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# Zero Waste Rural Community Complex ($ZWRC^2$)

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**Abstract**

Millions of people living in rural areas in some developing countries are entombed in extreme poverty well beneath any definition of human decency. They live in squalid areas due to the absence of adequate sewage system, lack of agricultural and municipal solid waste management. As an easy and cheap solution to their problems, residents of rural communities either throw their wastes in the streets and in the nearest water way or burn them in the field. These unintended practices contribute to the deterioration of the quality of air, water, soil and food. In addition to the environmental problems, rural communities in developing countries suffer from illiteracy, unemployment, high risk for disease, high mortality rate, and low life expectancy. Due to this tragic situation, it became imperative to find a solution to reach zero pollution in rural areas. Since the emergence of the concept of sustainable development many efforts have been made to apply the ‘cradle-to-cradle’ approach in different sectors where all waste is used for the production of other goods. Unfortunately, the application of ‘cradle-to-cradle’ concept in rural communities to approach 100% full utilization of all types of wastes is not sufficiently explored. The aim of this paper is to propose solutions for the waste problem in rural areas through the concept of environmentally balanced rural complex called “Zero Waste Rural Community Complex ($ZWRC^2$)”. The idea is to develop a complex in each rural community that groups compatible, simple and low cost technologies including briquetting, composting, biogas, and animal fodder. All wastes generated from the rural community will be transported to this complex and fully utilized as raw material to produce organic fertilizers, energy, animal fodder and other useful products depending on market

need.

**Keywords:** Sustainable Rural Community, Zero Waste Rural Community Complex, Cradle-to-Cradle

## 1. Introduction

Rural communities in developing countries, especially lower and lower middle-income countries, are confronted with many environmental issues. Rural villages do not have adequate sewage system and treatment plants resulting into low quality of drinking water. Even in areas where enough potable water is supplied, no adequate sanitation is available. According to the United Nations World Health Organization (WHO), only 45% and 31% of rural residents have access to basic sanitation in Africa and Asia, respectively (World Health Organization, 2000).

In Egypt the majority of the Egyptian population has access to potable water, while only urban areas and some large rural villages possess wastewater networks and treatment facilities. The government of Egypt has substantially invested in the water service coverage. Many villages have been provided with potable water, which has resulted in a dramatic increase in water consumption. Unfortunately, the government efforts to supply sanitary services have lagged far behind the supply of potable water. Only 4% of the Egyptian villages have sanitation service coverage (El-Zanfaly, 2015). Also Abdel-Shafy *et al.* stated that about 90% of the rural population in Egypt has no access to sewer systems and wastewater treatment facilities (Abdel-Shafy & Aly, 2002).

As a result, households' in areas not connected to sewage system resort to informal method of wastewater disposal. In rural areas the sanitary drainage in household is connected to septic tanks to collect sewage, and then wastewater is either directly piped to the nearest water canal or pumped to a sewage collection car every week and then dumped in remote locations or farmland polluting the soil and crops (El-Haggar, 2007). Unfortunately, some water canals are directly used for irrigation and others are used as a source of water for drinking. Abdel Wahed *et al.* (Wahed et al., 2015) studied the water quality in Fayoum, a city in Egypt located southwest of Cairo. The investigation indicated that drinking water and irrigation water have high level of metals, salinities, and microbiological content due to direct disposal of household sewage in water canals as well as overflow of sewage tanks into water canals. Yet, people in Fayoum are directly using this water without treatment causing waterborne diseases (Wahed et al., 2015). Water canals have become a sink for human activities and disposal venue for sewage, leading to poor quality of water. Also, untreated sewage sludge is directly, without any treatment, used as a fertilizer for agriculture (El-Haggar, 2007). These unintended practices contribute to the deterioration of quality of air, water, soil and food and to the spread of diseases. Many research noted that poverty as well as poor infrastructure to provide clean water and evacuate waste are the main reasons for pollution and many health problems (El-Zanfaly, 2015; UNICEF. 2011; Hopkins & Mehanna, 2000). Many diseases arise from water contamination including typhoid, diarrhea, bilharizia, hepatitis C. In fact, studies showed that eighty-eight percent of reported cases of diarrhea worldwide are due to water contamination and insufficient hygiene (El-Zanfaly, 2015; El-Gammal, 2012). In Egypt, 25.1% of total burden diseases can be alleviated by improving quality of drinking water sanitation and hygiene (El-Zanfaly, 2015; Prüss-Üstün et al., 2008).

