers because of its potential for cost reduction, efficient management, reduced environmental hazards in case of accidents; more reuse opportunities and many other advantages (Venhuizen D., 1997b; Otterpohl et al, 1997; Butler and MacCormick, 1996). Decentralization requires the choice of efficient and affordable wastewater treatment technologies which can be placed close to the human settlements without causing nuisance to the community.

2.4 The non-conventional sewerage systems

The settled sewerage and the simplified sewerage are appropriate for small communities. These sewerage systems are well tried and robust offering the same benefits and convenience as conventional sewerage at much lower cost and less demand on water for their operation. The two systems offer opportunities for long-term and large scale solutions enabling faster and sustainable expansion of wastewater services as concluded by an international conference on low cost sewerage in (Mara D., 1996), a round table on innovative experiences from Latin America in sanitation for the urban poor in July 1998 (UNDP – World Bank, Water and Sanitation Programme 1998) and a regional workshop on wastewater management for small communities in the Eastern Mediterranean Region (WHO-CEHA, 1998).

2.5 Settled sewerage:

Settled sewerage is a sewerage system that is designed to receive only the liquid portion of household wastewater. Solids are removed in an interceptor tank which is part of household connection. The clarified effluent flows by gravity into the sewers, which are designed as gravity fluid conduits. The settled sewerage costs are quite low in comparison to conventional sewerage mainly due to shallow excavation depths, use of small diameter pipe work (commonly 75-100 mm PVC) and simple inspection chambers.

Settled sewerage is commonly used in Australia, the United States, Columbia, Nigeria and Zambia. The systems is also termed small bore sewers, small diameter gravity sewerage (SDGS) in the USA, solids free sewerage in Columbia, septic tank effluent drainage (STED) in South Africa, and common effluent drainage in Australia. Settled sewerage is appropriate for low-density residential and commercial developments such as small communities and residential developments around urban areas where it is used as alternative to the more costly conventional sewerage. It is also appropriate for areas that already have septic tanks but where the soil no longer accept all the septic tank effluent and can also be used as a means to upgrade onsite systems.

2.6 Simplified sewerage:

Simplified sewerage is a wastewater collection system that is designed to receive all household wastewater. It is essentially similar to conventional sewerage, but without any of the latter's conservative design features. Costs are low, and can even be lower than on-site sanitation. The low costs of simplified sewerage are due, as in the case of settled sewerage, to shallow excavation depths, small diameter pipe work and simple inspection units in place of large manholes. In Brazil, it is serving more than one million people. The largest area of application is in the capital Brasilia with more than 400,000 clients representing all social and income levels (Nazareth P, 1998). The system is increasingly being used in Africa and Asia. Simplified sewerage is most appropriate in high-density, low-income housing areas where there is no space for on-site sanitation pits or for the solids interceptor tanks of settled sewerage. Unlike conventional sewerage systems, the non-conventional settled and simplified shallow sewerage are not water intensive and therefore they are more suited to the condition of small communities.
The low-income urban areas which are densely populated but use very little water can be served by shallow sewerage system. Treatment processes can be tailored to the quality of the wastewater generated from each separate subsystem. The use of settled and simplified sewerage systems becomes appropriate not only for small communities but also in sections of larger communities if the decentralized approach is adopted.

3- Methodology

The main tasks under this study were performed through four steps and can be categorized as follow:

3.1 Assessment of the existing situation of water and wastewater facilities:

Data was collected and assessed refering to population, water supply systems, wastewater facilities, wastewater quantities, wastewater qualities and future plans, feasible sanitation systems and geo-technical studies.

