COMPREHENSIVE UTILIZATION OF HUMAN AND ANIMAL WASTES

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Abstract
The paper discusses how to treat human and animal wastes with anaerobic digestion to obtain environmental and sanitary benefits as well as various approaches to utilize biogas and biogas fluid and biogas fermentation residues. In rural area biogas technology treating human and animal wastes is closely connected with the development of sustainable agriculture, which can rationally balance energy exploration, environmental protection, social progress and economic results. Moreover, it is possible to establish various eco-agricultural patterns linked with biogas suited to local conditions. Efficient organic liquefied fertilizer is developed from human wastes while anaerobic digestion is adopted to make public-hazard-free excrements from public toilets in cities.

Key words
human and animal wastes, anaerobic digestion, biogas ecology, organic liquid fertilizer, sustainable development

1. Introduction

A great deal of human and animal wastes is inevitably produced with human survival and development. It is a must to properly treat the excrements so as to make a clean environment. Rational utilization is the optimal way to maintain ecological recycling and sustainable human development. So excrements should be regarded as a kind of resource. It is also wise to seek for potential utilization of such resource for sustainable development in the future. Practice of the past two decades have proved remarkable achievements in treating excrements and household sewage with anaerobic digestion technology. The technology is applicable to organic sewage with different concentration either on small scale or mass treatment. The treatment costs less and can recover some amount of energy. No other technology can replace anaerobic digestion in treatment of high water content excrements. Based on years of researches and practice, the paper aims to develop feasible and effective approaches to developing human and animal wastes.

2. Benefits of environmental protection and sanitation with application of anaerobic digestion technology

2.1 Environmental protection & sanitation

The popularization of biogas digesters is more than a solution to energy shortage in the countryside. It also helps to improve the energy consumption structure of rural households. Meanwhile the spread can substantially protect forest vegetation from deforestation and contribute positively to improve underdeveloped rural sanitation. Take Yunnan Province as an example, the construction of one biogas digester can prevent 0.2 Ha. woodland from being felled every year. Annually saved firewood reaches over 2,000kg. Biogas digesters play an important role in treating excrements from farmers, live stock and poultry so that firewood piles and haystacks as well as dunghills are eliminated. As a result, rural areas have taken a new look with greatly improved sanitary conditions. Such gratifying change is also conducive to ethical progress. With the application and popularization of biogas, labour used to collect firewood has been saved. Clean energy utilization frees rural women from smoky kitchens. The application of liquids and solids frombiogas tanks greatly improves rural sanitation and avoids environmental pollution caused by chemical fertilizer and pesticides.

Public-hazard-free treatment of excrements from toilets is an effective solution to preventing pollution to rivers and lakes as well as water body eutrophication. With such treatment the COD value of effluent is less than 200mg/L, which is up to the discharge standard of city sewage. Meanwhile it is still possible to recover energy contained in excrements—biogas. A great deal of excrements can be used to develop organic fertilizer which serves as partial substitute for chemical fertilizer. Thus negative impact and harm to the environment caused by chemical fertilizer can be mitigated.

2.2 Sanitation

When excrements are treated in anaerobic digesters many common pathogens and parasitic ova can be killed including *Salmonella*, *Shigella*, *Poliviruses*, Colititre, *Schistosoma ova*, *Hookworm ova* and *Ascaris ova*. (Tab.1)

Tab.1 The Survival Time of Pathogens and Parasitic Ova during Anaerobic Digestion Process

Pathogens &parasitic ova	Thermophilic fermentation (53-55 degrees C)		Mesophilic fermentation (35-37 degrees C)		Ambient temp. fermentation (8-25 degrees C)	
	days	Fatality (100%)	days	Fatality (100%)	days	Fatality (100%)
Salmonella	1~2	100	7	100	44	100
Shigella	1	100	5	100	30	100
Poliviruses			9	100		
Colititre	2	10^{-1}~10^{-2}	21	10^{-4}	40~60	10^{-4}~10^{-5}
Schistosoma ova	Several hours	100	7	100	7~22	100
Hookworm ova	1	100	10	100	30	90
Ascaris ova	2	100	36	98.8	100	53

In rural areas where biogas has been popularized sanitation can be greatly improved with decreased incidence of parasitic diseases. The following are specific illustrations.

— The elimination of fly and mosquito infested places helps to drastically reduce the density of fly maggots.

— Pollution of water bodies by pathogens and parasite is mitigated.

— The spread of prevailing diseases are under effective control.

— The incidence of infectious diseases in the intestinal tract are reduced.

2.3 Inhibitory effect of biogas fluid to pathogens

Biogas fluid shows noticeable inhibitory effects on *Escherichia coli*, baby pig Salmonella, pig erysipelas, 10 strains of *Penicillium* and *Asperigillus*, over 10 strains of plant pathogens, 23 kinds of crop diseases and 14 varieties of pests.

In a word eco-agriculture pattern utilizing biogas can integrate crop plantation with livestock breeding, development of agricultural specialty and energy consumption of rural households, which helps to improve agricultural practice, enhance farmers' awareness of science and technology and promote the development of public-hazard-free agricultural products. Meanwhile such patterns contribute to poverty elimination, environmental protection, soil erosion prevention and rural economy promotion.

3. Comprehensive biogas utilization technology in rural areas

There are various approaches to biogas utilization and the following are relevant technologies.

