Waste Management as an Approach for Sustainable Development: A study in a rural area in Egypt

Hend zaki, Yasser Farghaly, Fahd Hemeida

Abstract—Waste management strategies are largely non-existent in rural areas in Egypt, as more than 70% of the waste generated is not collected and is being disposed in open dumps or canals which have turned into garbage dumps and are brimming with organic and solid waste. Improvements in waste management strategies are urgently needed to combat the resulted health services high costs and alleviate environmental hazards. The aim of this research is to explore new strategies and establish guidelines for waste management that can be applied in Egypt with an economic return for individuals, thus achieving sustainable development. To achieve this aim a qualitative analysis of waste management strategies of a rural village in Beheira was conducted. Their problems and habits were studied, interviews were held and questionnaires were distributed and collected with the inhabitants. In addition, an anaerobic digester prototype was implemented in a house and its economic return on the family was calculated.

Index Terms— Anaerobic digester, Biogas, Renewable energy, Rural areas, Solid waste, Sustainable development, Waste management.

u

1 Introduction

SOLID waste management (SWM) is one of the most pressing challenges that the Egyptian authorities are facing for decades. However, it is not only limited to the waste collection and disposal, but it comprises waste collection, transportation, sorting, recovery and disposal [1], [2]. Rapid urbanization and the change in consumption patterns increase the solid waste production as it is a byproduct of human activities, resulting in increasing the magnitude of the problem [1]. It is stated that the city that is not able to manage its waste effectively, is rarely able to manage the more complex services like transportation, education, or health [3].

More than one ministry or structure are responsible for solid waste management in Egypt , however each ministry proposes every management process separately which shortages the vision of planning and cooperation [4], [5].

In 2015, Egypt produced nearly 90 million tons of municipal solid waste, agricultural waste, industrial waste, construction and demolition waste, and other hazardous materials [4]. Solid waste collection systems collect between 50-65% of waste in urban areas, while in rural areas 30% of waste is collected [1], [6]. The poor disposal practice and uncollected waste result in a loss of 1.5 % of GDP for health impacts. The low income population is affected more by the burdens imposed by insufficient solid waste systems [7].

Dumping of waste in canals in Egypt became a series problem and an urgent intervention is needed, as waste plugs the flow of the canals and prevent the water from reaching agricultural lands, as what happened in El-harooneya canal when excessive branching of the water canal together with the waste disposal in the small passages of water led to loss of water at the terminates of the canal [8].

Solid waste can be considered as a valuable resource if it is properly used, however it can result in serious reverse impacts on the health of the public and the environment if it is not effectively managed [9], An example is seen in burning of fossil fuels and the emission of carbon dioxide from burning waste resulting in the increase of the greenhouse gases in the atmosphere, which has caused a rise in temperature [10]. In addition, the canals became a breeding ground for flies, mosquitoes and other insects. This correlates with the children living nearby being susceptible to diarrhea, cholera and other waterborne diseases.

In this regard, renewable energy recovery strategies such as biogas are suggested. Biogas which is generated from anaerobic digestion can replace the conventional fossil fuels, thus reducing greenhouse gases emission [10]. Compost and biogas production from organic waste is widely accepted as a best practice in Africa [11].

Biogas can be generated from varied options of biomass as crop residues, livestock farm waste, food waste [10]. Therefore, the solid waste produced from rural areas has a high potential for the production of biogas from the anaerobic digester. As a result, waste management systems for households scale could eradicate or reduce the process of waste collection and transportation. In addition, it doesn't require a special infrastructure while transforming garbage into energy source and safe product with no harmful emissions [12].

The aim of this research is to explore new strategies and establish guidelines for waste management that can be applied in Egypt with an economic return for individuals, thus achieving sustainable development.

To achieve this aim a qualitative analysis of waste management strategies of a rural village in Beheira was conducted. Their problems and habits were studied, interviews were held and questionnaires were distributed and collected with the inhabitants about waste management finally, their awareness was raised by involving them. In addition, an anaerobic digester prototype was implemented in a house and its economic return on the family was calculated.

2 Solid Waste Management

Solid waste is any unusable or unwanted material, by-products or substances [13]. The quantity of waste generated differs from city to city and season to season and is affected by the level of economic development and activity of a country [14]. It may be categorized according to:

Its source or origin to: Municipal solid waste (MSW), agricultural waste, industrial waste, construction and demolish waste, institutional waste, municipal services waste [3], [15].