3.2 Set the strategy of the Wastewater system Design:

The following steps have been used for development of the proposed selection tool: Determine System design Strategy including Preliminary system screening, Wastewater characteristics, Initial Site Evaluation, Preliminary screening of disposal options, System Selection, Detailed site evaluation procedures, and Selection of most appropriate system. This would be a step ahead to the System Design and Management

3.3 Hydrology and Geotechnical Zoning of Sohag:

The groundwater, sub-soil water, and the soil formation have great effect on some of wastewater system options in terms of treatment and disposal especially those depending on the on site treatment and disposal. Therefore, it was a must to survey both the hydrology and geotechnical characteristics of the Sohag governorate to facilitate the selection process of such options.

3.4 The Selection Matrix:

To propose specific options for collection, transportation, treatment, and disposal of wastewater, factors affecting the selection of wastewater system are the character sites, wastewater quantity and quality, land availability, and available technologies. The proposed selection tool and the followed criteria based on the scientific background for the eligible wastewater options and the specific Condition of Sohag was explained. The proposed selection matrix covers the possible / feasible options against the potential site conditions and design parameters. The wastewater options were divided into three groups: collection, treatment, and disposal. The collection group includes collection tanks, transportation by evacuation trucks, small bore sewers, simplified sewerage system, and conventional sewerage system. The treatment group includes the on-site sanitation options as well as other treatment systems including lagoons systems, suspended growth as well as attached growth systems. The third group, disposal, includes discharging to an existing sewerage pumping station or wastewater treatment plant, soil aquifer disposal, discharging to an existing agricultural drain after treatment without violating the environmental regulations, and reuse in irrigation to cultivate trees as a source of wood. The idea of selection was based on the scientific background of the available technologies suitable for the target communities. For the ease of the selection process, the decision was made to do the selection of the technology by elimination of the invalid options for the specific conditions for specific community. The output of such process would be a single or (group) of technical option (s) to be economically assessed and make the final selection based on the economical assessment considering the capital as well as the operating costs. Figure (1) illustrates the parameters and the possible options for the wastewater system components.

Wastewater System Selection Matrix

Parameter		Actual Data	collection / conveyance				Treatment					
			C. tanks	Trucks	SBS	Convent	ST/PT	ST/CP	ST/CWL	ST/ SP1	SP2	AS
Total Population	<500											
	<1000											
	<5000											
	<10000											
	>10000											
Water Consumption (l/cap/day)	<50											
	<75											
	<100											
	>100											
Availability of Land (m2/per)	<1.0											
	1-2											
	>2											
Distance to Existing/Planned WWTP (Km)/PST	3-5											
	>5											
Groundwater Supplies	Artesian											
	Gravity											
Soil Conditions												
Top Soil Formation	Sand/Gravel											
	Clay											
	rock											
Level of GWT	<2.5 m											
	>2.5 m											
Nearby Drain	<1km											
	>1km											
Land reclaimation	yes											
	No											
Feasible or Valid Options												
Specific Cost (LE/person)												
FINAL SELECTION												

Selection Matrix

Legend:

C.Tank: Collection Tank — *CWL: Constructed Wetland* — *PST: Pumping Station*

SBS: Small Bore Sewers — *SP: Stabilisation Ponds* — *WWTP: Wastewater Treatment Plant*

ST: Septic Tank — *AS: Activated Sludge* — *Invalid Option*

PT: Percaulation Trench — *AAFBR: Anaerobic Fixed-bed Reactor*

CP: Cesspool — *TF: Trickling Filters*

Notes: 1) Fill in actual data, hide invalid raws, and identify the valid option. 2) Based on cost comparison and specicifc site circumsta

Figure (1) The Proposed Selection Matrix

4. Results and Discussions

4.1 Survey and Analyses

4.1.1 Results related to water Consumption and Wastewater Discharges

Survey of the present situation of collection and disposal of waste water in all villages of Sohag has been done by a questionnaire form. Wastewater Collection and Treatment Questionnaire is including: village name, location, population, No. of families, area, climate condition, hydrological records, sanitation measures, water source and water supply system, depth of ground water table, type of underground layers, sources of wastewater produced, type of waste waters, treatment system used (if any), point of discharge, Per capita wastewater production, soil permeability, type of sewerage system, and wastewater analysis. The most important information related to water consumption and wastewater discharges for the governorate of Sohag GOS was demonsrated in table (1) and figure (2).

