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How to utilize sustainably bioenergy and plant nutrients from organic waste in Guatemala and thereby avoid emissions and costs

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Summary: We propose a holistic system that contains hygienic collection devices, short transports and sustainable biological methods for the treatment of organic waste in high-tech industrial units. It will avoid losses that pollute air and water and cause great costs. Vegetation from the countryside delivers food, feed and fibre to urban areas, which contain chemical elements that are bound by bioenergy. After food consumption, food waste and human waste occur which we want to use hygienically as raw material. We want to treat grey water in local biological facilities and use it for irrigation and other purposes. Thus, both citizens' and society's costs will decrease. All waste originating from plants and animals can be converted into biogas and to biofertilizers that are important for soil fertility, carbon sequestration and biodiversity in the soil. We propose the development of decentralized local systems adapted to individual neighbourhoods / areas / districts / quarters that increase awareness, social responsibility and security. Many green jobs in a clean work environment will be created.

Keywords: Biodiversity; Bioenergy; Biofertilizers; Carbon sequestration; Food waste; Grey water; Human waste; Optimal Solids Anaerobic Digestion (OSAD); Plant nutrients; Renewable Organic Matter (ROM)

Introduction

Solid and liquid organic waste causes polluting emissions and huge economic losses when treated with unhygienic and unsustainable methods. Organic waste is Renewable Organic Matter (ROM) and originates from plants that are primary producers. During photosynthesis, solar radiation energy is converted to bioenergy in the plants' biomass by means of essential chemical elements. These elements are C, O, H, N, P, K, Ca, Mg, S, Cl, Fe, B, Mn, Zn, Cu and Mo. Stimulating chemical elements are, for example, Co, Cr, Ni, V, Sn, Li, F, SE and Si. All these chemical elements must be returned to cultivated fields to ensure the production of cultivated crops.

The content of the dry matter for vegetation is on average estimated at 30%. The content of carbon (C), oxygen (O) and hydrogen (H) occupies 96% by weight, which means that the share of energy in plants dry matter is considerably greater than the proportion of plant nutrients. Therefore, every treatment of ROM should aim at utilizing both bioenergy and plant nutrients. Plants are used as food, feed and fibre. Both bioenergy and chemical elements, many of which are called plant nutrients, are used by microorganisms and animals, including humans, and are finally found in the organic waste.

Composting is indeed a widely used method for recycling of plant nutrients and enhancing of organic matter in soils. Unfortunately, this method is not sustainable if we consider that of 100 kg of organic waste become about 30 kg of compost of uncertain quality. Losses of about 70% of weight are pollution that negatively affects health, the environment and the climate with odours, bioaerosols, plant nutrients, CO_2, water vapor, heat, etc. Experiments with composting in aerobic bioreactors in the laboratory resulted in weight losses of only 15% and the compost was ready for use after 10 days. (Gajdos, 1997). This method is economically unsustainable because equipment and handling costs are not covered by the value of useful compost.

Large amounts of organic waste are incinerated, thermally gasified or used for pyrolysis to produce biochar. All these thermal processes are unsustainable because they (i) cause life-threatening and climate-disrupting pollutants, (ii) cause losses of plant nutrients and (iii) kill all micro-organisms living on and in the FOM, which decimates biodiversity.

Only biological transformation processes in closed systems using cascade utilization of ROMs are sustainable and promote biodiversity. “The soil microbiota is the ‘biological engine of the earth’ necessary for sustaining vital ecosystem processes and maintaining soil functions” (Nura A. Abboud, 2017). Cascade use when organic waste from one system can be raw material for the next is a major challenge for bioeconomy. This opens great opportunities to positively influence Sustainable Development Goals 2030.

In the Metropolitan Area of Guatemala City approximately 60-65% of waste is organic, around 12% is paper. The city authorities have initiated activities for closure and rehabilitation of the disposal site (Rodic-Wiersma, 2012). Since about 70% of the household waste in most of countries is ROM, radical changes in the management of organic waste, including human waste, are required. In 1996, a draft was presented that pointed to opportunities for introducing a more sustainable management (Gajdos, 1996, 1998). Ecologically efficient and long-term sound waste management from households describes logistics in future decentralised bioconversion systems and compare present and future management of waste and wastewater (Svedelius, 2002). The purpose of this paper is the further development of proposals presented in the previous work and adapting them to the needs of Guatemala.

Methodology

We propose Sustainable Biological Recycling System (SBRS). Prototypes of hygienic collecting devices for food waste and human waste are developed. Sketch for local high-tech biogas plants for individual neighbourhood/ area/ district/ quarter that will increase awareness, social responsibility and safety and that use Optimum Solids Anaerobic Digestion (OSAD) is here presented. We estimated the content of bioenergy in organic waste from 3,000 inhabitants as well as amount of organic carbon, carbon sequestration and losses of CO_2 during impropriate management. With the help analyses of food and toilet waste, we calculated the content of the nutrients nitrogen (N), phosphorus (P) and potash (K) in food waste and human waste and the value lost with the current system for waste and wastewater management.

Results and Conclusions

To avoid long transports and open systems during treatment of organic waste and human waste, that are expensive and cause carbon leakage, and pollution of air and water, a holistic approach SBRS is suggested. SBRS contains following parts: hygienic collecting devices, short transports to quarter high-tech biogas plants that use OSAD for bioconversion to achieve high yields of biogas and biofertilizers. This is the basis for sustainable management of organic waste for cost-effective use of bioenergy plant nutrients and promoting biodiversity in soils.