Its contents to: Wet / organic waste (decomposes easily especially in warm weather ex: left-over food, garden waste). Or Dry / non-organic waste (doesn't decompose easily ex: plastic, rubber, glass, metal) [5], [14].

Its hazardous potential to: Toxic, non-toxic, infectious, radioactive, flammable, etc.

2.1 Fundamental elements of solid waste management

Solid Waste Management involves activities associated with the six fundamental elements of

- Waste generation
- Handling, separation, and storage at the source.
- Collection.
- Transfer or transport.
- Processing and transformation.
- Disposal

Solid Waste management is a responsibility of the municipality. However, in many African municipalities achieving this goal is barely fulfilled as a result of undeveloped and inconvenient services. This is due to lack of legislations, poor infrastructure, limited recycling activities, and poor facilities for safe handling, treatment, and disposal of such waste [5], [16].

2.2 Solid waste management hierarchy

Most developed countries have already stated their strategies and policies on the principles of the waste hierarchy. The design of the hierarchy may differ among countries, however waste prevention through efficient use of raw materials and resources is the first preference to most of them [3], [17], [18]. The hierarchy usually adopted is: prevention and reduction, re-use, recycling, recovery and disposal.

2.2.1 Prevention and reduction

Prevention and Reduction means eliminating the amount of waste produced at the source. Reduction can be carried out through consumers polices and extended producers [15], [19].

2.2.2 Reuse

Reuse means using a product on more than one occasion, either in its original or modified form for other purpose– using empty jar for storage-. Reusing of a product doesn't return it to the industry for reprocessing, that's why it is more preferable than recycling as the material doesn't go through a detailed treatment process thus saving energy and material usage [5], [19].

2.2.3 Recycling

Recycling means the removal of useful materials (paper, glass, plastic, and metals) from the trash to be treated or reprocessed to be used as raw materials in the manufacture process for subsequent reuse either for its original form (e.g., paper recycling) or for other purposes (e.g., recycling plastic bottles into fleece jackets) [5], [20].

2.2.4 Recovery

The waste management hierarchy prioritizes energy recovery over disposing waste to landfills. Material recovery or energy recovery can take numerous forms of the waste that can't be reused or recycled and recover energy from them through transformation to any beneficial purpose by thermal, chemical, or biological treatment. Treatment methods are selected based on the quantity, composition and form of the waste materials [15], [17], [19], [21].

2.2.5 Disposal

Waste management practices cannot eliminate the need for landfills completely. Waste that can't be transformed or recycled and holds no further value that can be recovered must be landfilled. However, the disposal of waste in landfills remains the least preferable option. Types of disposal are: Sanitary / secure landfills, Controlled dumps and Open dumps [5], [15], [17].

2.3 Solid waste management in Egypt

In 2015, Egypt produced nearly 90 million tons of all wastes. However, 81 % of the waste generated is dumped in random dumps which are not controlled and only 7 % of the waste is dumped in controlled sanitary landfill sites. The recycling and recovery rates didn't exceed 12 % [4], [22], while only 7 % of the waste is composted [6]. The poor disposal practice and uncollected waste result in an estimated loss of 1.5 % of GDP for health impacts across Egypt. The low income individuals are more affected by the burdens imposed by insufficient solid waste systems [7].

Solving the waste problem in rural areas is becoming more challenging as the majority is of low socioeconomic level and

ISSN 2229-5518

they aren't aware of the consequences of not having a waste management services this is further complicated by the lack of technology which could help in such communities [19].

2.3.1 Solid waste composition according to source

Waste composition differs between countries, even within one country the type of waste vary according to season, location, and urban patterns. Wherefore the waste composition in Egypt – a developing country- is not the same as a developed country [19]. The waste composition in 2015 shows that agricultural waste is the biggest constituent, while municipal solid waste accounts for 25 %, the composition of waste is presented in figure 1 [4].

Fig. 1. Illustrates the composition of waste according to source.

