AGRICULTURAL WASTE AS AN ENERGY SOURCE IN DEVELOPING COUNTRIES

A case study in Egypt on the utilization of agricultural waste through complexes

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ABSTRACT

The main problems facing rural villages in developing countries are agricultural waste, sewage and municipal solid waste. However, few studies have been conducted on the utilization of agricultural waste for composting and/or animal fodder. Most of the proposed solutions have not been implemented because they did not meet the basic elements of sustainability: social progression, technical and technological improvements, environmental protection and economic development.

This poster presents a sustainable solution by combining all wastes generated in rural areas in one complex: EBRWC (Environmentally Balanced Rural Waste Complex) that has been developed to produce valuable products with zero pollution. Such a complex is generated from agricultural waste, disposal of sewage in water canals and disposal of municipal solid waste.

Several compatible techniques are located together within this agricultural complex: utilizing briquettes as a renewable energy source; using anaerobic digestion (biogas) to produce energy and fertilizer; composting for soil conditioner; animal fodder and other recycling techniques for solid waste. The main outputs of EBRWC are fertilizer, energy, animal fodder and other recycled materials depending on the availability of wastes, and according to demand and need.

1. INTRODUCTION

Egypt has an agricultural tradition which goes back thousands of years, and plans to expand this tradition in the future. In order to combine the old traditions with modern technologies to achieve sustainable development, waste should be treated as a by-product. The main problems facing rural areas today are agricultural waste, sewage and municipal solid waste. They represent a crisis for sustainable development in rural villages as well as to the national economy. However, few studies have been conducted on the utilization of agricultural waste for composting and/or animal fodder, and none of them has been implemented in a sustainable form. This study combines all major sources of pollution/wastes generated in rural areas in one complex: EBRWC that produces fertilizer, energy and animal fodder in response to market demand and need.

The estimated amount of agricultural waste in Egypt ranges from 22 to 26 million dry tonnes per year. Some of the agricultural waste is used as animal fodder, other waste is used as fuel in very primitive ovens which causes many health problems and damage to the environment. The rest is burned in the field, causing air pollution problems. The type and quantity of agricultural waste in Egypt changes from one village to another and from one year to another because farmers always cultivate the most profitable crops suited to the land and the environment. The five crops with the highest amount of waste are rice, corn, wheat/barley, cotton and sugar cane.

Rural villages in Egypt have had drinking water systems for a long time but not sewer systems. Areas of urban Egypt close to Cairo have no sewage treatment networks. Instead under each house there is either a septic tank where sewage is collected or a PVC pipe which transports the sewage directly to the nearest canal. Some households pump their sewage from the septic tank to a sewer car once or twice a week and it is dumped a long way from the house.

In general, a huge amount of sewage and garbage is generated in the villages. Because of the lack of a sewer system and a garbage collection system, sewage is drained and garbage is thrown into the nearest canal causing soil, water and visual pollution as well as health problems. Some canals are used for irrigation, others are used as a source of drinking water.

2. ENVIRONMENTALLY BALANCED RURAL WASTE COMPLEX

The EBRWC can be defined as a selective collection of compatible activities located together in one area (complex) to minimize (or prevent) the impact on the environment and treatment costs for sewage, municipal solid waste and agricultural waste. A typical example of such a rural waste complex consists of several compatible techniques such as briquetting, anaerobic digestion (biogas), composting, animal fodder and other recycling techniques for solid wastes located together. Thus, EBRWC is a self-sustaining unit that draws all its inputs from rural wastes, achieving zero waste and pollution. Some emissions may be released into the atmosphere, but the emission level would be significantly less than that of the raw waste fed into the EBRWC.

A typical rural waste complex would operate to utilize all agricultural waste, sewage and municipal solid waste as sources of energy, fertilizer, animal fodder and other products depending on the constituents of the municipal solid waste. In other words, all the wastes will be used as raw material for a valuable product according to demand and need within the rural waste complex. Thus a rural waste complex will consist of a number of compatible activities, the waste of one being used as raw material for others, with no external waste generated from the complex. This technique will produce different products as well as keep the rural environment free of pollution from sewage, agricultural and solid waste. The main advantage of the complex is that it helps the sustainable development of the national economy in rural areas.

3. AGRICULTURAL WASTE AS AN ENERGY SOURCE

Agriculture biomass resources in Egypt are estimated to be around 25 million tonnes (dry matter) per year. Fifty percent of the biomass is used as fuel in rural areas by direct combustion in low efficiency traditional furnaces. The traditional furnaces are primitive mud stoves and ovens that produce large quantities of air pollution and are extremely energy inefficient. The agriculture biomass waste (resources) consist mainly of cotton stalks, rice straw, etc.