Anaerobic Digestion (AD) using waterborne systems is costly to build and operate when only 3 to 10% of dry matter (DM) is used in the process. The research shows that about 30% DM can give 6 to 7 times more biogas per volume of bioreactor

(Rivard 1993). Instead of digestate with a few % of DM that is costly to transport, OSAD we will produce biofertilizer which, in post-treatment, becomes easily manageable organic fertilizer of high quality and value. Quarters high-tech biogas plants of various sizes should be able to reprocess locally available solid organic waste and human waste from between 500 and 5,000 inhabitants.

Food waste from kitchens, restaurants, school canteens and households are today collected with unhygienic and loss-making methods. Open systems contribute to pollutions and loss of energy and plant nutrients. Prototype of hygienic collecting device for food waste Collecting Food Waste BAS (CFW-BAS) that uses foil of biomaterial to pack food waste by welding is presented on http://biotransform.eu/wp-content/uploads/2015/03/CWF-BAS-2018-eng.pdf.

For the sake of sustainability, the water toilet should be abolished in favour of a completely new unit. Human waste can be collected hygienically and separated from grey water from household baths, dishes and laundry. Grey water must be treated with biological methods in quarterly water treatment plants and used locally for irrigation, fountains or for other purposes. Industries already have an obligation to clean waste water according to the Polluter Pays Principle (PPP). Drainage systems and sewage treatment plants can handle storm water. Prototype of hygienic equipment Collecting Closet BAS (CC-BAS) that packs human waste by welding in foil of biomaterial is shown on http://biotransform.eu/wp-content/uploads/2015/03/Future-toilet-CCbas-BS-RS.pdf.

The profits are great when nutrients and bioenergy that are present in the human waste are utilized by means of hygienic and user-friendly equipment, modern logistics that use light electric vehicles for short transports and become biogas and biofertilizer. At the same time, large amounts of drinking water are saved. Prototype of hygienic device Collecting Closet BAS (CC-BAS) is presented on http://biotransform.eu/wp-content/uploads/2015/03/Future-toilet-CCbas-BS-RS.pdf.

Producing biogas and biofertilizer by using Optimal Solids Anaerobic digestion (OSAD) that is going on in closed bioreactors is more profitable than Anaerobic Digestion (AD) that use water as transport media for organic waste. Local high-tech biogas plants using the OSAD method should: 1) adapt well-insulated bioreactors to optimum water content for microorganisms; 2) Use automated pre-treatment of all types of organic waste, such as food waste and human waste mixed with plant waste from gardens, parks, cemeteries, forest as well as organic waste from the food industry, horticultural and agricultural companies including manure and 3) ensure hygienic working environment. Only when these three points are met can the high-tech biogas plant maximize the production of biogas, optimize the quality of the biofertilizers and achieve profit.

OSAD is presented on http://biotransform.eu/wp-content/uploads/2015/03/Biogas-plant-for-OSAD-July2018-RS.pdf.

Bioenergy in biogas and organic carbon in organic waste from 3,000 inhabitants and from their surroundings as well as impact on CO_2 was estimated. When roughly 6 tonnes organic waste is treated between 6 and 10 GWh of bioenergy per year is in the biogas. In biofertilizers it is estimated to remain between 4 and 8 GWh of bioenergy per year. Annually, biofertilizer will contribute to cultivated land with between 66 and 130 tonnes of organic carbon as a carbon sequestration, which corresponds to emissions of between 240 and 480 tonnes of CO_2.

Monetary losses for non-recycling of three main plant nutrients in food waste and toilet waste from 3,000 inhabitants was calculated. Some food waste is washed down to sewage, some is collected by unhygienic and polluting methods, some is used for incineration. According to the Swedish Environmental Protection Agency, 97 kg of food waste per person were in 2016 submitted from households. From 3,000 persons there are 291 tonnes of food waste per year. The value of N, P and K corresponds to EUR 4,600 per year. In the current system appears bioaerosols, emissions of nitrogen and sulphur compounds, etc. CO_2 disappear during collection, transport and treatment. Should all this food waste be incinerated 165 tonnes of CO_2 would be released to the air.

On average, residents leave 1 litre of urine and 0.2 kg of faeces per person and day, which is 438 kg per year (Svedelius, 2014). From 3,000 people there are 1,314 tonnes of human waste per year. The value of N, P and K is approximately EUR 16 400 per year. Growers must buy mineral fertilizer and soil degradation continues. Costs for chemicals and pollutants throughout treatment of wastewater should be added to today's monetary losses. Should the sewage sludge be incinerated to extract with very costly methods only phosphorus, all organic carbon will be converted to about 17,412 tons per year of CO_2 and lost into the air.

Where to build Sustainable Biological Recycling System (SBRS) in Guatemala?
* New Apartment Complex called "Boreal Residences Phase I" is planned (2019-01-22) for approximately 500 inhabitants where SBRS can be implemented.
* A residential complex is planned to be built in the district of Capira, (January 17, 2019). For approximately 4,000 to 5,000 inhabitants SBRS can be realised.

Local industry can build equipment for hygienic collection of food waste and human waste, as well as local high-tech biogas plants and local biological treatment plants for grey water. Instead of expanding or renovating current systems that are expensive, centralized, unhygienic, creating pollution and losses, sustainable decentralized waste management systems should be built to avoid both emission and costs.

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