Proposed Sustainable Rural Community Framework

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Abstract

Rural communities are confronted with many environmental issues. The main problems rural villages are suffering from are lack of adequate sewage system, absence of wastewater treatment plants, poor management of agricultural waste and municipal solid waste. These problems have 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. The concepts 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. Unfortunately, the conservation of natural resources in rural communities to approach 100 % full utilization of all types of wastes by cradle-to-cradle concept was not sufficiently explored.

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 in each rural village that groups compatible technologies including briquetting, composting, biogas, etc…. All types of waste generated from the rural community will be transported to the facility as raw material to produce organic fertilizer, energy, animal fodder and other useful products depending on market need.

Keywords: Rural community, Sustainable development, Zero pollution, Cradle-to-cradle, sustainable rural community

Introduction

Rural communities in developing countries are confronted with many environmental issues. The utmost important problem rural villages suffer from is lack of adequate sewage system and absence of treatment plants causing low quality of drinking water. For instance, only 4% of the Egyptian villages have sanitation service coverage [1]. Instead, dwellings are equipped with 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. Unfortunately, some water canals are used for irrigation and others are used as a source of water for drinking. Abdel Wahed *et al.* [2] 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 [2]. Water canals have become a sink for human activities and disposal venue for sewage, leading to poor quality of water as shown in Figure 1. Also, untreated sewage sludge is directly, without any treatment, used as a fertilizer for agriculture. 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 [1,3-6]. 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 [1,7]. In Egypt, 25.1% of total burden diseases can be alleviated by improving quality of drinking water sanitation and hygiene [1,8].

Figure 1: Waterway contaminated with sewage in Fayoum, Egypt

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 [9]. 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. 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. 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 as shown in Figure 2 or water canals, which contribute to the heath, ecological and environmental problems facing rural communities.

Figure 2: Solid Waste dumped in street in Fayoum, Egypt

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" [10]. People realized that sustainable development cannot be achieved without the involvement of policy makers, environmentalists, society and business community [11,12]. 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 [11,13]. 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 [7].

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. 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 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,…) 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.

Proposed Framework for Sustainable Rural Community

The main idea is to develop in each rural area 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 3. This complex/facility 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.

