

A TECHNOECONOMIC APPROACH TO SOLID WASTE DISPOSAL  
AND HANDLING IN DAKHLIA GOVERNORATE

by

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مدخل تقني واقتصادي لمعالجة وتداول المخلفات

الصلبة بمحافظة الدقهلية

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جامعة المنصورة

أن تحول الفضلات والملوثات المتطايرة والمحطمة للتوازنات البيئية والطبيعية الي  
مصادر للمواد المفيدة ومصادر للطاقة هو من أهم الموضوعات التي تعود علي الدول  
النامية بفوائد عديدة منها ما هو اقتصادي وما هو بيئي .  
المخلفات الصلبة في بيئة محافظة الدقهلية يتسبب عنها مشاكل عديدة منها علي  
سبيل المثال :

- ١- المناظر الكريهة المنافية للذوق السليم .
- ٢- تجمع الذباب والميكروبات والروائح الكريهة وتسبب مخاطر صحية عديدة .
- ٣- زيادة تلوث الهواء بما يصدر منها من غازات عديدة وغبار .
- ٤- زيادة تلوث المياه بما ينجرف منها من سوائل ودقائق عند نزول الأمطار .
- ٥- التأثير الكبير علي التربة والتوازنات الطبيعية فيها .
- ٦- زيادة في احتمالات الحرائق .

ومن التكنولوجيا الحديثة لمعالجة المخلفات الصلبة التي تسبب المشاكل السالفة  
المذكر هو الهضم البيولوجي لهذه المخلفات حيث ينتج عن هذه العملية مواد ذات مورد  
اقتصادي ، بالإضافة الي التخلص من التلوث البيئي الناشئ من هذه المخلفات .  
ويهدف هذا البحث الي دراسة جدوي فنية واقتصادية لتقييم عملية التخلص من  
الفضلات الصلبة عموما في محافظة الدقهلية وتحويل هذه المواد الي مواد ذات عائد  
اقتصادي والتخلص من المشاكل البيئية الناتجة من هذه المواد .

ومن أهم نتائج هذه الدراسة الآتي :

- ١- كمية المخلفات الصلبة التي يمكن جمعها في محافظة الدقهلية حوالي ٥٢ مليون  
طن سنويا .
- ٢- كمية الطاقة الناتجة من عملية الهضم البيولوجي لهذه المخلفات تكفي لاستهلاك  
المحافظة من الوقود الغازي اللازم لعملية الطهي (٢,٦ × ١٠<sup>٦</sup> م<sup>٣</sup>) . كذلك تكفي لإنارة  
وتدفئة جميع مزارع الدواجن بالمحافظة (٨ × ١٠<sup>٦</sup> م<sup>٣</sup>) ، أما كمية الغاز المتبقية (٥٢  
× ١٠<sup>٦</sup> م<sup>٣</sup>) يمكن استخدامها لتوليد طاقة كهربائية مقدارها ١٤ × ١٠<sup>٦</sup> كيلو وات .
- ٣- بتقدير القيمة السمادية في المخلفات الصلبة الناتجة من عملية الهضم البيولوجي  
أوضحت النتائج أنه يمكن تغطية جميع احتياجات الأراضي الزراعية بمحافظة الدقهلية  
وبزيادة مقدارها ١٣٤% ، ٣٦٧% ، ١٩٥% من الأسمدة الكيماوية التي تحتوي علي  
النيتروجين والفوسفور والبوتاسيوم علي الترتيب .

### ABSTRACT

Due to the rapid increase of population in rural areas, specifically in Dakhliya Governorate, and the limited dwelling areas; the solid waste emanating either from stables, large animal stocks or agricultural waste causes hygienic problems, air pollution, water pollution, effects on the ecological balance and greater risk of dangerous fire.

Anaerobic digestion is considered as one of the new trends in solid waste disposal. The anaerobic fermentation process is employed in/or by:

- 1- Industrial and municipal sewage treatment facilities.
- 2- Agricultural and animal biogas systems.
- 3- Garbage dumps/landfills.

For industrial and municipal waste water treatment plants the prime objective is to stabilize the sludge and exploit the biogas as an energy carrier for fueling the thermal process.