Another important problem facing rural villages is poor agricultural waste management. Rural communities generate huge amounts of agricultural wastes in many forms including straws, shells, stalks, husks, wood and forest residue. The amount of agricultural waste in Egypt is around 30-35 million tons per year (Abou & Sawan, 2010). However, agricultural waste is poorly handled due to the absence of environmental awareness and low level of knowledge of farmers. Governments reinforced regulations and laws to commit farmers to immediately dispose of agricultural residues using safe disposal methods (El-Haggar, 2007). Farmers see the disposal techniques and environmental protections procedures as a financial burden as they are very expensive. Consequently, farmers burn most of wastes in fields as a cheap solution to quickly re-cultivate their lands. Some of the agricultural wastes are used as animal fodder and others are used as fuel in very primitive ovens (El-Haggar, 2007). These traditional methods of using agricultural waste cause extensive environmental pollution. Many harmful and toxic gases are emitted and the microbial activity in soil is reduced causing soil degradation, poor quality of agricultural production, and extensive air pollution.

Similarly, most of municipal solid wastes generated are either burnt or end up in open, public and random dumpsite or water canals, which contribute to the heath, ecological and environmental problems facing rural communities.

The poor management of agricultural waste, municipal solid waste, and wastewater has placed a relentless pressure not only on the environment of rural villages, but also on the economy, health and well-being of people. Indeed, individuals living in rural communities not only suffer from poor living conditions but also from many diseases as well as from unemployment

The environmental, economic and social tragic situation facing rural villages, especially in developing countries, associated with dumping and burning waste as an easy and cheap solution cannot be ignored. Since the emergence of the concept of sustainable development many efforts have been made to reach zero-pollution. Sustainable development is defined by the World Commission on Environment and Development as “The development that meets the needs of the people today without compromising the ability of future generations to meet their own needs” (Brundtland & Khalid, 1987). People realized that sustainable development cannot be achieved without the involvement of policy makers, environmentalists, society and business community (El-Haggar, 2007; El-Haggar, 2009). Various strategies have been suggested in the literature to reduce the effect of waste on the environment and to reach sustainable development. Indeed, the concept of cradle-to cradle has been developed to move from linear system to cyclical flow of material to address natural resource depletion and environmental issues caused by human activities and poor waste management (El-Haggar, 2007: McDonough & Braungart, 2010). Unfortunately, very few studies have been conducted on the utilization of waste generated from rural communities and none of them has been implemented in a sustainable form (El-Gammal, 2012).

Finding new sources of raw material is becoming costly and difficult. On the other hand, the cost of traditional methods of waste disposal is exponentially escalating and it is becoming hard to locate disposal sites (El-Haggar, 2007; El-Haggar, 2009). Consequently, it is imperative to develop a new hierarchy for waste management to approach full utilization of waste.

The aim of this paper is to propose a framework to aid a rural community reach zero-pollution. The main idea is to develop a facility (Zero Waste Rural Community Complex) in each rural village, which groups compatible techniques such as briquetting, composting, biogas, etc. This facility will receive all types of wastes generated from the rural village (i.e. municipal solid waste, sewage, agricultural waste, etc.) as raw material and re-process them using different technologies to produce organic fertilizer, energy, animal fodder and other useful products depending on market need. Hence, developing this facility will help the rural community fully utilize all types of waste, conserve natural resources, protect the environment, improve the health condition of rural community, develop new job opportunities, and reduce cost of goods.

## 2. Proposed Zero Waste Rural Community Complex (ZWRC$^2$)

The main idea is to develop in each rural area a Zero Waste Rural Community Complex (ZWRC$^2$), which is a facility that collect all types of waste generated within the community and groups compatible and easily accessible technologies. This facility is divided into five main units including (1) animal fodder unit, (2) briquetting/alternative solid energy unit, (3) biogas unit, and (4) composting/ organic fertilizer unit, (5) recycling of municipal solid waste unit. The facility will receive all types of wastes generated from the rural village naming, agricultural waste, municipal solid waste, wastewater, as a source of raw material. These materials are then distributed among the five different units to produce fertilizer, bio-energy, animal fodder and other products according to the market and need as illustrated in Figure 1. This complex will therefore allow to fully utilize all types of wastes generated from rural communities, protect the environment, improve public health, produce valuable products, conserve natural resources, develop new job opportunities, and reduce cost of goods.