2.3.2 Solid waste composition according to content

Organic / biodegradable: which accounts to the greatest amount of waste: 50-60%; Paper and Cardboard are 10%; Plastic accounts for 13%; Glass are 4%; Metals: are 2%; finally other waste accounts for 15%, Shown in figure 2 according to EEAA Egypt state of the environment 2015 report [1].

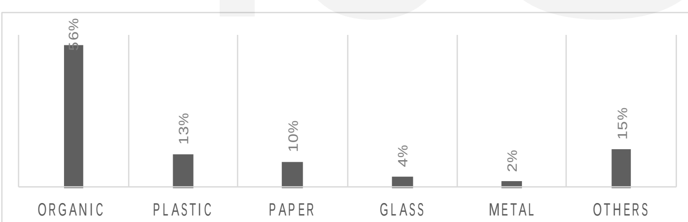

Fig. 2. Shows the composition of waste according to content.

- *Hend zaki is currently pursuing masters degree program at the Department of Architectural Engineering and Environmental Design, AASTMT, Egypt. E-mail: hindzaki@ymail.com*
- *Yasser Farghaly is an associate professor at the Department of Architectural Engineering and Environmental Design, AASTMT, Egypt. E-mail: yfarghaly@hotmail.com*
- *Fahd Hemeida is an assistant professor at the Department of Architectural Engineering and Environmental Design, AASTMT, Egypt. E-mail: fahd.omar@aast.edu*

3 Methodology

To achieve the research aim, a qualitative analysis of waste management strategies of a rural village in Beheira was conducted. The inhabitants' problems and habits were discussed, interviews with the gate keeper and two garbage collectors were held, focus group discussion were done and questionnaires with 52 inhabitants and two supermarkets about waste management were distributed and collected. Then all the collected data were analyzed. Finaly, an anaerobic digester prototype was implemented in a house and its economic return on the family was calculated.

4 Research case study

Aziz Bahary is a small village with 165 households, it is located within the premises of Beheira governorate. The total area of the village is 36,514.23 m2 [23]. The settlement is surrounded by agricultural fields. The total population is 830, out of which 250 are men, 240 are women and 340 are children. The average household size is 5.36.

Many houses have a cowshed in their ground floor. There are 105 residential buildings, 1 mosque, & 3 supermarkets.

4.1 Village problems:

Aziz Bahary is suffering of a lack of waste management system due to the absence of garbage collectors. Moreover, many households dispose their waste in canals which have turned into garbage dumps and are brimming with solid waste, streets, agricultural lands or vacant lands. Figure 3 is showing the location of the garbage on the village plan.

Additionally, the price of the butane gas cylinders increased from 15 L.E (on 1 / 10 / 2016) to 25 L.E (on 4 / 11 / 2016) and reached up to 40 LE and more (on 1 / 8 / 2017) [24] .This has a great effect on the residents, as each house uses in average 2 or 3 cylinders monthly.

4.2 Types of village waste mostly generated

According to source:

- Residential and commercial waste (generated from households & supermarkets)
- Agricultural waste (generated from poultry farms, animal farms, planting and harvesting of trees)

According to content

- Wet or organic waste (biodegradable / compostable): ex. left-over food, agricultural waste, wood, animal waste.
- Dry or non-organic waste: ex. plastic, rubber, glass, metal, paper, diapers.

Fig. 3. Shows that the waste is disposed in the canals (A), streets (B) or any vacant land (C).

4.3 Data preparation phase

Primary data are built on a number of activities. These include:

Field surveys and walkthroughs; Primary field visits have been performed on the 12th of August 2016 to become familiar with the village and distinguish the social constraints and the residents' problems.

An Individual interview with the village gatekeeper (Sheikh Khaled); as he is familiar with all the village inhabitants and is responsible for solving the village problems.