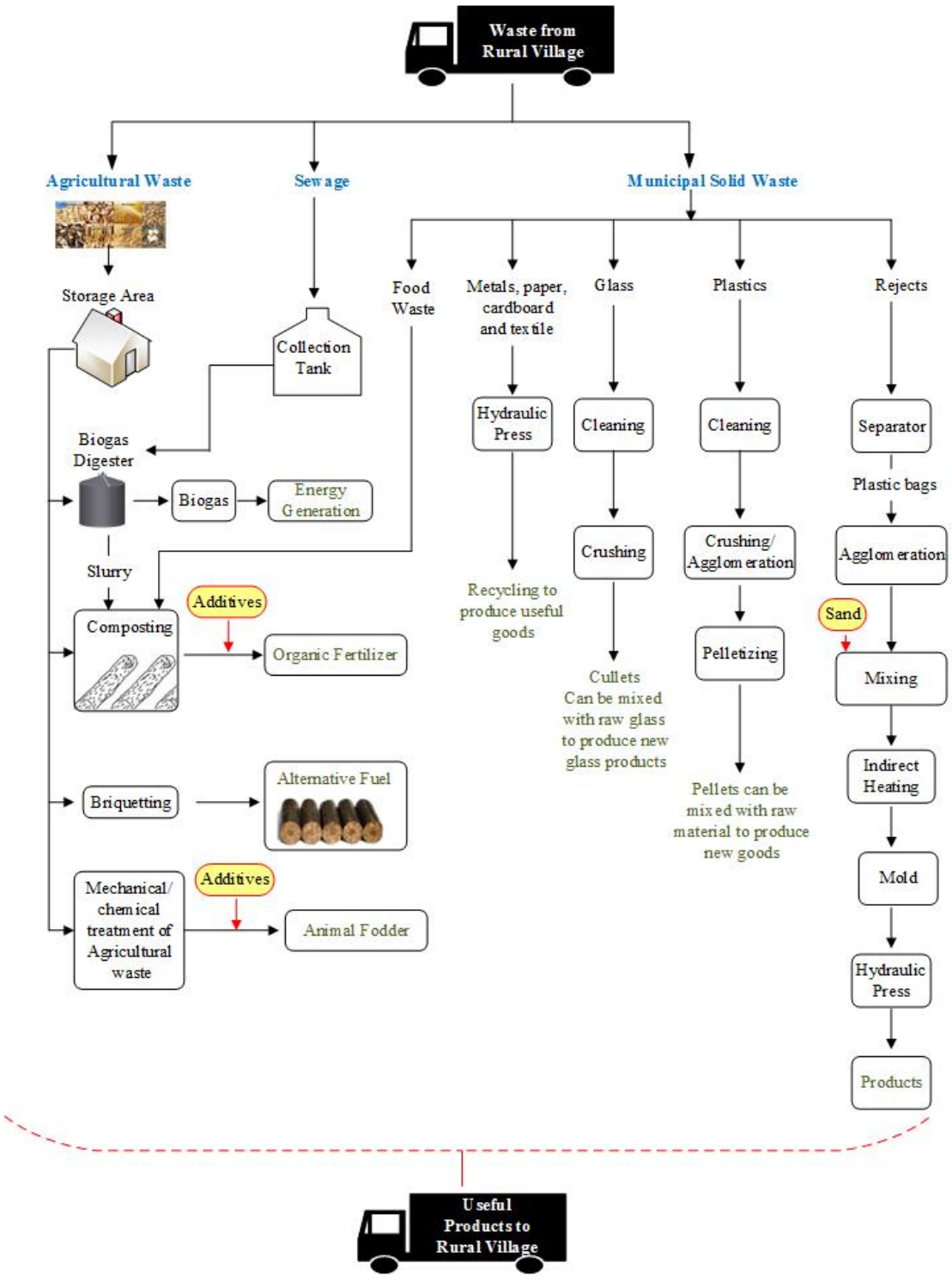

Figure 3: Rural Waste Facility

Animal Fodder

Many rural communities, especially in developing countries are confronted with deficiency of animal food stuffs, 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 [11]. 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. 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 [9,11,14]. 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 [11].

Briquetting

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 [15]. Agricultural waste usually straws, wheat straws, cotton stalks, corn stalks, sugar cane waste, fruit branches, … are collected, reduced in size, dried, compacted by extruder or press [11]. In other words, unused material is compressed 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 [11].

Biogas

Many rural communities in 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. 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 [16]. 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.

Rural communities generate huge amounts of wastes including agricultural waste, municipal wastewater, and organic waste from garbage, food processing plants, animal manure and dead animals. These wastes are biomass or organic carbon based material, which can be used as a source of biogas and fertilizer as illustrated in Figure 4.