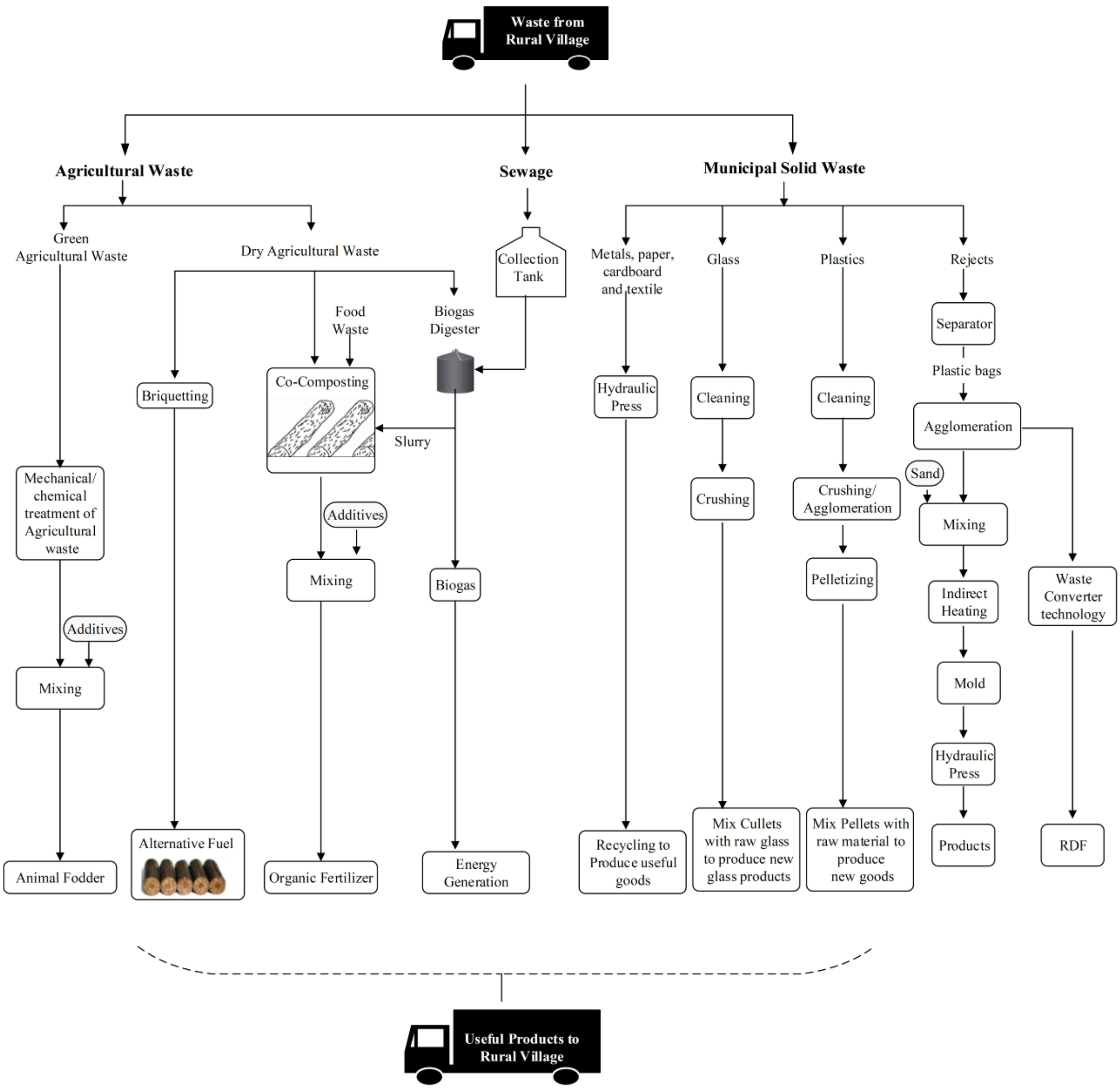


Figure 1. Zero Waste Rural Community Complex (ZWRC$^2$)

## 3. Composting

Composting is the process of deliberately breaking down or decomposing complex organic matters under controlled conditions into simple substances that can then be used as plant nutrients via aerobic fermentation (El-Haggar, 2007; Misra et al., 2016). This process occurs in nature, called rotting, but slowly. The objectives of composting are to accelerate the naturally occurring decomposition process and to create the optimum environment for the process to take place. In the composting process organic waste with certain oxygen and moisture content is digested by bacteria and is converted into soil conditioner. Four main factors can guarantee good quality of compost and proper decomposition rate without odor emissions (El-Haggar, 2007):

(1) The most important factor is carbon to nitrogen (C/N) ratio. Studies showed that the optimum C/N ratio is 30:1. If the C/N ratio lower than 30:1 (i.e. the carbon content is low) nitrogen is lost in the form of ammonia as microbes has not enough energy (carbon) to consume nitrogen. If the C/N ratio is too high, the decomposition process requires more time.