Households' questionnaires; these started on the 4th of October 2016 and completed on the 9th of December including a questionnaire of 52 households, some of which having a cowshed while others not, as shown in figure 4

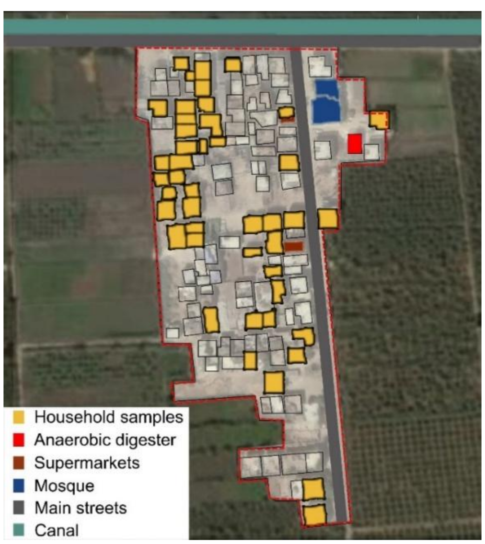

Fig. 4. Shows the houses where the questionnaires were collected, the location of the two supermarkets and the anaerobic digester

Supermarkets' interviews; the interview was held on the 6th of October 2016 with two supermarkets.

Focus Group discussions; Data was obtained from two focus group discussions and individual in-depth interviews, prepared and held in the village.

Interviews with two garbage collectors; a phone call interview was done with two garbage collectors working in villages near Aziz Bahary to know more information about the waste collection system.

4.4 Implementing an anaerobic digester

On the 2nd of October 2016, an area of (3.5 *4.5 m^2) was digged for the digester. Then the labors began the construction of the first and largest dome (digester tank). The selected place is located next to the cowshed to be easier for the households to feed the unit.

The digester consists of two spherical domes, a mixing tank, gas outlet pipe and a place for collecting the manure. The construction phase took 5 days, then the household started feeding the digester with diluted manure every day for 45 days, finally the biogas was generated from the gas outlet pipe. Figure 5 illustrates the timeline of the construction of the anaerobic digester.

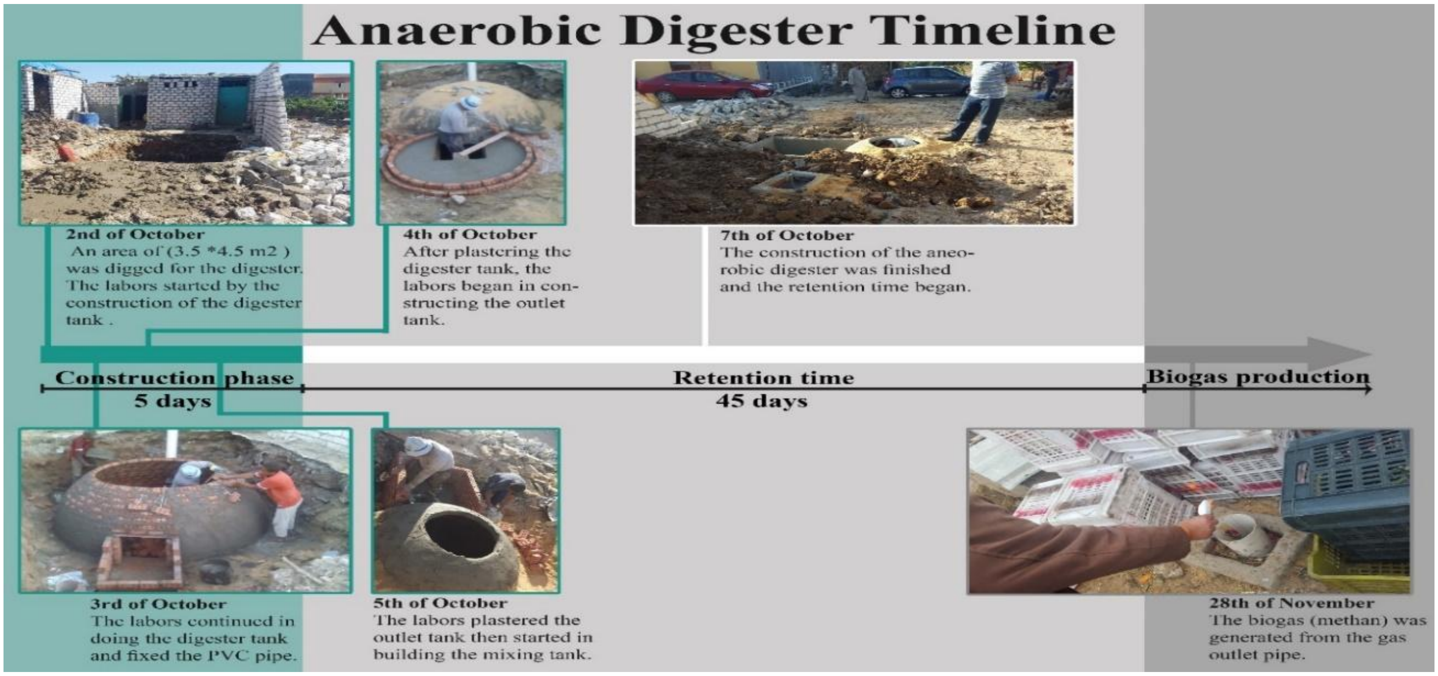

Fig. 5. Illustrates the timeline of the construction of the anaerobic digester.

