Cost Optimization of Sewerage Systems in Rural Areas in Egypt

Khaled Zaher Abdalla, Sarah Mohamed Sharaf

Abstract— ***Collection of wastewater is considered one of the major environmental problems in Egypt. More than 50% of Egypt villages have no facilities of wastewater collection. Small bore sewer system is a good alternative for wastewater collection system especially in rural areas because the construction cost of small bore sewer system is cheaper than that of conventional sewer system. However, detailed analysis is required to determine the optimum conditions at which small bore sewer system will be a better choice. This paper aims to provide an estimation of total costs for both small bore sewer systems and conventional sewer systems using data of eight different villages in rural areas in Egypt. The villages were chosen in Menofyia and Assuit governorates. Two equations were obtained that can be used to obtain the total costs of both small bore sewer systems and conventional sewer systems for rural areas of similar characteristics to those studied. The optimum population values, at which the small bore sewer system will be the best alternative, were obtained.***

Index Terms— ***Collection systems; Conventional sewer system; Cost; Rural areas; Small bore sewer system***

I. INTRODUCTION

Highlight a section that you want to designate with a certain style, and then select the appropriate name on the style menu. In most developing countries, wastewater is a matter of concern that needs to be addressed because it can have a negative impact on health [1]. It can cause several diseases such as diarrhea, which is considered as the leading cause of child deaths in Africa [2]. One of the main objectives of a wastewater system including collection and treatment is to protect the receiving medium [3]. Thus, proper planning, design, construction and operation of systems for collection and treatment systems of wastewater are essential. Sewers, which convey wastewater, are often classified according to their use. They can carry domestic sewage, industrial waste, ground, surface, and storm water that enter through joints, manhole covers, and defects in the system [4,5]. Preliminary investigations, which are based on estimated flows, approximate ground contours, the location of the streets, and the locations to which the sewage is to be taken, provide a basis for cost estimates which are used to evaluate the feasibility of a project and to determine the suitable type of collection system that can be used [4]. Ideally, the cost of collection and treatment of wastewater is among the main parameters that should be taken into consideration in rural areas [4,6]. Wastewater collection systems are responsible for safe and secure disposal of various types of wastewater [7,8].

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Khaled Zaher Abdalla, Assistant Professor, Sanitary and Environmental Engineering Division, Public Works Engineering Department, Faculty of Engineering, Cairo University, Giza, Egypt.

Sarah Mohamed Sharaf, Graduate student, Faculty of Engineering, Cairo University, Giza, Egypt.

Conventional sewer systems and small bore sewer systems are among the collection systems of wastewater that can be used. Conventional sewer system is a network of sewers laid deep into the ground at a gradient that ensures a self cleansing velocity between 0.6 m/s and 0.75 m/s [9,10]. Conventional sewer systems can be separated systems or combined systems [5]. Small bore sewer systems (SBS) are systems that receive only the liquid portion of household wastewater for off-site treatment and disposal; while grit, grease and other solids which might cause obstruction in the sewers are separated from the waste flow in septic tanks installed upstream of every connection to the sewers [11]. In the small bore sewer system, household domestic wastewater are collected in the septic tanks at which it is retained for about 2 to 3 days. During this period, wastewater undergoes sedimentation and decomposition. After that, wastewater leaves tanks through the pipes as a result of the difference in elevation, and not by gravity (slope) as in conventional systems, thus requiring no deep excavations. As the wastewater is partially treated within the septic tank leading to the removal of solids, minimum or no slope sewers could be used [12]. The main advantages of SBS over the Conventional Sewer system are: reduced water requirements, reduced excavation, reduced materials costs, and reduced treatment requirements. However, the principal disadvantage of the SBS is the need for periodic evacuation and disposal of solids from each septic tank [11]. Because of the lower costs of construction and maintenance and the ability to function with low quantity of wastewater, small bore sewers can be used where conventional sewer systems are inappropriate especially in rural areas [13,14]. Poverty and priorities for industrial investments are the main obstacles in making decisions about construction of wastewater facilities in rural areas [15]. Since financing of wastewater collection systems and wastewater treatment plants are quite costly, most developing countries including Egypt, face problems regarding these projects [16]. Because of poor urbanization in rural areas, the sewer systems built are economically much more expensive [17]. Thus, collection of wastewater is considered as one of the major environmental problems in Egypt especially in rural areas. In the management of wastewater at rural areas not connected to a sewer system, an optimized conditions for wastewater system should be developed [15,18]. More than 50% of Egypt villages have no facilities of wastewater collection. Almost sewerage coverage in rural areas is absent, although rural population densities are often high. In areas without sewerage networks, wastewater is often collected in septic tanks or other forms of on-site sanitation systems. In these installations, frequent leakage and/or overflow occur mainly due to poor quality of construction and maintenance. A sustainable sanitation system must be affordable to construct, operate and maintain [19]. For sanitation to be sustained over the long term, financial resources are needed to put appropriate