(2) A minimum moisture content is required in compost piles to keep micro-organisms alive. Studies showed that the ideal moisture content is ranging between 40% to 60% to reach optimum microbial activity rate and inhibit odor emission.

(3) The temperature usually ranges between 32 ℃ to 60 ℃. During the bacterial activity heat is generated at the center of the compost pile then temperature cools to ambient temperature as organic matters are consumed. When the temperature decrease the pile should be turned to introduce un-decomposed material at the center of the pile.

(4) Composting is an aerobic fermentation process; therefore, it requires continuous oxygen supply. There are different techniques to aerate the compost pile including: (1) natural composting by turning the compost pile, (2) passive composting by placing perforated PVC pipes at the bottom of compost piles to distribute air inside the pile, (3) forced composting is similar to passive composting except that the ends of pipes are equipped with blowers to optimize and maintain air flow and velocity entering compost piles.

The main advantages of composting is the improvement of soil structure by adding organic matter and pathogens structure as well as utilizing agricultural waste that can cause high levels of pollution if burned. Natural rocks such as phosphate (source of phosphorus), feldspar (source of potassium), dolomite (source of magnesium), etc. can then be added to the compost to produce organic fertilizer for organic farming, which can replace expensive imported chemical fertilizers (El-Haggar, 2007; El-Haggar et al., 2004; El-Haggar et al., 2004).

**Organic Fertilizer Case Study**

El-Haggar (El-Haggar, 2007) investigated the composting process of mixture of different types of wastes including animal manure (cow dung), poultry manure, cane sugar waste (pitch) and natural rocks. Each pile was turned weekly and moistened. The composting period extended for 10 weeks after the fermentation period.

In this experiment animal manure is considered the main source of soil fertilizing material. Pitch is a sugarcane waste. This material is used as a bulking agent to adjust C: N ratio. These materials were also mixed with natural rocks including phosphate rocks, feldspar, dolomite, sulfur and bentonite to produce good quality fertilizer. Rock phosphate is recommended in organic farming as a source of phosphorous for plants. Phosphorous is important in agriculture as it helps growth of plants. Any deficiency of this element restricts the growth of plant, the metabolisms of fats, and the function of the processes in root development and the ripening of seeds (El-Haggar, 2007). Feldspar is the source of potassium, dolomite is the source of magnesium, and sulfur is categorized as a natural pesticide and contributes to the protection of plants from pest infections (El-Haggar, 2007). Bentonite contains potassium silicate, magnesium, calcium, and iron. Bentonite provides coherence between soil particles, which results in improving the absorption of other elements and keeping a reserve of water.

Physical and chemical parameters were tested to investigate the performance of the composting process and according to El-Haggar (El-Haggar, 2007) the following findings were observed:

- The bulk density of the compost increased by 20 to 32% due to decrease in the volume and increase in composed material breakdown.
- pH value of the compost decreased with time and reached 6-8
- The organic matter decreased by 40%
- The organic carbon decreased by 44%
- The total nitrogen increased by 64% with time during the composting process due to destruction of organic matters
- C:N ratio decreased with time and stabilized due to losses of organic matter to reach 14.2:1
- Ammonia decreased with time during the composting process due to the conversion of ammonia to nitrate during nitrification process.
- Total phosphorous increased with time by 20.61% due to release of micro-elements
- Total potassium increased also due to release of macro-elements
- Soluble calcium increased by 150.65% and soluble magnesium increased by 147.8% due to the transformation of macro-elements to soluble form
- Acid producing bacteria decreased as well as the fecal bacteria, total coliform bacteria, nematode, Salmonella and Shigella decreased with time. By the third week of composting the pathogenic detection started to approach zero.

This research work is an illustration that composting is an easy and cost-effective technique to convert organic waste into soil conditioner and organic fertilizer and close the loop reaching a cradle-to-cradle approach. This produced organic fertilizer can replace expensive chemical fertilizers used by the farmers to compensate the soil for its loss of organic matter. A passive composting method, aerate the compost piles by turning them, is recommended for rural communities as it required less capital cost and running cost compared to forced aeration techniques (El-Haggar, 2007).

