PN-AAZ-614 Egypt: Biogas

THE 'BIO' CONNECTION:

Biomass — Biogas — Bioproductivity

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Fatma El-Gohary is Research Professor of Environmental Sciences and Director of Water Pollution Lab at the National Research Centre, Cairo. She has undertaken a number of research projects on the treatment of industrial wastes, water pollution, bioconversion, etc. and has been one of the principal investigators of an extensive research programme on the environmental aspects of the River Nile, after the building of the Aswan High Dam. Dr. El-Gohary has recently initiated a major research and development bioconversion programme in Egypt.

It would be misleading if one were to say that the conversion of biomass (organic matter; eg. human and animal wastes, agricultural and agro-industrial residues, etc.) into biogas (about ⅔ methane and ⅓ carbon dioxide) by anaerobic digestion (fermentation by bacteria in an atmosphere devoid of oxygen) is a new technology. Anaerobic digestion has been known for more than three centuries; during the past fifty years or so, some countries in Europe (eg. the Federal Republic of Germany, France, etc.) and in North America have built anaerobic digesters to treat their sewage and in many cases have used the resulting biogas — sewage gas — as a source of energy. In 1951, for example, 48 sewage treatment plants in the Federal Republic of Germany provided more than 16 million m^3 of biogas, 3.4 per cent of which was utilised for power production, 16.7 per cent for digester heating, 28.5 per cent delivered into the municipal gas supply system, and 51.4 per cent converted to vehicle motor fuel.

Although small biogas plants were built in some developing countries (especially in the People's Republic of China and India) in the 1950s, the main thrust to develop biogas plants came in the late 1960s and early 1970s; the so-called energy crisis of the early 1970s intensified such programmes, which are now being carried out in more than thirty developing countries. To give a few examples:

In India, more than 36,000 biogas (called 'gobar' gas) plants were built up till 1975-76; now the figure reaches about 80,000, mostly small family size plants. In the People's Republic of China there are about eight million of such plants; in Korea about 27,000 and a few hundreds each in Pakistan, Nepal, the Philippines, Thailand, Indonesia, Sri Lanka, etc. Other countries (eg. Tanzania, Botswana, Ethiopia, Kenya, Egypt) have installed experimental and/or a small number of operational biogas plants. Although most of those constructed are of family size providing from 2-5 m^3 of gas per day (with digester size of about 10-25 m^3), community-size plants have been built in some countries (eg. in the People's Republic of China, India, Sri Lanka).

Many options exist for utilising biogas. It can be used directly in gas burning appliances for cooking, lighting and refrigeration or it can be used as fuel for internal combustion engines. Although at present the primary use of biogas in most developing countries is for cooking and lighting, it is also used for running irrigation pumps and machinery and for small scale electricity production.

But biogas is not the only valuable product of anaerobic digestion of organic matter. The effluent and sludge remaining, after digestion has taken place, is a rich and effective fertiliser. Anaerobic digestion conserves the nutrients (especially nitrogen compounds), and the sludge produced is believed to have a fertiliser value greater than that of the original raw material. The use of effluents produced in biogas plants as a fertiliser has led to an increase in the yield of some crops by 10-28 per cent in the People's Republic of China and India as compared to the use of original excreta. Experiments in the Philippines have shown that rice fertilised with synthetic commercial urea had an average yield of 6.5 tonne/ha, whereas rice fertilised with effluents from biogas plants produced 8.3 tonne/ha. Furthermore, the effluents can be used for growing algae (in algae ponds) that can be used as animal feed for poultry, cattle, pigs, etc. The water from the algae ponds (containing algal-bacterial biomass suspension) can be used to feed fish ponds; yields of *Tilapia* of over 7 tonne/ha were achieved in field experiments (other species of fish can also be produced).

Moreover, anaerobic digestion provides a means for environmentally-sound management of organic wastes; or, as expressed by the Chinese, 'turning the harmful into the beneficial'. This is of particular importance in rural areas of the developing countries which generally lack adequate systems for the disposal of organic wastes. Such wastes pose the gravest health hazards because they carry the pathogens of water borne diseases (cholera, typhoid, dysentery, etc.), and are a breeding milieu for different parasites (schistosomes, hookworms, etc.) which are causing widespread incidences of different diseases in rural areas. Anaerobic digestion of organic wastes to a large extent eliminates these organisms, leading thereby to improvements in general public health. The use of biogas can also reduce the demand for firewood and charcoal in some areas, encouraging the conservation of forest resources and reduction of the process of soil degradation and desertification.