Table (1) Water Consumption and wstewater Characteristics for GOS

Water Consumption(l/c/d)		Average loads in rural wastewater (g/c/d)					
<1000 capita	50-95	COD	BOD_5	SS	TN	PO_4	Oil and grease
1000-5000	75-100	120-210	60-83	65-75	13	7	10-15
>5000	90-105						
Total needed hydraulic load for WWTPs (m^3/d)		560,000		Total organic load for (kg/d)			333167
				Suspended solids for (kg/d)			254567

4.2 Soil Properties

4.2.1 Hydrology of Sohag Governorate

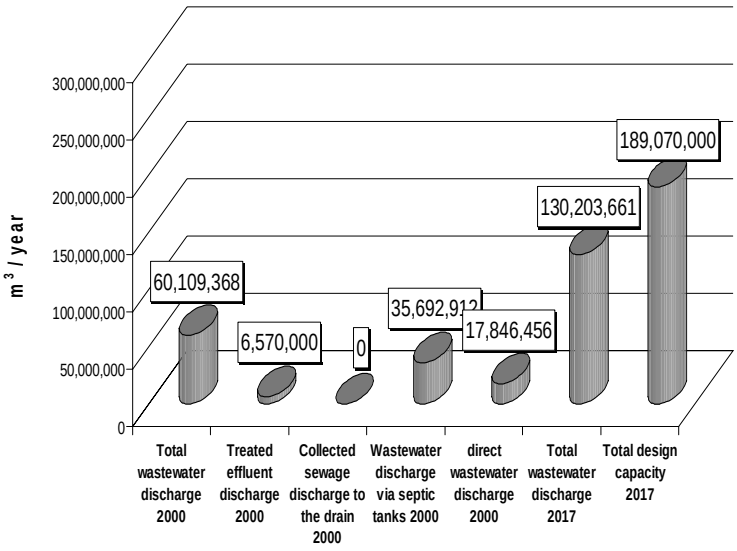


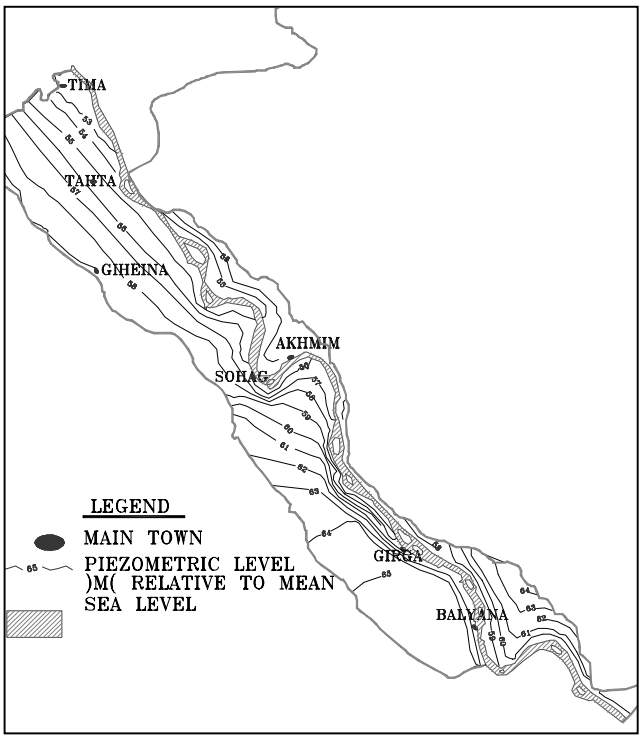
Figure (2) Wastewater Discharges Distribution in GOS

The aquifer is composed of sand and gravel with clay lenses. The maximum thickness of the aquifer is about 250 m at the center of the Nile valley, reaching 50 m at the border. The depth to the groundwater in the alluvial plain varies from one locality to another and is affected by the ground elevation, the level of water in the canals, the water level in the aquifer in addition to many other local factors. Generally, the depth to groundwater ranges between 0.5 m to 6m in the Nile valley and between 8 m to more than 25 m on the border of the valley (Abu El Ella, 1992). Figure (3) shows a contour map of the ground water elevation in the Pleistocene aquifer (Faid, 1990). From this Figure, it can be seen that the groundwater elevation varies between 65 m at the south to 53 m at the north.