## 4. Animal Fodder

Many rural communities, especially in some low and lower middle income developing countries are confronted with deficiency of animal foodstuffs, which causes reduction in animal production. To overcome this deficiency, raw material for animal foodstuff is imported at inherent high cost. Hence, transforming agricultural wastes into animal foodstuffs can help in overcoming this deficiency.

Many agricultural wastes cannot be directly consumed by animals as they are too big and too tough to be directly digested by animals. To overcome these issues mechanical and chemical treatment methods were proposed to transform agricultural waste into a digestible form (El-Haggar, 2007). Mechanical treatment consists of chopping, shredding, grinding, moistening, soaking in water and streaming under pressure. However, mechanical methods require high capital and running cost, which make them not widely spread (El-Haggar, 2007). Chemical treatment of agricultural waste with urea or ammonia was proven to be more feasible. It is reported that good quality animal fodder can be obtained by injecting ammonia or urea to the mass of waste (El-Haggar, 2007; Abou & Sawan, 2010; Huber et al., 1979). The treated waste is then covered with a 2mm thick polyethylene wrapping material for 2 weeks in summer and 3 weeks in winter. Finally, the treated material is uncovered and left for 2 to 3 days to release all remaining ammonia before using it as animal feed (El-Haggar, 2007).

## 5. Briquetting

The primary source of energy for cooking and heating in rural villages in developing countries is via burning wood and other agricultural products. This practice results into deforestation and depletion of natural resources. One way to efficiently make use of existing resources is through briquetting. Briquetting consists of collecting combustible material like agricultural waste that are not useable due to lack of density and compressing them into solid fuel of a convenient shape that can be burned like wood and charcoal.

Agricultural waste has two main disadvantages that prevent it from being directly used as fuel. The first problem with agricultural waste is that it burns rapidly and it is difficult to maintain a steady fire for a long period. The second problem is that agricultural waste has a form and structure that is not suitable to be used in traditional coal pots and stoves. Therefore, one approach is to increase the density of agricultural residues by pressing them to form solid fuel pellets or briquettes (Maninder et al., 2012).

Agricultural waste usually straws, wheat straws, cotton stalks, corn stalks, sugar cane waste, fruit branches, … are collected. Then they are reduced in size by chopping, crushing or shredding. The raw material is then dried by subjecting it to sunrays and/or using heater. The raw material is mixed with a binding material like tar, animal manure, or sewage sludge. Finally, feedstock is compressed via compaction or extrusion (El-Haggar, 2007). In other words, the aim of briquetting is to compress unused material to form relatively high-density solid fuel to be used for domestic and/or industrial applications. Briquettes are also easy to use, transport and store. Briquetting will help decrease the volume of waste causing many environmental disasters and produce efficient solid fuel of high thermal value. It was reported that some developing countries including India, Thailand, and some places in Africa have tried substituting fuel wood and coal with fuel briquettes to overcome the firewood shortage and farm waste disposal problems (El-Haggar, 2007). Briquetting is a very attractive method to recycle agricultural waste in rural villages in developing countries, as it is an easily understandable technology and simple to operate.

## 6. Recycling of Municipal Solid Waste

Municipal solid waste (MSW) is a major concern in rural communities in some developing countries. Most of the MSW generated in rural villages ends up in open, public and random dumpsites resulting into environmental, economic and social problems (El-Haggar, 2007). Indeed, leaving the MSW without recycling causes environmental problems as bad odors are emitted, which attract flies and mosquitos carrying diseases. Some of the municipal solid waste is left in dumpsite and streets, which results into groundwater contamination from uncontrolled leachate. The rest of the MSW is burnt releasing greenhouse gases to the atmosphere. Sometimes MSW is dump in water canals resulting into water pollution. MSW are usually collected, sorted, and landfilled or incinerated. These techniques require high capital and running costs and also can cause environmental depletion if not properly maintained as well as depleting the natural resources (waste) (El-Haggar, 2007; El-Haggar, 2009; El-Haggar, 2015). Also, the accumulation of piles of garbage in the streets can cause physiological problems proven to affect individual work efficiency. Recycling of MSW in rural villages in developing countries is very challenging as the majority of the population is not sufficiently aware of the size of the problem and suitable technology to recycle MSW are not available. Usually developing countries tend to import technologies, which are expensive and not compatible with the developing countries environments.