Fig. 1: Mixing agricultural residues [8]

One of the main agricultural wastes is cotton stalk. In Egypt, the amount of cotton stalk produced is estimated at 1.6 million tonnes/year (corresponding to 740,000 TOE/year). According to the Ministry of Agriculture, regulations and resolutions require farmers to dispose of cotton plant residues using environmentally safe disposal methods immediately after harvesting (within 15 days). The easiest and cheapest method is to burn the cotton stalks as soon as possible in the field. The reason behind this regulation is to kill insects and organisms which carry plant diseases. But in reality the cotton stalks are stored for a long time giving the cotton worms the chance to complete the worm life cycle and attack the cotton the following season. This process leads to a total energy loss estimated at 0.74 MTOE/year that has a high monetary value (220 million LE/year) in addition to the negative environmental impact due to releasing vast amounts of green house gases.

Moreover, the traditional storage systems for plant residues on farms, on the rooves of buildings, allow insects and diseases to grow and reproduce. In addition they pose a fire hazard.

Fig. 2: Turning and moisturizing compost windrows [7]

4. BRIQUETTING SYSTEM

The briquetting process is the conversion of agricultural waste into uniformly shaped briquettes that are easy to use, transport and store. The idea of briquetting is to use materials that are otherwise not usable due to a lack of density, compressing them into a solid fuel of a convenient shape that can be burned like wood or charcoal. The briquettes have better physical and combustion characteristics than the initial waste. Briquettes will improve the combustion efficiency of existing traditional furnaces. In addition to killing all insects and diseases they reduce the risk of fire in the countryside.

The idea of briquetting is to use materials that are not otherwise usable due to a lack of density, compressing them into a solid fuel of a convenient shape that can be burned like wood or charcoal. Briquettes were discovered to be an important source of energy during the First and Second World Wars for heat and electricity production using simple technologies. One of the recommended technologies is lever operating press (mechanical or hydraulic press). Briquetting allows ease of transportation and safe storage of wastes as they have a uniform shape and are free of insects and disease carriers. The advantages of briquetting are:

- gets rid of insects
- decreases the volume of waste
- efficient solid fuel of high thermal value
- low energy consumption for production
- protects the environment
- provides job opportunities
- less hazardous.

Fig. 3: Briquettes generated from agricultural waste [8]

Raw materials suitable for briquetting are rice straws, wheat straws, cotton stalks, corn stalks, sugar cane waste (baggas), and fruit branches. The briquetting process starts with the collection of wastes followed by size reduction, drying and compaction by extruder or press.

5. COMPOSTING

Composting is the aerobic decomposition of organic materials by micro-organisms under controlled conditions. In 1876 Justus von Liebig [1], a German chemist calculated that North African lands that were supplying two thirds of the grains consumed in Rome were becoming less fertile and loosing their quality and productivity. He found, on conducting research, the reason behind this phenomenon: when crops are exported from North Africa to Europe, their wastes do not go back to North Africa but are flushed into the Mediterranean. Agricultural waste is rich in organic matter. This matter is derived from the soil and the soil needs it back in order to continue producing healthy crops. However, this was not the case and, in von Liebig's opinion, was a breaking of the natural loop that gives the land back its nutrients. He called this phenomenon the "direct flow". The German scientist proposed artificial fertilizers, which were meant to compensate the soil for loss of organic matter, but they were not the same as natural fertilizers.

Composting is one of the best known recycling processes for organic waste to close the natural loop. The major factors affecting the decomposition of organic matter by micro-organisms are oxygen and moisture. Temperature, which is a result of microbial activity, is also an important factor. The other variables affecting the process of composting are nutrients (carbon and nitrogen), pH, time and the physical characteristics of the raw material (porosity, structure, texture and particle size). The quality and decomposition rate depends on the selection and mixing of raw materials.

Fig. 4: Composting of agriculture waste [8]

Aeration is required to recharge the oxygen supply for the micro-organisms. The passive composting method [2] is the recommended technique for the Egyptian environment for technical and economic reasons. 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.

Because compost materials usually contain some biological resistant compounds, a complete stabilization (maturation) during composting may not be achieved. The time required for maturation depends on environmental factors within and around the composting pile. Some traditional indicators can be used to measure the degree of stabilization such as decline in temperature, absence of odour, and lake of attraction of insects in the final products.

6. BIOGAS

Biogas is the anaerobic fermentation of organic materials by micro-organisms under controlled conditions. Biogas is a mixture of gasses mainly methane and carbon dioxide that results from anaerobic fermentation of organic matter by bacteria. Biogas is ranked low in priority in Egyptian energy policy and there is no estimate of the share of biogas of the total biomass potential.