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infrastructure in place [20]. The required budget to cover all villages in Egypt with wastewater facilities, including collection and treatment works, is about 100 billion Egyptian Pounds. 60 % of this budget is the cost to conventional sewerage systems [21]. Egyptian Government cannot provide the required budget to cover 100% of the population with sewerage system in the near future because of the limited budget and limited labor force. Therefore, other cheaper alternatives for wastewater collections with low cost should be used. Small Bore Sewer System is a good alternative for wastewater collection system especially in the rural areas because the construction cost of small bore sewer system is cheaper than conventional sewerage system. However, detailed analysis is required to determine the optimum conditions at which small bore sewer system will be a better choice. It is possible to generate a large number of potential combinations of wastewater collection and treatment procedures, but the entire process of selection of the optimum solution will become more difficult [22-26]. Moreover, selection of the optimum wastewater collection in rural areas is a complex process [27]. The main objective of this paper is to provide an estimation of total costs of small bore sewer system and conventional sewerage system, and to determine the optimum conditions at which small bore sewer systems will be the favorable alternative.

II. METHODOLOGY

Rural areas in Egypt consist of Ezbet, Nag, Kafr, Village and Markaz. The population in the previous communities ranges from 1000 persons or less in Nag to more than 100,000 capita in Markaz. In order to study and evaluate the feasibility of using small bore sewer system in rural areas in Egypt, eight different villages with different population were selected. The selected villages were 6 villages in Quesna Markaz in Menofyia governorate and two villages in Assuit governorate. The population and areas of these villages are shown in Table 1. In these villages, no sewerage system exists. The generated wastewater, that flows from residential houses, is collected in septic tanks, and evacuated and disposed into the nearest agriculture drain. Most of the existing tanks have no bottom, and the wastewater flows to the ground water which led to the increase in the water table and increase the possibility of pollution of groundwater. A rough estimation of total costs for small bore sewer systems and conventional sewer systems was performed for the selected villages, then a comparison between these costs was done to determine the optimum conditions. The total costs were obtained based on a design period of 30 years. The total costs of small bore sewer included the costs of pipes, septic tanks, flushing points, and desludging, while the costs of the conventional sewer systems included the costs of pipes, manholes, force mains, and pump stations. The desludging costs were calculated by converting the annual cost to the present value (2014).

Table 1. Data of the selected villages

Village	Markaz / Governorate	Population at year 2044 (capita)	Area (m2)
Monshaat Om Khnan	Quesna/ Menofyia	5255	66544
Kafr Zain El Deen	Quesna/ Menofyia	8644	99700
Kafr Absheesh	Quesna/ Menofyia	13069	157329
Shoubra Kobala	Quesna/ Menofyia	19154	258700
Ashleem	Quesna/ Menofyia	27567	486150
Al Agayza	Quesna/ Menofyia	36441	631195
Al Akal Kebli	Al Badari /Assuit	27681	229697
Al Neekeela	Abu Tieg /Assuit	68996	554110

III. RESULTS AND DISCUSSION

Table 2 shows the total costs of conventional systems and small bore sewer systems for the selected villages. The costs are shown in Egyptian pounds. Since the population density is not constant, the total costs are function of both population and area, and the relation may be a direct or inverse proportional depending on the population density. To determine the optimum conditions, a relation between the total costs and the population density was obtained as shown in Fig. 1. Two equations were obtained from the graph. The first equation represents the total costs of conventional sewer systems as a function of population density. The correlation coefficient was found to be 0.924. The second equation represents the total costs of the small bore sewer systems as a function of population density. The correlation coefficient was found to be 0.98. Using these equations, once can obtain the relation between total costs of conventional sewer systems and small bore sewer systems versus population for a given area. Fig. 2 to 7 represent the difference between the total costs of conventional sewer systems and small pore sewer systems, (Total costs of Conventional sewer systems - Total costs of small bore sewer systems), versus population for 5, 10, 15, 20, 25, 30 feddans respectively. The points of intersection of the curves with X-axis in each of these figures represent the critical point at which the total costs of conventional sewer system are equal to the total costs of small bore sewer system. Thus, the total costs of small bore sewer systems will be less than the total costs of conventional sewer systems for a given area provided that the population do not exceed the values shown in Table 3.