4.2.2 Geotechnical Zoning of Sohag Governorate

The geological and hydrological studies of the governorate given in the previous sections, complemented by the available geotechnical data, are used to develop a geotechnical zoning map of the governorate. Figure (4) shows the zoning map of the inhabited area in the governorate. As stated before, the zonation in this map was made based on the results of the geological study and the available geotechnical data. Whenever discrepancy between the results of the geological studies and the available geotechnical data occurred, the zonation was made based on the available geotechnical data since it gives more detailed consideration of formation of the top soil layers. Thus, the borders of the zones in this map are slightly different than what exist in the geological map since they were modified

based on the available geotechnical data. The zonation in this map was made considering the soil formation within the top 15.0 m (the depth covered by most of the available boreholes). As seen in Figure (4), the inhabited area in the governorate has been divided into six zones.



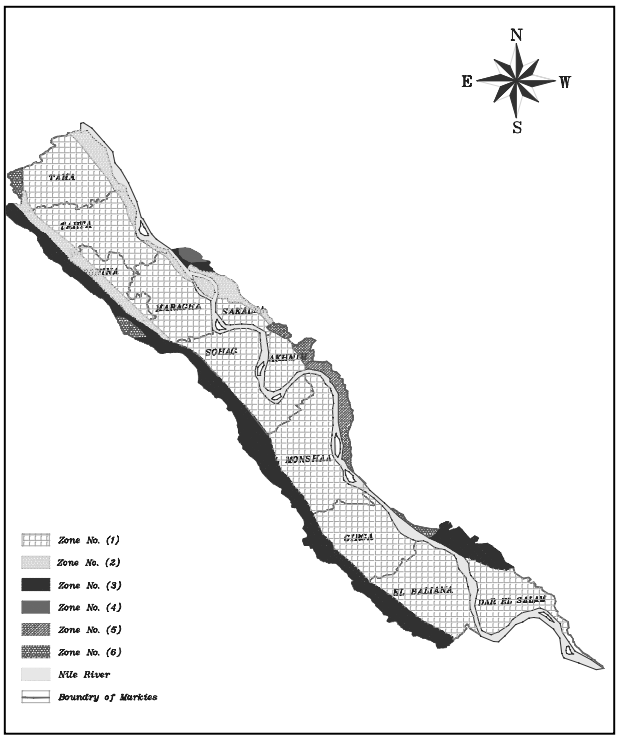


Figure (3) Hydrological Map of GOS **Figure (4) Geo-technical Zoning of GOS**

4.3 Application of the proposed Selection tool

The following criteria have been used to select te target villages as a step ahead to the selection of the most urgent pilot village. To facilitate the application and close monitoring, all target villages for this study should have the following conditions: Near to the city of Sohag, Base map and survey drawings must be available, close to the mother village, having social and local active organizations, ready to share the project cost (house connections), sever shortage in wastewater services, does not included in the national wastewater plans, possibility of treated effluent reuse.

4.3.1 Setting Priorities

Thirteen villages have been chosen as target villages among larger number of villages. These villages were selected based on the selection criteria of the target villages. To determine the priority of implementation, it was necessary to set certain factors and weight for each factor to score the priority of each village. The factors controlling the priority are:

no of beneficiaries, no of households, architectural and structural conditions oh buildings, conditions of water supplies, standard of living, health aspects, social and local activities, project cost, possible extension to accommodate discharges from other villages, and availability of maps. Base on that, the results of prioritization process were concluded with score for each village determining the implementation priority.