MSW is usually composed of recyclables including organic matters, paper, metal, textile, glass, plastics and non-recyclables called rejects. It is recommended to have a unit in the proposed facility that receives MSW as raw material. MSW is collected and transported via trucks to the recycling unit and MSW is placed on a conveyor belt, where it is manually sorted.

The recycling process of thermoplastic consists of washing, then cutting and shredding or agglomeration depending on type of plastic, and pelletizing. The formed pellets can then be reprocessed to form products suitable for the market need. Glass are cleaned and crushed into small pieces called cullets, which can then be mixed with raw material to produce new glass products. This will reduce not only the required raw materials but also the required energy. Metal, paper, cardboard and textile wastes are compressed using a hydraulic press for easy storage, handling and transport to recycling facilities. Then metals are melted to form ingots that can then be used to produce metal products. Also, compacted paper, cardboard and textile can then be reprocessed to produce useful products. Food waste can be recycled via composting as described above.

In addition to recyclables, MSW also contains rejects that are unrecyclable. For example, black plastic bags used for garbage are contaminated with organic waste and small pieces of glass that are hard to sort (rejects). The recycling process of rejects consists of first separating the rejects from other wastes through screen separator. Then rejects are agglomerated and mixed with additives to adjust their properties and finally heated and pressed to be reshaped into useful product such as bricks, interlocks, table tops, manholes, and other products depending on market need (El-Haggar, 2007).

**Products from Plastic Rejects**

El-Haggar (El-Haggar, 2007) investigated the use of plastic rejects to produce useful goods. First the plastic rejects such as black plastic bags is separated from organic waste. The plastic is then inserted into an agglomeration machine. The agglomeration machine contains a cylinder with four rotating blades at the bottom to cut as well as pre-heat and pre-plasticize the plastic. The agglomerated plastic reject is mixed with reinforcing material, sand. The mixture is heated in a furnace. The furnace consists of a combustion chamber that is used to distribute the heat uniformly along the cylinder container. It also contains a motor and gear driving system so that the raw material is blended while being heated. The produced paste is then poured in a mold and compressed to take the required shape. This material is used to produce interlocks that can be used for pavements, gardens, factory floors, backyards, etc. Then the top of plastic rejects interlocks could be coated with higher plastic waste quality to produce more appealing products. According to El-Haggar (El-Haggar, 2007), the cost of the plastic rejects interlock is 30 to 50% (depending on the type of top layer coating) cheaper than traditional interlocks with high mechanical properties (El-Haggar, 2007).

The same process is used to produce a number of other products. El-Haggar [4] reported that the plastic rejects could be used to make cheaper and high quality manholes. Usually manholes are made of cast iron or reinforced fiberglass. Also El-Haggar produced road ramps from the plastic rejects (El-Haggar, 2007). Traditionally, road ramps are made from cast iron, rubber, or asphalt mix.

This research work illustrates that municipal solid waste can be an important source of raw material to produce useful products in different applications. Such activities can be beneficial for rural area from an economical, environmental and social point of view.

## 7. Biogas

Many rural communities in some developing countries are affected by incessant power outage; therefore, they meet their energy needs via traditional energy sources including firewood, dung and crop residues. These traditional methods are often expensive and/or time-consuming. At the same time these rural areas generate huge amounts of waste including agricultural waste, municipal wastewater, and organic waste from garbage, food processing plants, animal manure and dead animals and suffer from poor waste management. These wastes are biomass and/or organic carbon based material. It is reported that every year natural anaerobic degradation of organic matter releases 590 to 800 million tons of methane in the atmosphere (Bond & Michael, 2001). Hence, biogas is proposed as a substitute for firewood and dung that can meet the energy needs of the rural population.

Biogas is produced through anaerobic fermentation of organic carbon based material such as plant residue including rice straws, wheat straws, malt straw, ground cotton stalk and corn stalk under controlled environment, in the absence of oxygen. Bacteria digest organic material to form a mixture of methane and carbon dioxide. Biogas is a clean, efficient and renewable source of energy that can be used as a substitute for natural gas or liquefied petroleum gas in rural communities. The energy content of 1.0 $m^3$ of purified biogas is equal to 1.1 L of gasoline, 1.7 L of bioethanol, or 0.97 $m^3$ of natural gas (Rajendran et al., 2012). The slurry from the digester is rich in ammonium and other nutrients used as an organic fertilizer, which makes this slurry suitable to be used as fertilizer.