Table 2. Total costs of conventional systems and small bore sewer systems

Village	Total costs of conventional system (LE)	Total costs of small bore sewer system (LE)
Monshaat Om Khnan	8285813.75	4942076.165
Kafr Zain El Deen	9697986.5	5946020.107
Kafr Absheesh	7608572.5	4675870.047
Shoubra Kobala	17888093.75	11766315.51
Ashleem	18921750	14149475.35
Al Agayza	30640250	22086979.16
Al Akal Kebli	23187390	18340406.18
Al Neekeela	29208500	32750628.25

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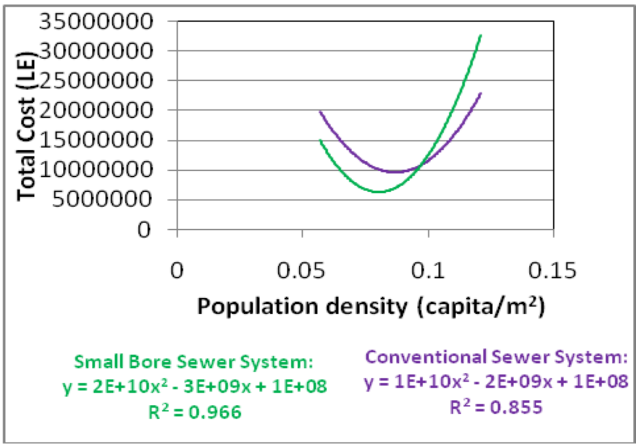