— Indirect biogas used as heat energy: preservation of fruits and vegetables, storage of grain and agricultural produces and its sideline products.
— Direct biogas use as heat energy: processing of agricultural produces and its sideline products, raise the greenhouse temperature for seedling, incubation and silkworm keeping.
— Biogas used to increase the temperature of greenhouses and CO_2 concentration.
— Biogas fluid can be used to soak seed, spray as leave fertilizer and control crop diseases and pests. It is also applicable in soilless culture.
— Biogas fluid / biogas fermentative residues can be used to feed pigs and raise fish.
— Biogas fertilizer is a substitute for chemical fertilizer to improve soil.
All the above can be developed and integrated with agriculture in line with local conditions so that feasible biogas eco-agriculture patterns are available with regional distinction. The typical patterns are as follows.

"Four in One" in north China: In a greenhouse a biogas digester and a pig sty are built, namely greenhouse, vegetable growth, pig feeding and biogas digester are combined. Thus biogas fluid can be used to grow vegetables, spray as leave fertilizer and control crop diseases and pests. Biogas can be used to increase the temperature of greenhouses and CO_2 concentration within them. With the temperature of greenhouses increased vegetables can grow well and pigs are well-fed. Moreover, biogas productivity is high.

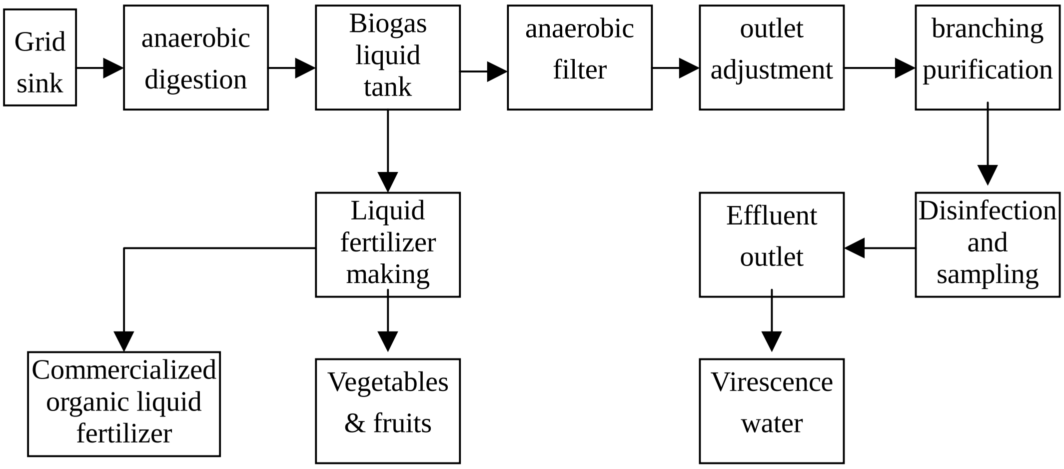
"Pig-Biogas-Fruit" pattern in the south: The pattern is utilized to develop live stock breeding and excrements from the breeding enter biogas digesters. Biogas can be a solution to household fuel; biogas fertilizer is used to grow fruit trees and vegetables as well as a pest control agent. Green food can be developed from the pattern.

"Mulberry Based Fish Pounds-Biogas" pattern in the moist regions south of Yangtze River: Fish pounds are dug out of wetland and bases are formed around them to plant mulberry trees, fruit trees, vegetables, sugarcane, flowers, crops and so on. Water is stored in the ponds to raise fish with some phytoplankton planted. Beside the ponds pig sties and biogas digesters are built and biogas liquid and biogas fertilizer can be utilized to raise fish and grow crops.

Biogas engineering in live stock breeding farms: Chicken dung from henneries goes into the first anaerobic digester to realize biogas fermentation and its residues can be added to pig feedstuff in pig feeding. Pig dung enters the second anaerobic digester and biogas fermentation is conducted. Biogas fluid and biogas fertilizer flow into the ponds to raise fish. The remaining biogas liquid and biogas fertilizer can be used in vegetables and fruit trees as well as succulence. Biogas can provide breeding farms and food processing with energy and power.

4. Treatment and utilization of excreta in toilets

Anaerobic digestion and the technique of branching purification grooves are adopted to treat excreta and flushing water from toilets. The anaerobic digestion involves hybrid anaerobic digesters and anaerobic filters. The technique flow is as follows.



The technique consumes no energy which means low operating costs. It can recover biogas with satisfactory treatment results. The treated effluent can reach the third or second issued discharge standard and it can be used as virescence water around the toilets. Besides, efficient organic liquid fertilizer can be developed from the biogas fluid coming from biogas fluid tank. Such fertilizer is handy to use with sanitation and perfect fertility.

In the above technique the volume of a grid sink is 0.5~0.8m^3 and the sink is used to eliminate suspension and deposit sands and gravels. A hybrid anaerobic digester can be designed with two or more layers whose volume is 55% ~60% of the total. Feeding material goes into the bottom and effluent comes from the middle and upper layer. The liquefied fertilizer tank with a volume of about 1m^3 functions to adjust the biogas storage capacity of hybrid anaerobic digesters, biogas liquid from which can be developed biogas fertilizer. An anaerobic filter is designed to feed material from the bottom and discharge effluent from the upper layer. Its volume is 15~20% of the total with inner dangling fiber. An outlet tank is used to regulate the water level and biogas storage of the anaerobic filter so as to get the sediment of a small amount of activated slurry and conduct sampling and analysis of anaerobic digestion efficiency. Its volume is 0.5 m^3. Branching purification trough can be divided into 4 or 6 deflection chambers and hard and soft material is fed into them. The trough volume is 20~25% of the total. The volume of the sampling and disinfection tank is 0.5 m^3. It is for the sampling and analysis of the effluent. Under certain circumstances effluent can be disinfected and treated. After that the effluent can be directly discharged.