4.3.2 Selection of wastewater System components

The starting point of the system selection for a community is the specific parameters and site conditions of the pilot village. The developed selection matrix was designed to simplify the selection and the evaluation process. The matrix includes the required data for each parameter. Based on the scientific background and the specific conditions of the pilot village, the valid options of each component were identified. For the ease of application and analysis of such matrix, a computer program was developed with several subroutines for each to identify the options and cost effectiveness.

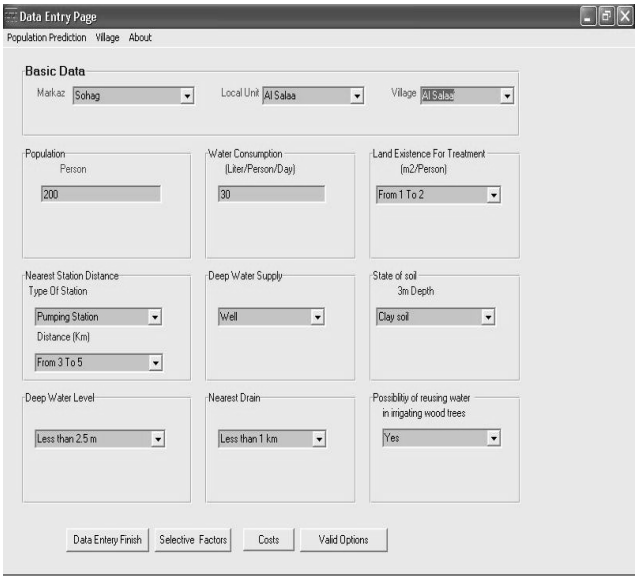


Figure (5) Data Entry Page

The final results of the selection process are the possible options for each wastewater component. Then, the final selection between the valid options was based on the technical and economic eligibility for each option. Figures 5, 6, and 7 illustrate some demonstrations for the developed computer program for data entry, valid options, and cost estimates, respectively. For the pilot village the selected wastewater system components are shown in figure (8). The selection includes the system components for collection & transportation, using simplified sewerage system, treatment using stabilization ponds, and reuse of treated ww in cultivation of woods farms (more than 50 acres).

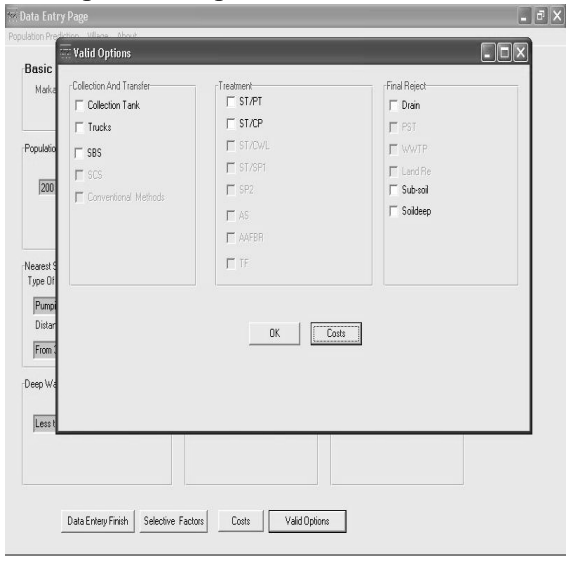


Figure (6) Valid Options Page

The results obtained from this study could be summarized as the following:

1. Simple and easy to operate and update, a computer based selection tool was designed and tested considering technical, economical, environmental, and social aspects as well as community participatory approach.
2. A strategy to set implementation priorities was developed for technically eligible and fair selection in case of limited financial resources. Determination of preference factors and villages' priorities depending on evaluation of No. of beneficial, population density, No. of houses, house connection, living standard, health state, cost, and social acceptance.
3. The Geotechnical zoning of GOS was developed and divided into six zones according to the soil formation and structure based on the available soil bores in different area of the governorates.
4. The proposed technique was tested for a group of villages to set priorities and select a pilot village. Then the selection matrix based on the elimination of the invalid options using the developed computer program was applied to identify the most appropriate options for the wastewater system components in terms of technical and economical aspects.