5 Discussion

The households' questionnaire analysis shows that 96.2 % of the households dispose their non-organic waste in the canals, while 40.4 % dispose the organic and non-organic waste in the canal, turning it into a dumping site. The majority of the sample 80.8 % suffer from the foul odor and diseases while disposing the waste, thus believe that finding a proper waste management system is a necessity.

In the households' questionnaire the families were asked to propose a solid waste management system that suits them. The families said that the village needs a waste collector, 71 % said he can come 3 times a week, 67.3 % stated that he can come any time of the day, 79.2 % suggested that the collection location shall be at the beginning of the street, 84.6 % can pay him 10 pounds per month, 44 % of the households said that the commitment of the garbage collector is the key for the system to continue and succeed, 58.3 % recommended raising the awareness of the people to keep the area clean and 56 % suggested that the religious leaders can help in doing this.

Additionally, one of the strength characteristics of this village is that 82.7 % of the households sort the waste before disposing it, hence they have the potential to establish a waste management system by collecting and recycling the non-organic waste by the waste collector and using an anaerobic digester for the organic remnants.

More than 70 % of the waste generated in Aziz Bahary consists of organic waste, thus the focus of the improvement in the waste management system should focus primarily on the organic waste management in households, in addition most of the inhabitants are farmers who need compost regularly.

The anaerobic digester saves money for a household. It also has lesser negative impact on the environment and humans, as it doesn't require a special infrastructure or the transportation of waste to a long way to disposal sites. Additionally, it allows garbage to be changed into energy sources and safe products with no harmful emission.

The household's scale digester can be applied in two situations; either the households pool their manure for a single digester if each family doesn't own the required head or space, or the households own the necessary number of heads of livestock as the case in Aziz Bahary. In this case, the family installs the digester at their house, uses the produced manure for feeding the digester, uses the slurry for their land and uses the gas in their own kitchen. Forty six point two percent of the families in Aziz Bahary have a cowshed and 79 % of them accepted to share with their neighbors in a digester. The following figure 6 illustrates the households that own a cowshed at their home

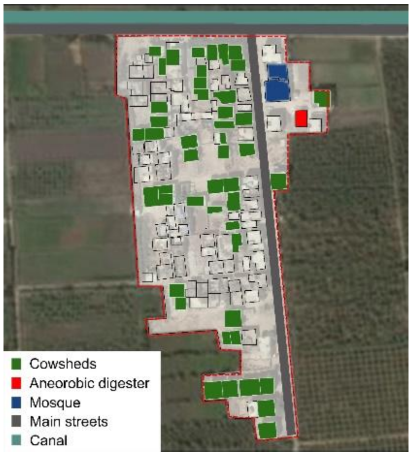

Fig. 6. Illustrates the households that own a cowshed at their home.

5.1 Feasibility study of anaerobic family scale digester

The average households' size in Aziz Bahary is 5.36. Most of the families rent or own a small plot of agricultural land, on which they cultivate food, animal or cash crops.
Ninety percent of the families own more than 1 head of live-stock, sometimes some goats, a donkey and / or some poultry. The animals stay in the cowshed all day long and the manure is collected twice a day and is applied to the land. A major loss of waste nutrients takes place due to the disposal of 55.8% of the households' organic waste without treatment.

In addition of using animal dung, farmers use chemical ferti-lizers in order to retain soil fertility. Farmers indicated using about 10 bags of fertilizers (of different types) per acre per year. On the mid of November 2016 the average price of the bag ranged between 110 LE and 145 LE per 50 kg bag, so the annual cost was around 1275 LE per acre. However, on august 2018 the prices of the fertilizers' bag increased –due to infla-tion- to range between 210 and 225 according to its type.