Fig. 5: Biogas digester unit and gas collection [8]

Huge amounts of organic waste such as agriculture waste, sludge from municipal treatment plants, and organic waste from garbage as well as animal manure and animal carcasses are generated in Egypt. Table 1 shows a sample of types and quantities of organic wastes generated in Egypt. All these can be considered biomass that is organic carbon based material, which could be an excellent source for biogas and fertilizer.

Table 1: Sources and quantities of organic wastes

Organic waste source	**Quantity**
Agricultural waste	25 million tonnes of dry material/year
Municipal solid waste	6.6 million tonnes of dry organic waste/year
Sewage treatment plants	4.3 million tonnes of dry sludge/year

Until now biogas activities in Egypt have focused mainly on small-scale plants with a digester volume of 5-50 m^3 with a few exceptions such as the Gabel Al-Asfar plant. The biogas potential in Egypt was evaluated in 1995 by the Danida team. The team found that Egypt has a substantial amount of biomass resources, which could be used for biogas plants. The total energy potential of centralized biogas plants with 50 to 500 tonnes/day input was estimated to be about 1 million TOE. If the total technical potentials were exploited, it was estimated that Egypt could produce 40% of its present electricity consumption from biogas and save a substantial amount of chemical fertilizer.

A realistic potential was 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 processing solid organic municipal waste, new industrial cities and tourist villages.

7. ANIMAL FODDER

The deficiency of animal foodstuffs in Egypt reaches more than 3 million tonnes of energy a year. Transforming wastes into animal foodstuffs would help a great deal in overcoming this deficiency. These wastes have a high content of fibre that makes them not easily digestible. The size of the waste in its natural form might be too big or tough for the animals to eat. To overcome these two problems several methods were used to transform the agricultural waste into a more edible form with a higher nutritional value and better digestibility.

Mechanical and chemical treatment methods were used to transform the shape of the roughage (waste) into an edible form. The further addition of supplements can enrich the foodstuffs with missing nutritional contents. The mechanical treatment method consists of chopping, shredding, grinding, moistening, soaking in water and steaming under pressure. The mechanical method has proved to give good results with high levels of digestibility but they have never beenwidespread on the market level because of the high cost and unfeasibility for small farms.

The chemical treatment method with urea or ammonia is more feasible than the mechanical treatment method. The best results were obtained by adding 3% of ammonia (or urea) to the total mass of the waste. It is recommended to cover the treated waste with a wrapping material usually made out of polyethylene (2 mm thickness). After 2 (summer) – 3 (winter) weeks, the treated waste is uncovered and left for 2-3 days to release all the remains of ammonia before use as an animal food.

8. HOUSEHOLD MUNICIPAL SOLID WASTE

Household municipal solid waste represents a crisis for rural areas where people dump their waste in the water canals causing water as well as visual pollution. Household municipal solid waste consists of organic, paper, plastic, tin, aluminum, textile and glass waste, and dust. The quantity changes from one rural community to another. It is very difficult to establish recycling facilities in rural areas where the quantities are small and change from one place to another.

It is recommended to have a transfer station(s) located in each community to separate the wastes, compact and transfer them to the nearest recycling centres. The transfer station consists of a sorting conveyer belt to sort valuable waste from organic waste which is compacted in a hydraulic press. The collected organic waste can be mixed with other rural waste for composting or biogas as explained above.