Many countries started using biogas, China is the leading country in this area currently having more than 30 million household digesters and aiming to reach 80 million by 2020 to serve 300 million people. Also India has around 3.8million household digesters. There are 162 farms scale plant in America serving 41,000 homes. Also there is a large number of farm plants in Europe. Indeed, Germany has more than 4,000 farm scale digesters, Austria has 350, United Kingdom 65 (Rajendran et al., 2012). However, biogas technology is not very popular in Africa and needs to be more researched via universities and research centers to suit different country's needs.

**Biogas: Case of Egypt**

Egypt generates large amounts of different types of organic wastes. In fact, Egypt generates 34 million tons of agricultural waste per year, 28 million tons of municipal solid waste, and 4.3 million tons of dry sludge per year (El-Haggar, 2007). Although these large amounts of organic wastes are considered an excellent source for biogas technology to produce energy, rural areas in Egypt suffer from constant power outage.

Most of the biogas plants constructed in Egypt are small-scale plants with digester volume ranging from 5 to 50 $m^3$. The DANIDA team evaluated the biogas potential in Egypt in 1995 (El-Haggar, 2007) and estimated that the total energy potential of centralized biogas plants to be about 1million TOE (Ton Oil Equivalent) with a 50 to 500 ton/day input. DANIDA team estimated that 4% of the present electricity consumption could be covered by biogas applications. The potential sites for large biogas plants were identified by the team as being large cattle and dairy farms, communities in old and new villages, food processing industries, sewage treatment plants, waste treatment companies regarding solid organic municipal waste, new industrial cities, and tourist villages.

## 8. Refuse- Derived Fuel (RDF)

Nowadays, lack of energy is a considerable issue globally and many developing countries meet their demanded fuel from other countries. RDF, which stands for Refuse-Drived Fuel, is proposed as an alternative source of fuel. RDF refers to solid fuel derived from municipal and/or industrial solid waste that is used in the production of alternative fuels or energy. These wastes usually have high calorific values. RDF is used in some countries including Australia, Belgium, Denmark, Italy, and Turkey in the cement industry (Hajinezhad et al., 2016; Kara et al., 2008). In Europe it is reported that 30,000ton of RDF is used in 2003 and in Turkey a cement plant is aiming to use 35000ton/year of RDF (Hajinezhad et al., 2016). A study was conducted at the American University in Cairo and showed that plastics (polypropylene), agricultural waste (rise straw, corn husk, rice husk and onion leaves) and other types of waste such as tires have high average calorific value when compared to fossil fuels like diesel and coal (Shahat, 2016).

## 9. Conclusion

The environmental tragic situation facing rural communities associated with poor waste management cannot be ignored. It is imperative to find innovative solutions to reach zero-pollution in rural areas. In this paper, it is proposed that the government, the rural community, business community and academic institutions and research centers collaborate to develop an environmentally balanced rural waste facility in each rural village called “Zero Waste Rural Community Complex”. This facility groups simple and obtainable technologies in one area to fully utilize all types of wastes generated in rural village and produce useful products. The proposed facility contains storage areas and tanks to store agricultural waste, municipal solid waste and sewage. Agricultural waste is distributed among different units to be processed to produce useful goods. Some of the agricultural waste is mechanically and/or chemically treated to produce animal fodders and briquettes to be used as solid fuel. Part of the remaining agricultural waste mixed with sewage is used to produce biogas through anaerobic fermentation. The remaining slurry from biogas digester is mixed with agriculture waste and used as organic fertilizer as it is rich in ammonium and other nutrients to adjust the carbon to nitrogen ratio. Municipal solid waste is also recycled to produce useful products depending on market need. Consequently, this facility will combine all wastes generated in rural areas into one location to produce valuable products. This approach will; therefore, help conserving natural resources, protecting the environment and public health, developing new job opportunities, and reducing the cost of goods.

## References

Abdel-Shafy, H., & Aly, R. (2002). Water issue in Egypt: Resources, pollution and protection endeavors. *Navigation, 49*(3.1), 4-6.

Abou Hussein, S., & Sawan, O. (2010). The Utilization of Agricultural Waste as One of the Enviromental Issues in Egypt (A case Study). *Journal of Applied Sciences Research, 6(*8), 1116-1124.