To illustrate the potential of wide scale use of anaerobic digestion, it is estimated that if 60 per cent of the organic wastes of the farm animals in South-East Asia had been collected in 1975 and digested for biogas production, the energy produced would have been equivalent to about 57 million barrels of oil. This amount would have reduced the total oil imports of South-East Asia in that year by about 15 per cent. In addition, the amount of effluents which would have been used as fertiliser would have saved some 200 million US dollars worth of chemical fertiliser.

Having said that, it should be noted that the process of anaerobic conversion is not as simple as generally stated by some or as presented by the media. A biogas plant is not just a hole in the ground in which wastes are dumped and then allowed to take care of itself. It is true that farmers in the People's Republic of China and in some other countries build their own family-size biogas plants, but they copy a simple formula and a well researched design, otherwise leaks would occur or no gas would be produced. Anaerobic digestion is a complex process, the efficiency of which depends on many factors, the most important of which are the digester design, the composition of organic waste, the temperature of digestion, the acidity in the digester and the carbon/nitrogen ratio of the waste material.

Many designs of biogas plants have been proposed: combined digester-gas holder plants, floating gas holder types and separate gas holder units. The plants are built using a variety of materials: brick, cement, concrete, steel, plastic, etc. The input to the digester can be human or animal wastes, agricultural residues, cultivated biomass (algae, water hyacinth, etc.) but a mixture of one or more of these is generally preferable to maintain a carbon/nitrogen ratio of about 25–30 : 1, which is the optimum for biogas production. The milieu of fermentation should be kept slightly acidic at temperatures between 35 and 60° C. The biogas produced varies in composition according to the design of the digester and the composition of the feed material, but generally it consists of 65 per cent methane and 35 per cent carbon dioxide with traces of sulphide. Some biogas plants are provided with means to scrub off the carbon dioxide from the biogas and hence raise its calorific value (pure methane has a calorific value of 37.1 MJ/m^3, while biogas varies between 20–26 MJ/m^3). Although the sludge produced in the fermentation process is enriched in nutrients, it cannot be directly applied as a fertiliser or for fish farming because of its toxicity (largely due to the presence of hydrogen sulphide). Sludge conditioning is, therefore, important in order to eliminate such toxicity and permit its use for different purposes. At the Maya Farms in the Philippines, sludge-conditioning plants have been built adjacent to the biogas plants. The solids recovered from the sludge have been processed into an excellent animal feed material (dried sludge was found to be rich in vitamin B_{12}, a growth-promoting factor in animal feeds).