Comparing the initial cost of the 2m³ digester with the annual savings of organic fertilizers and biogas subsidy shows that The digester is repaid in approximately 2-3 years as illustrated in table 1, table 2 and figure 7.

Table 1 illustrates the cost of the different sizes of the digester on Novem-ber 2016 and the yearly produced manure [25].

Volume of unit (m3)	Dimen-sions (m)	Animal dung /day	Butane cylinder/ month	Manure produced yearly in sacks		Implem-entation days needed	Cost LE
				Urea	Super phosphate		
2	3.2*3.2	50	2-3	6	12	4	5400
3	3.6*3.6	75	3	9	18	4	6000
4	4*4	100	4	12	24	5	8000
6	4.6*4.6	150	6	18	36	7	10,000

Table 2 shows the annual savings of 2m^3 household digester on 2016

Parameters	Total cost (LE)
Initial cost	5400
6 sacks urea fertilizers	6 * 145= 870
12 sacks super phosphate fertilizers	12* 110= 1320
Operation & maintenance (5 % of initial cost)	-270
Butane gas cylinders (2.5)	2.5*25=62
Annual savings of fertilizers	870 + 1,320 = 2190
Annual savings of butane cylinders	62* 12 = 744
Total saving	2,190+ 744 - 270= 2664 L.E

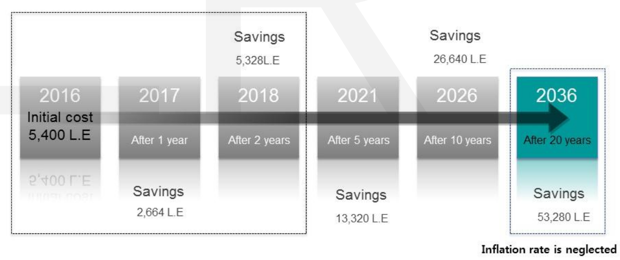

Fig. 7. Illustrates the lifetime savings of the 2m^3 digester

5.2 The feedback of the family that implemented the anaerobic digester

The family rents an agricultural land of one acre, they use the produced slurry from the digester in cultivating their land. Mohamed the family's elder son, who is responsible for taking care of the digester, said that the digester is working properly except for the fact that the produced biogas is weak due to the long distance between the digester and the kitchen. The 2m³ digester is supposed to save 2-3 butane gas cylinder per month. Nonetheless, in their case it only saves 1 cylinder per month.

However, the produced slurry save more than half the amount of the chemical fertilizers that the family used to buy. Mohamed said that in the past he used to buy 12 chemical fertilizers bags every year, but now he just uses 4 bags of chemical fertilizers beside the produced manure. He stated that he uses only half the amount of the produced manure, because their land is 1 acre and the 2m³ digester can serve a 1.5-2 acre land.

As of august 2017 the average price of the chemical fertilizers went up to 220 LE per 50 kg bag, and the butane gas cylinder became 40 LE. However the initial cost of the digester increased to 6700 instead of 5400. Comparing the initial cost of the implemented digester with the annual savings of organic fertilizers and biogas subsidy, the digester is repaid in approximately 3-4years as shown in table 3 and figure 8.

Table 3 illustrates the annual savings of the implemented digester:

Parameters	Total cost (LE)
Initial cost	6700
4 sacks urea	4 *225= 900
4 sacks super phosphate	4* 210= 840
Operation & maintenance (5 % of initial cost)	-335
Butane gas cylinders	1* 40= 40
Savings of fertilizers	900+840= 1740
Annual savings of butane cylinders	40 * 12 = 480
Total saving	1,740+ 480-335=1885 L.E

Fig. 8. Illustrates the lifetime savings of the implemented digester

Nevertheless, the implemented unit could save more as it is supposed to produce manure equivalent to 6 sacks of urea and 12 sacks of super phosphate as shown in table 1 in this case when comparing the initial cost of the digester with the annual savings of organic fertilizers and biogas subsidy, the digester is repaid in less than 2 years as shown in table 4 and figure 9.