Bond, T., & Michael, R. (2001). History and future of domestic biogas plants in the developing world. *Energy for Sustainable development, 15*(4), 347-354. https://doi.org/10.1016/j.esd.2011.09.003

Brundtland, G. H., & Khalid, M. (1987). Our common future. *New York*.

El-Gammal, H. A. (2012). Water Quality Protection in Rural Areas of Egypt. *International Water Technology Journal, 1*, 230-238.

El-Haggar, S. (2007). *Sustainable Industrial Design and Waste Management: Cradel-to-Cradle for Sustainable Development*. Elsevier Academic Press.

El-Haggar, S. M. (2009). Industrial solid wastes utilization and disposal. *Environmental Engineering: Environmental Health and Safety for Municipal Infrastructure, Land Use and Planning, and Industry*, Sixth Edition, 1-81. https://doi.org/10.1002/9780470432822.ch1

El-Haggar, S. M. (2015). *Sustainability and Innovation: The Next Global Industrial*

*Revolution*. The American University Press.

El-Haggar, S., Ahmed, M., & Hamdy, A. (2004). Production of Compost from Organic Agriculture Enriched with Natural Rocks. *Egyptian Journal of Applied Sciences*, *19*(7B), 784-799.

El-Haggar, S., Ali, B., Ahmed, S., & Hamdy, M. (2004). Increasing Nutrients Solubility from Natural Rocks During Composting of Organic Waste. *Mina Journal of Agricultural Research and Development, 24*(1), 71-88.

El-Zanfaly, H. T. (2015). Water Quality and Health in Egyptian Rural Areas. *Journal of Environment Protection and Sustainable Development, 1*(4), 203-210.

Hajinezhad, A., Halimehjani, E., & Tahani, M. (2016). Utilization of Refuse-Derived Fuel (RDF) from urban waste as an alternative fuel for cement factory: A case study. *International Journal of renewable Energy Research, 6*(2), 702-714.

Hopkins, N., & Mehanna, S. (2000). Managing Personal Health in a Polluted urban Commons. *Journal of Social Sciences, 4*(1), 111-116.

Huber, J., Foldager, J., & Smith, N. 1979. Nitrogen distribution in corn silage treated with varying levels of ammonia. *Journal of Animal Science, 48*(6), 1509-1515. doi:10.2527/jas1979.4861509x

Kara, M., Günay, E., Tabak, Y., Yıldız, Ş., & Enç VO. (2008). The usage of refuse derived fuel from urban solid waste in cement industry as an alternative fuel. *In Proceedings of the 6th IASME/WSEAS International Conference on Innovation Heat Transfer, Thermal Engineering and Environment (HTE'08).*

Maninder, R., Kathuria, S., & Grover S. 2012. Using Agricultural Residues as a Biomass Briquetting: An Alternative Source of Energy. *OSR Journal of Electrical and Electronics Engineering (IOSRJEEE), 1*(5), 11-15.

McDonough, W., & Braungart, M. (2010). *Cradle to cradle: Remaking the way we make things.* MacMillan.

Misra, R. V., Roy, R. N., & Hiraoka, H. (2016). *On-farm composting methods*. Rome, Italy: UN-FAO.

Prüss-Üstün, A., Bos, R., Gore, F., & Bartram, J. (2008). *Safer water, better health: costs, benefits and sustainability of interventions to protect and promote health*. World Health Organization.

Rajendran, K., Aslanzadeh, S., & Taherzadeh, M. (2012). Household Biogas Digesters-A Review. *Energies, 5*(8), 2911-2942. https://doi.org/10.3390/en5082911

Shahat, F. (2016). Investigating the use of solid waste as alternative fuels in Egypt. M. Sc. Thesis, The American University in Cairo

UNICEF/ World Health Organization (WHO). (2011). Drinking Water: Equity, Safety and

Sustainability. JMP Thematic Report on Drinking Water.
http://www.wssinfo.org/fileadmin/user_upload/resources/report_wash_low.pdf.

Wahed, M. S. A., Mohamed, E. A., Wolkersdorfer, C., El-Sayed, M. I., M'nif, A., & Sillanpää, M. (2015). Assessment of water quality in surface waters of the Fayoum watershed, Egypt. *Environmental Earth Sciences*, *74*(2), 1765-1783. https://doi.org/10.1007/s12665-015-4186-0

World Health Organization. (2000). G*lobal water supply and sanitation assessment 2000 Report*. World Health Organization.
http://www.who.int/water_sanitation_health /monitoring/jmp2000.pdf.