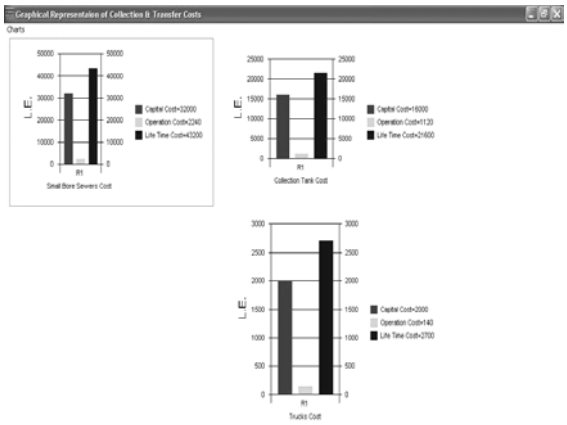


Figure (7) Cost Estimates Page

	First Stage El Hagarsa village o Collection o Pumping o Treatment (1st Stage)	Second Stage El kawamel & A Gharib villages o Collection o Pumping o Treatment (2nd Stage)
Collection	Simplified Sewerage System	Simplified Sewerage System
Transportation	Main Pumping Station	Secondary Pumping Station
Treatment	Stabilization ponds	Stabilization ponds
Disposal and Reuse	Reuse in Cultivation of Wood trees (Local Contribution)	

Figure (8) The WW system components for the pilot village

5. Conclusion

The study proved the possibility of setting and successfully applying the proposed strategy of ww components selection as a helpful and simple technique for evaluation and selection of the most appropriate technical / economical options in the rural areas in Sohag Governorate. Also it is considered as a starting point to touch the actual need of wastewater systems for each village depending on its conditions and preference according to specific criteria for implementation priority. Based on the results obtained for the sanitation system options, a master plan for the rural sanitation systems could be developed considering the context of the national plans. Then, the system design can be prepared for the most preferable options to achieve the village's need as a part of Sohag rural development program considering the sustainability of the project by setting the appropriate system management.

Acknowledgments

The authors introduce their respect to the team participated in this study as a part of Sohag rural development program. Although the study philosophy and concept was developed by Dr. Hisham S.A. Halim *(the first author)* as the principal investigator of this study, the authors highly appreciate and thank the geotechnical department and the centre of Civil engineering and research at Faculty of Engineering, Cairo University for their great support to prepare and finalize the study. Finally, the authors feel very grateful to the project management team from GOS for their support during preparation of the site work.