Table 4 illustrates the annual savings of a 2m³ digester as of august 2017:

Parameters	Total cost (LE)
Initial cost	6700
6 sacks urea	6 *225= 1350
12 sacks super phosphate	12* 210= 2520
Operation & maintenance (5 % of initial cost)	-335
Butane gas cylinders (2)	2* 40= 80
Savings of fertilizers	1350+2520= 3870
Annual savings of butane cylinders	80 * 12 = 960
Total saving	3,870+ 960-335=4495 L.E

The initial cost of implementing a digester is divided between the construction work done by the family, company's supervision and construction materials cost. By comparing the lifetime saving of the 2m³ digester on 2016 and that on 2017, it is showed that the savings of the digester in 2017 is almost the double of that on 2016, as only the construction materials price increased which accounts almost to 40 % of the initial cost, but on the other hand the price of the saved chemical fertilizers bags increased to the double as shown in table 4.

Fig. 9. Illustrates the lifetime savings of a 2m³ digester as of august 2017

6 Conclusions:

Solid waste composition in Egypt is dominated by organic material (56 %). This constitutes an opportunity for solid waste composting and the use of the compost as an organic fertilizer thus fostering sustainability.

The government needs to encourage systems that manage the waste at the source and that maximizes the separation of recyclable material at the source so as to reduce the amount of waste to be disposed and the cost related to it. In addition, the engagement of the local communities in raising the awareness and motivating the households to compost and recycle is required.

There is a set of limiting constraints that face rural areas, these require innovative waste management systems, such as:

The limited land availability for disposing waste, which led to the waste being dumped into irrigation canals and agricultural drains;

The geographical location of rural communities, as each community contains small populations relatively and large distance separating them;

Most villages suffer from poor mobility in their premises, because of their narrow and unpaved streets; and

The willingness and the ability of the inhabitants to pay for waste management services are limited, due to their low income statues, which leads to them being less appealing to private sector companies.

Despite the aforementioned limitations, municipalities are required to apply strict regulations and fines to prevent the dumping of waste in canals and in public spaces.

The anaerobic digester not only reduces the pollution produced due to burning waste or disposing it into canals, but also solves the gas cylinder shortage, produces organic fertilizers for healthier livings, and saves money for the households. In addition the importance of the bio-fuel becomes more eminent in rural areas when taking the increase of butane gas cylinders into consideration as the recent increase of the prices led to the escalation of the expenses for those who need them the most.

Moreover, the impact of producing organic fertilizer also plays an important role, as it is a replacement of the currently wasted manure which provides weak fertilization and necessitates the use of chemical fertilizers which costs more and affects both the farmers and the governmental spending.

Finally the cost of implementing an anaerobic digester is directed towards the company's supervision, the construction work -which can be done by the family members- and the construction material. Although the spending for the company's supervision and that for construction work are almost the same from 2016 to 2017, the price of the chemical fertilizers increased by 40 %, so the annual saving of the digester in 2017 is almost double that of 2016.

References

[1] Egyptian environmental affairs agency (EEAA), Egypt State of the Environment Report 2012: the English report [online], 2015. Available from: http://www.eeaa.gov.eg/portals/0/eeaaReports/SoE2013en/SOEreport_2012_english.pdf [Accessed on 19-09-2017]

[2] S.M. Milik, *Assessment of solid waste management in Egypt during the last decade in light of the partnership between the Egyptian government and the private sector,* (2011).

[3] D. Hoornweg, P. Bhada-Tata, *What a waste: a global review of solid waste management. Urban development series knowledge papers*; no. 15. Washington, DC: World Bank Group. http://documents.worldbank.org/curated/en/302341468126264791/What-a-waste-a-global-review-of-solid-waste-management. (2012).

[4] Egyptian environmental affairs agency (EEAA). Egypt State of the Environment Report 2015: the Arabic report [online] , 2017. Available from: http://www.eeaa.gov.eg/portals/0/eeaaReports/SoE2016AR/%D8%AA%D9%82%D8%B1%D9%8A%D8%B1%20%D8%AD%D8%A7%D9%84%D8%A9%20%D8%A7%D9%84%D8%A8%D9%8A%D8%A6%D8%A9%20%D9%81%D9%89%20%D9%85%D8%B5%D8%B1%20%D9%84%D8%B9%D8%A7%D9%85%202015.pdf [Accessed on 19-09-2017]

[5] M.I.M. Ibrahim, N.A.E.M. Mohamed, *Towards sustainable management of solid waste in Egypt,* Procedia Environmental Sciences, 34 (2016) 336-347. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1878029616300524.