Fig 1. Relation between total costs and population densities

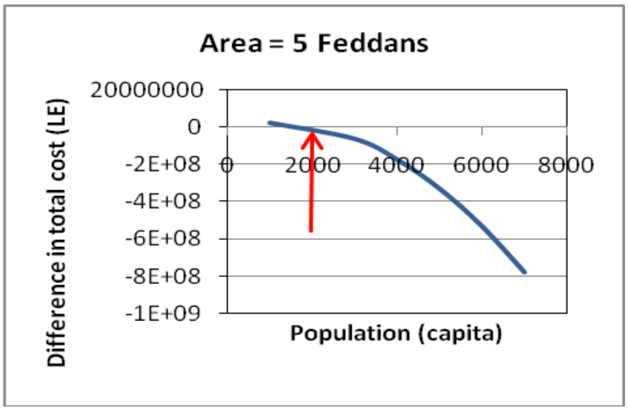

Fig 2. Difference in total costs versus population for area of 5 feddans

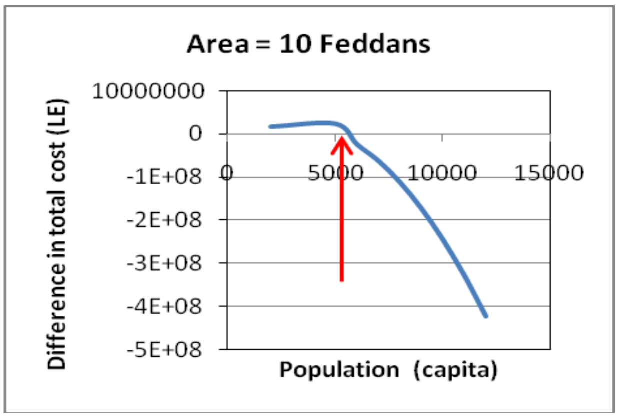

Fig 3. Difference in total costs versus population for area of 10 feddans

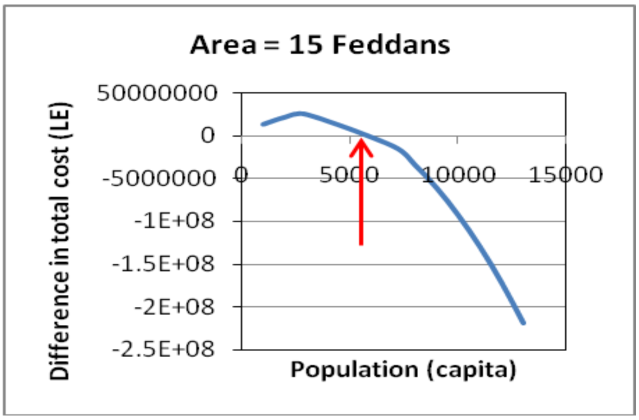

Fig 4. Difference in total costs versus population for area of 15 feddans

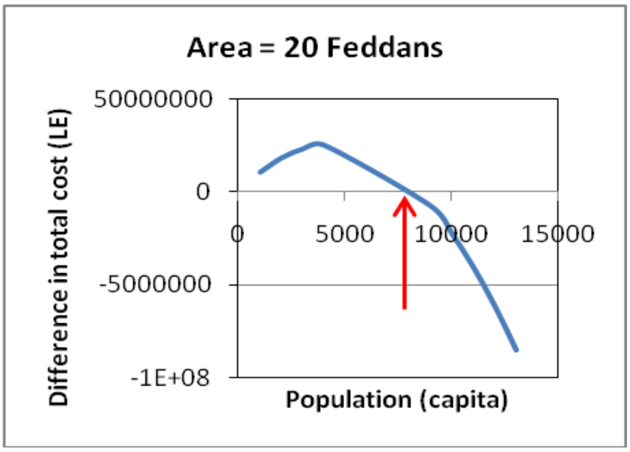

Fig 5. Difference in total costs versus population for area of 20 feddans

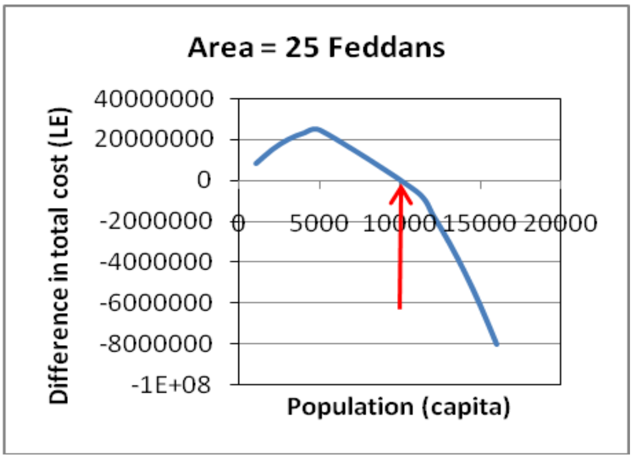

Fig 6. Difference in total costs versus population for area of 25 feddans

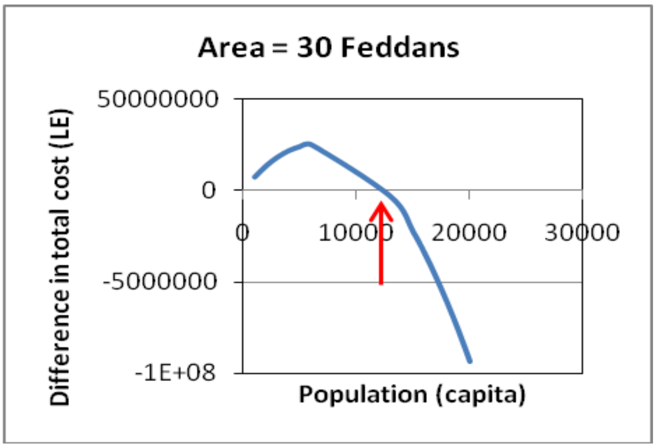

Fig 7. Difference in total costs versus population for area of 30 feddans

Table 3. Population at which the total costs of small bore sewer system will be equal to the total costs of conventional sewer system for a given area

Area (Feddans)	Population (Capita)
5	1,700
10	5,600
15	5,900
20	8,000
25	10,000
30	12,000

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IV. CONCLUSION

The conclusions obtained are as follows;

- Small bore sewer system is a suitable system for collection of wastewater that can be used in rural areas.
- Population densities in villages in Egypt are not constant, so the total costs of collection systems of wastewater will be a function of both population and area of these villages.
- In rural areas, the population below which the total costs of small bore sewer systems will be less that that of conventional sewer systems depends on the area.
- A rough estimation of the total costs of conventional sewer systems and small bore sewer systems can be obtained for a certain village using equations obtained in Fig. 1, provided that this village has similar characteristics to those studied in this paper. For different villages, further studies will be needed.

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