6. References:

1- Dr. Amir H. Mahvi (2000). Prevailing of Wastewater Management in small Communities in Iran, Technical report, WHO.
2- Lettinga G. et al. (1993) Anaerobic treatment of domestic sewage and wastewater. Wat. Sci. Tech., 27, 9, 67-73.
3- M.M. Ghangrekar (2003): Performance and low cost potency of sewage treatment. Preceding of the 9 the IWA Specialized conference Design, Operation and economics of large wastewater treatment plants, pp. 379-386.
4- Harremoes, P. (1997). Integrated water and wastewater management, waster science and technology, 35(9), 11-20.
5- 5-Otterpohl, R. (2001). Design of highly efficient source control sanitation and practical experiences in decentralized sanitation and reuse. IWA publications, London.
6- On-Site wastewater treatment and disposal, EPA design manuals, www.epa.gov
7- EPA fact sheets on septic tanks, wetland, and anaerobic treatment.
8- Hisham A. Halim (2003) "Planning and Design of Rural Sanitation Systems for GOS, Final Report", Sohag Rural Development Program.
9- Jordan Ministry of Water and Irrigation (1998). *Wastewater Management Policy*. (Amman, Ministry of Water and Irrigation)
10- FAO (1997). *Irrigation in the Near East Region in Figures*. Water Report 9 (Rome, FAO)
11- Otis R. (1996).*Small Diameter Gravity Sewers: Experience in the United States.* In D. Mara (Ed.) Low-Cost Sewerage (Chichester, Wiley and Sons)
12- Mara D. (1996). *Unconventional Sewerage Systems: Their Role in Low-cost Urban*
13- *Sanitation*. In D. Mara (Ed.) Low-Cost Sewerage (Chichester, Wiley and Sons)
14- USEPA (1992a). *Small Wastewater Systems*. Report no 830/F-92/001 (Washington DC, EPA)
15- FAO (1997). *Irrigation in the Near East Region in Figures*. Water Report 9 (Rome, FAO)
16- Venhuizen D. (1997b). *Paradigm Shift*. Water Environment and Technology VOL. 9, NO. 8, pp.49
17- Otterpohl R., Grottcker, M., Lange J. (1997). *Sustainable water and wastewater management in urban areas*. Water Science and Technology, VOL 35 NO 9, pp. 121

18- Butler, R & MacCormick T. (1996). *Opportunities for decentralized treatment, sewer mining, and effluent reuse*. Desalination VOL 106 NO 1-3 pp. 273
19- UNDP – *World Bank Water and Sanitation Programme (1998)*. Roundtable on Innovative Experiences for Latin America in Sanitation for the Urban Poor, 17-18 July 1998 – www.wsp.org
20- WHO-CEHA (1998) *Unpublished proceedings of WHO/CEHA Regional Workshop onWastewater Management in Small Communities*, June 1998 (Amman).
21- 12-Hector A. Merino and Guevara (1991): *Provision de agua en las ciudades mexicanas. Un reto permanente. Banco Nacional de Obras y Servicios Publicos* (Banobars).
22- World Bank (2002), '*Arab republic of Egypt cost assessment of environmental degradation*', Report No. 25175-EGT.
23- Elmitwalli, T.A.; Al-Sarawey, A.; El-Sherbiny, M.F.; Zeeman, G. and Lettinga, G. (2002) *Anaerobic Biodegradability and Treatment of Egyptian Domestic Sewage*. In Proceeding of 5th IWA conference in "Small Water and Wastewater Treatment Systems" Turkey.
24- M.Sundaravadivel and S. Vigneswaran (2001): "*Wastewater Collection and Treatment Technologies for Semi-Urban Areas of India*", Wastewater Science and Technology Vol 43 No 11 pp 329-336.
25- Elmitwalli, T.A.; Zeeman, G.; Oahn, K.L.T.; Lettinga, G.: *Treatment of Domestic Sewage in a Two –Step System Anaerobic Filter/Anaerobic Hybrid Reactor at Low Temperature*. Water Research, Vol. 36, No. 9, 2002, pp. 2225-2232.
26- IWA (2002) *Anaerobic Digestion Model No. 1*. Report No. 13. IWA Publishing.
27- USAID, *http://www.usaid.gov/regions/ane/newpages/perspectives/egypt/egwater.htm*
28- Zeeman, G. (1991) *Mesophilic and psychrophilic digestion of liquid manure*. Ph.D. thesis, Wageningen University, Wageningen, The Netherlands.

7. Presentation of Authors

Hisham S. A. Halim, (1st author) is working at Faculty of Engineering Cairo University (Egypt) in the Department of Sanitary and Environmental Engineering. He is specialised in wastewater treatment and disposal.
Walid A. Halim, Researcher at Housing and Building Research Center, Cairo, Egypt. Currently: Institute of Water Quality and Waste Management, Hannover Uni., Germany.
M. Nazeih, Researcher at Housing and Building Research Center, Cairo, Egypt. Currently: Ph.D. student at Cairo University.