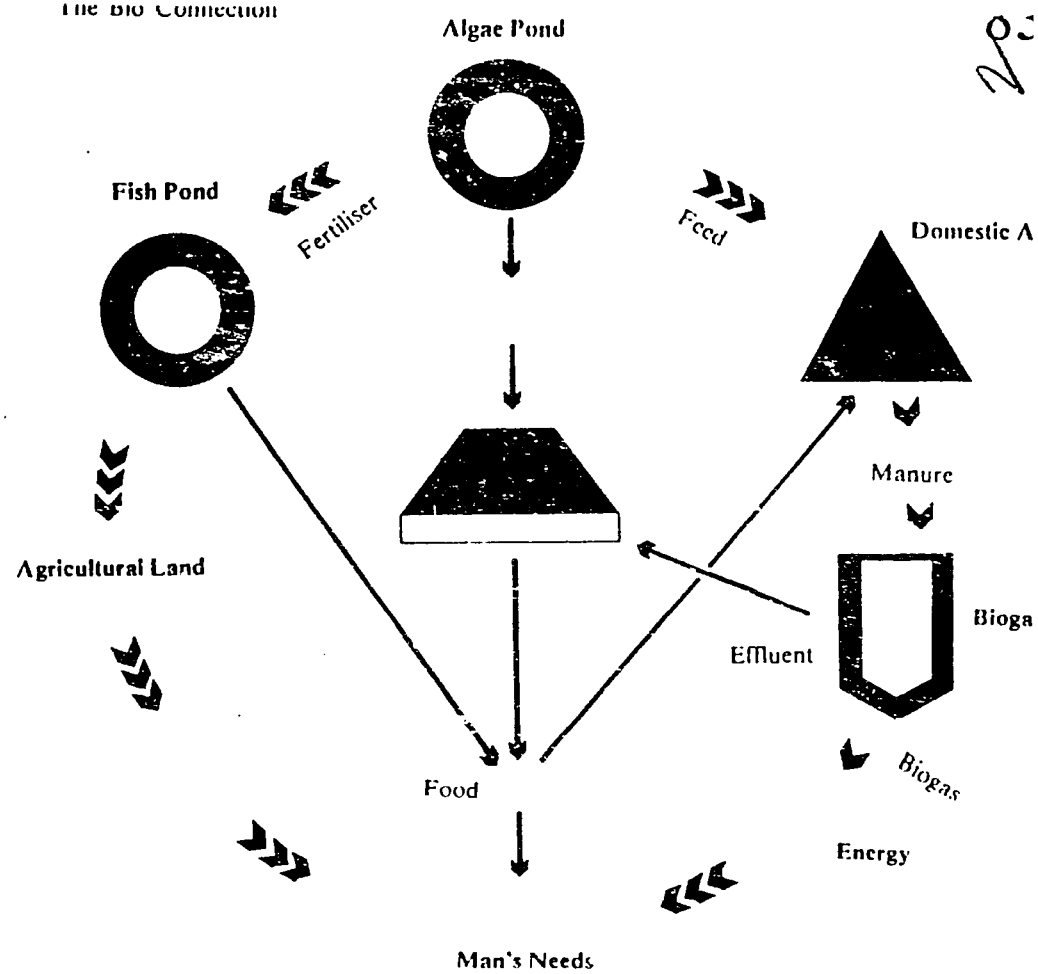
With the ever-increasing interest in building biogas plants, several basic chemical, microbiological, engineering and social problems have to be carefully studied to ensure the successful wide-scale adoption of anaerobic conversion technology. Several research and development programmes are under way in many countries to study these and other factors that influence the process of bioconversion. For example, pilot scale studies carried out at the National Research Centre in Cairo aim at the evaluation of the efficiency of anaerobic conversion mechanisms and at the evaluation of digested products such as fertiliser and soil conditioner. Special attention is given to the selective inhibition of hydrogen sulphide produced in the fermentation process and to the destruction of ova and embryos of hookworms. Prototype biogas plants at a cost of US $300–500 have been constructed. One of these plants (the Egyptian design) has

Table 1

Biogas Yield (m^3/tonne)*

Cattle dung	22–40
Pig Manure	40–60
Human faeces	20–28
Crop residues	30–40
Water hyacinth	40–50

*Fresh material.



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provisions for solar heating of feed water, composing of the digester effluent on top and attachment to both a latrine and an animal shed. The cost-effectiveness of bioconversion technology is also a matter of primary concern in such research and development programmes.

Yet an important question remains to be answered: why should we build biogas plants? The prompt answer that comes to many minds is the usefulness of biogas as fuel, especially in rural areas. But in some countries this will not be either cost-effective or sufficient (for example in countries where the animal wealth is rather limited or where rural electrification is extensive and butane gas or kerosine is widely used for cooking). The most adequate and far-sighted answer is that biogas plants should be built to recycle organic waste into beneficial products. Anaerobic conversion should be regarded as an environmentally-sound management technique that protects the environment, increases bio-productivity and provides an adequate energy source. Such biomass — biogas — bioproductivity integrated systems can lead to substantial and accelerated rural development, increase the base for food production and improve the quality of life fo millions of people in rural areas. Although such systems have been implemented on a small scale in some countries, for example in the Philippines (Maya Farm) and in the People's Republic of China, the time has come for a more wide-scale application of

Cheap, natural sources of energy must be harnessed to replace electricity as a driving force. Some of these, like the windmill, are time-honoured – others, like solar energy and bio-gas, are just beginning to come into their own.

such systems, especially at the community level. Biomass — biogas — bioproductivity systems at the village level, making use of human, animal and other organic wastes, can effectively transform the gloomy picture of rural areas through development of rural industries, provision of local job opportunities and progressive eradication of hunger and poverty.

Suggestions for Further Reading

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