[6] The Regional Solid Waste Exchange of Information and Expertise Network in Mashreq and Maghreb Countries – SWEEPNET. Country Report on Solid Waste Management. Cairo, Egypt: SWEEPNET; 2014.

[7] World Bank. Cairo Municipal Solid Waste Management Project (P152961). Report No. PIDC18002. Washington DC. , 2015. Available from: http://documents.worldbank.org/curated/en/245761468024247659/pdf/PID-Print-P152961-01-05-2015-1420469398757.pdf

[8] N. Magdy, أهالي دشنا عن ترعة الهارونية: "مفهاش مياه".. والمسئول: "لا في"!, in: اعلام, 2017.

[9] WaterAid. Solid waste management in Nepal. , 2008 Available at: www.wateraid.org/~/media/publications/solid-waste-management-nepal.pdf

[10] A. Gurung, S.-E. Oh, *Municipal Solid Waste Management: Challenges and Opportunities in Nepal, Korean* J. Soil Sci. Fert, 45 (2012) 421-427.

[11] UNITED NATIONS, E.A.S.C. ORIGINAL, Africa review report on waste management Main Report, in: INTEGRATED ASSESSMENT OF PRESENT STATUS OF ENVIRONMENTALLY -SOUND MANAGEMENT OF WASTES IN AFRICA, Sixth Session of the Committee on Food Security and Sustainable Development (CFSSD-6)/Regional Implementation Meeting (RIM) for CSD-18, 2009.

[12] H. Jouhara, D. Czajczyńska, H. Ghazal, R. Krzyżyńska, L. Anguilano, A. Reynolds, N. Spencer, *Municipal waste management systems for domestic use*, Energy, 139 (2017) 485-506.

[13] Cambridge dictionary [B1]. Cambridge University Press 2017. Available from: http://dictionary.cambridge.org/dictionary/english/waste [Accessed on 06-08-2017]

[14] 14) O.M. Opeyemi, *Proposal for New Waste Management System in Nigeria (Lagos State)*, in: International Business, 2012.

[15] I. Khan, N. Ashan, *Textbook of Solid Wastes Management* CBS Publisher & Distributors P Ltd, 2012.

[16] J.M. Mungure, Governance and Community Participation in Municipal *Solid Waste Management, Case of Arusha and Dar es Salaam Tanzania*, in, Aalborg University, 2008.

[17] G. Arzumanyan, *Municipal Solid Waste Management in Armenia Current Trends and Steps Forward*, (2004).

[18] UNEP, *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication* - A Synthesis for Policy Makers, in, 2011.

[19] S. M. El-Haggar, *Sustainable Industrial Design and Waste Management*. Elsevier academic press, pp. 149-158, 2007.

[20] R. El gazzar, B. Gomaa, *Municipal Waste Management in Egypt: An Investigation Study of Collection and Generation Process in Alexandria City*, Egypt. International Journal of Scientific & Engineering Research, 5 (2014) 1204-1206.

[21] M. Massoud, F. Merhebi, *Guide to Municipal Solid Waste Management*, in, American University of Beirut - Nature Conservation Center (AUB-NCC), American University of Beirut, 2016.

[22] The Regional Solid Waste Exchange of Information and Expertise Network in Mashreq and Maghreb Countries – SWEEPNET. Country Report on Solid Waste Management. Cairo, Egypt: SWEEPNET, 2010.

[23] Google Earth Pro 7.1.7.2606 (June 19, 2017). Beheira, Egypt. 31°12' 50.64" N, 30° 06' 51.15"E, Eye alt 1653 feet. Digital globe 2017. http://www.earth.google.com [July 10, 2017]

[24] Issa, A., El Adawy, M., Alaa, O., Fahmy, H., Hamed, H., Ali, Y., Samir, A., Hamida M. and Atallah, I., البوابة نيوز. الغاز نار.. أزمة "البوتاجاز" تشعل غضب المواطنين بالمحافظات.

06 July 2017. [Online]. Available from: http://www.albawabhnews.com/2600004 [accessed on 25-7-2017]

[25] M. Omar, engineer at Biomasr Company, Al Jizah, Egypt, personal communication, 2016.