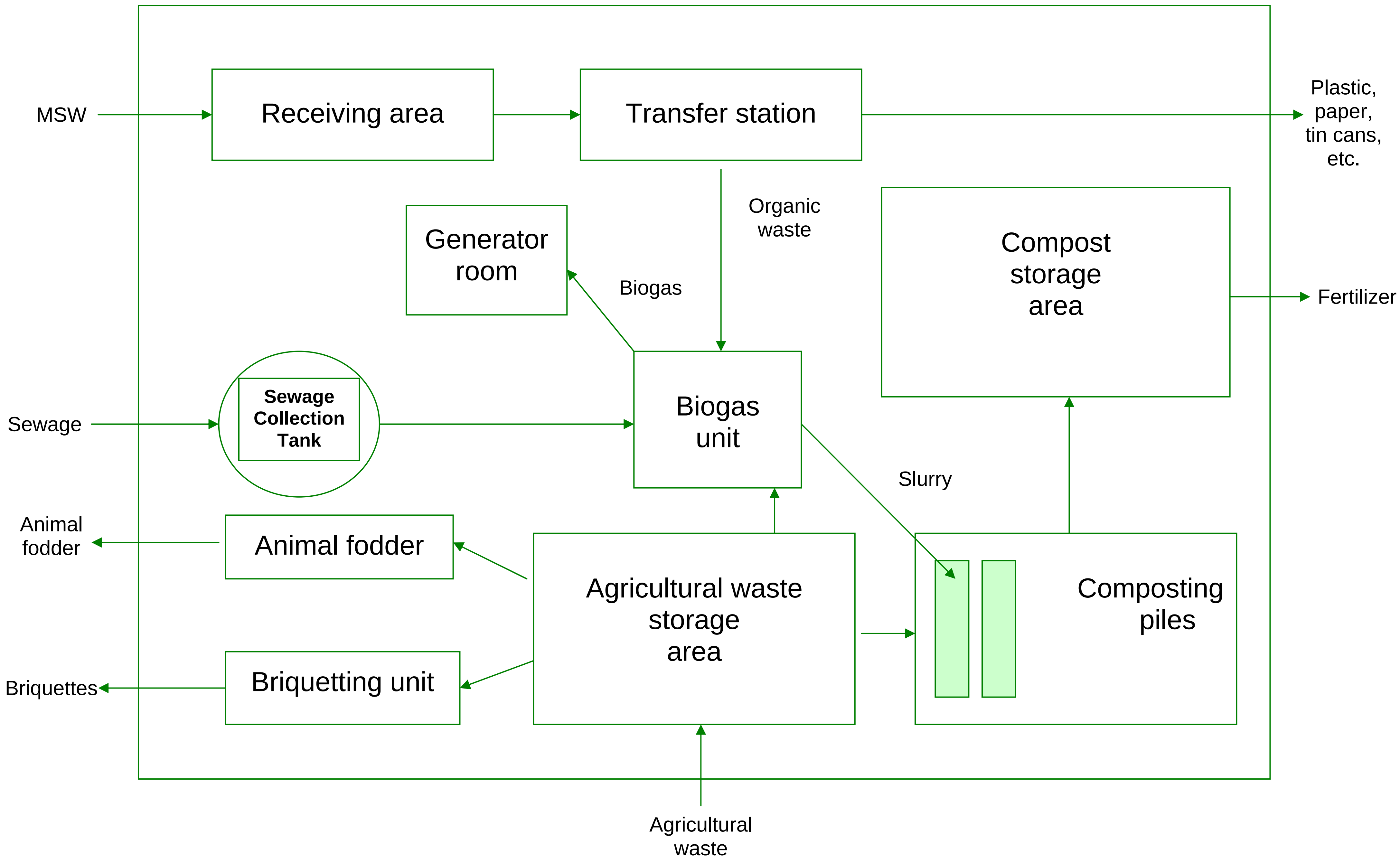

Fig. 6: Trash for recycling

9. EBRWC APPROACH

Rural waste can be utilized using the four techniques mentioned above. The distribution of these wastes over the four techniques: composting, briquetting, biogas and animal foodstuff takes into consideration the need to utilize all sewage (0.5-1.0% solid content) using the biogas technique and that:

- some agricultural waste will be added to the sewage to adjust the solid contents to 10%
- biogas generated will be used to operate the briquetting machine
- fertilizer from biogas unit (degraded organic content) will be mixed with the compost to enrich the nutritional value
- cotton stalks will be utilized using briquetting technique because they are too hard and bulky for the other techniques and have high heating value.

Based on the above criteria, the EBRWC will combine all wastes generated in rural areas in one complex to produce valuable products such as briquettes, biogas, composting, animal fodder and other recycling techniques for solid wastes. The main outputs of EBRWC are fertilizer, energy, animal fodder and other recycled materials depending upon the availability of wastes, and according to demand and need.

10. CONCLUSION

Several compatible techniques will be located together within the agricultural complex such as briquetting, biogas, composting, animal fodder and other recycling techniques for solid wastes (transfer station).

Converting rural waste into energy sources such as briquettes (solid fuel) and/or biogas (gaseous fuel) that is equivalent to millions of TOE/year will save a considerable amount of money and avoid negative environmental impacts and health hazards as a result of the field burning process.

Soil conditioner or fertilizer produced from composting and biogas units will enrich the soil, increase crop production, decrease the amounts of chemical fertilizer used and close the natural loop.

Converting agricultural waste into animal foodstuff will help a great deal in overcoming the deficiency of animal foodstuff in Egypt.

The EBRWC approach will combine all wastes generated in rural areas into one complex to produce valuable products. The EBRWC complex will consist of a number of compatible activities to produce different products as well as keep the rural environment free of pollution generated from burning agricultural waste, disposal of sewage in water canals and disposal of municipal solid waste. The EBRWC will provide job opportunities for young people.

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