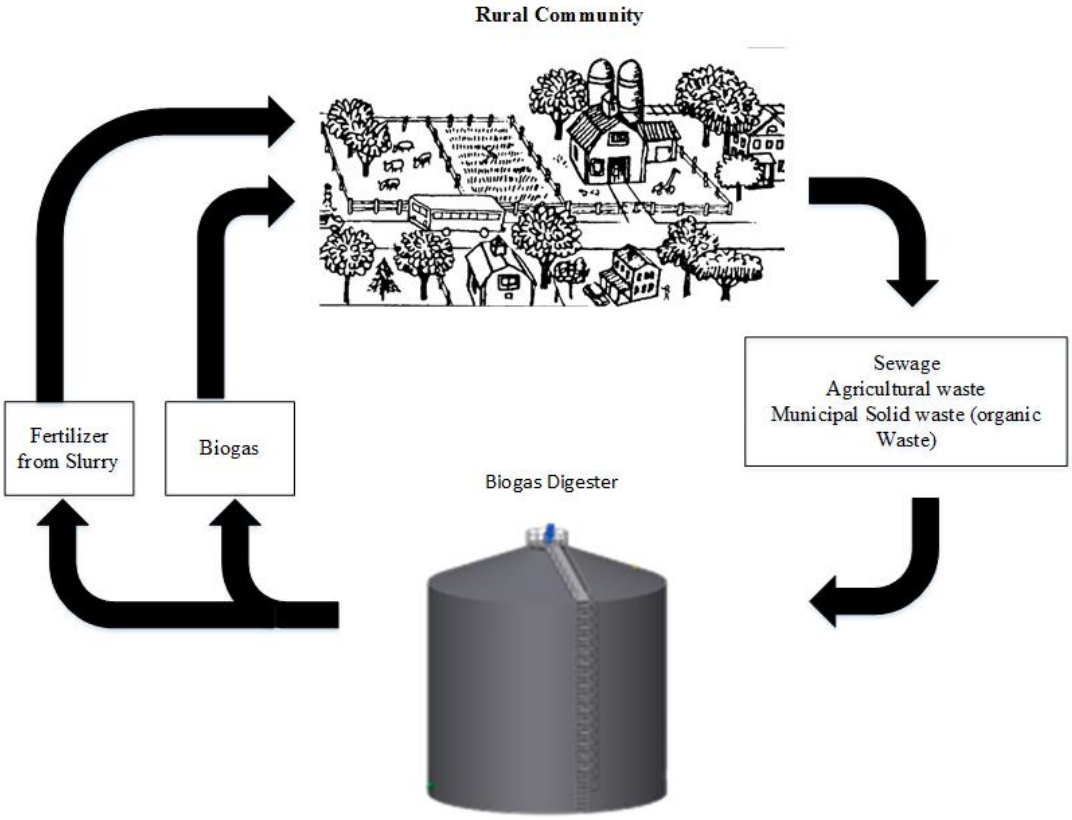

Figure 4: Biogas Process

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 [16]. 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.

Composting

Many rural communities in developing countries are forced to import fertilizers at a relatively high cost. Compositing is the aerobic fermentation of organic materials by bacteria under controlled conditions. Figure 5 illustrates 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: (1) moisture content usually ranges between 40% to 60%, (2) carbon to nitrogen ratio is usually 30:1, (3) temperature usually ranges between 32°C to 60°C, and (4) oxygen has to be supplied continuously [11]. 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 [17, 18].

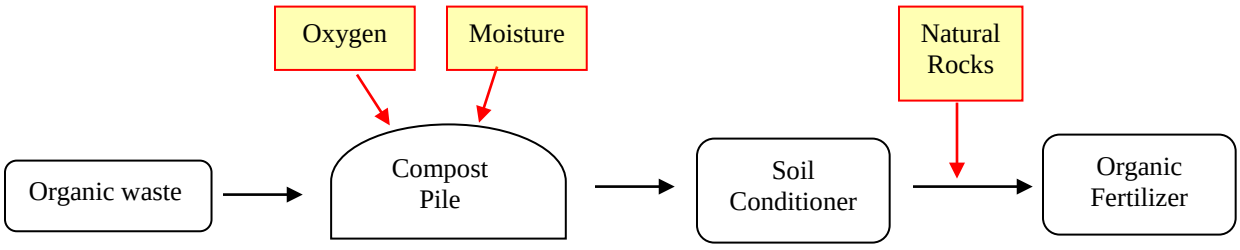

Figure 5: Composting and organic fertilizer Process

Recycling of Municipal Solid Waste

Municipal solid waste (MSW) is a major concern in rural communities in 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. 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). 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 [11].

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 a rural waste facility in each rural village. 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.

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