The anaerobic treatment of liquid manure from intensive livestock units should be carried out for the following reasons:

- (1) Breakdown of smells.
- (2) Production of biogas and
- (3) Improvement of fertilizer properties.

For sanitary landfills/dump sites, utilization of anaerobic treatment permits the collection of the inevitably produced biogas in a beneficial form.

The objective of this paper is to introduce the framework of the feasibility study for the evaluation of the biogas, produced from biofermentation of agricultural and animal waste and sewage sludge either for electricity generation or direct combustion. Also, the sludge produced from biofermentation would be evaluated as fertilizer or fodder additives as compared to its use in the raw form.

### INTRODUCTION

Rural areas in many developing countries are facing severe and interrelated problems of energy and environment. Growing shortages of traditional fuels are often due to increased population pressure on land, biomass and other limited resources. Dakhliya Governorate is considered as one of the areas suffering from the rapid increase in population with a limited dwelling areas and cultivated lands as illustrated in Fig. (1). Solid waste emanating either from stables or from large animal stocks in different areas in the Governorate causes the following problems:

- 1- Hygienic problems, to include the following:
  - Facilitating reproduction of flies and mosquitoes.
  - Air pollution from offensive odors.
  - Diseases and epidemics.
- 2- Its direct application as a fertilizer has the following disadvantages:
  - Costs of loading and transportation to field and of spreading it on the land.
  - Low nutrient-to-volume ratio.
  - Pathogenic carrier.
- 3- Many farmers use it as a filler in brick production via small kilns generating another environmental impact [1]

The solid waste produced from animals in Dakhliya Governorate amounts to about  $(4.66 \times 10^6)$  ton/year). The distribution of the different types of the farm animals, normally bred in rural areas, in the Governorate (as estimated in the year 1991) is displayed in table (1) and Fig.(2).

Recently, many poultry farms were established at different areas in the Governorate. These farms were built and distributed without any planning. No considerations were taken for hygienic and environmental problems. Liquid manure emanating from these farms causes the following problems:

- (a) Large areas are needed for spreading the manure for drying.
- (b) Offensive odors create a big problem with hygienic and environmental authorities.
- (c) Low demand and low prices offered for this manure as fertilizer.

In Egypt, the waste water treatment plants in the past were located in the main cities and were, mainly, trickling filter systems. Recently, many activated sludge plants have been constructed in many cities and villages and more activated sludge plants will be constructed in the near future. These plants will produce a large quantity of sewage sludge. Anaerobic treatment is employed for the stabilization of primary and secondary sewage sludges from municipal and industrial waste water treatment plants.

The biogas project issued by Egyptian Ministry of Agriculture and FAO did not imply Dakhliya Governorate in the plan [2]. The objective of this paper is to introduce the framework for performing a technoeconomic study of solid waste disposal and handling in Dakhliya Governorate. The elements of this study include the following:

- End-user and benefits.
- Problem definition.
- Objectives.
- Detailed description and technoeconomic approach.

#### END USER AND BENEFITS

To perform such a study, the anticipated results for application by the user are suggested to include the following:

- (1) Detailed assessment of current uses and impacts from solid waste disposal and handling.
- (2) Comparative techno-economic evaluation for different systems utilized for solid waste disposal in Dakhliya Governorate.
- (3) Detailed technology systems for the recommended solid waste disposal including:
  - a- Basis of design.
  - b- Detailed design implying profitable anaerobic systems and power generation systems of burner equipment.
  - c- Specifications (equipment, instrument, and materials)
  - d- Local and foreign components.
  - e- Operational instructions.
  - f- Budget estimates are to be provided.
- (4) Profits gained from anaerobic sludge as fertilizer or as additives for animal foods.
- (5) Environmental protection due to proper waste disposal.
- (6) Economical and environmental studies that can be used as a reference for other governorates.

#### PROBLEM DEFINITION

Rural areas in many developing countries are facing severe and interrelated problems of energy and environment. Growing shortages of traditional fuels are often due to increased population pressure on land, biomass and other limited resources.

The exploitation and further development of biomass energy sources is inextricably linked with broader environmental considerations. Solid wastes contribute to facilitate the reproduction of flies and mosquitoes which increases the demand for domestic insecticides which are considered as dangerous carcinogenic. Therefore, exploitation of

these solid wastes, in addition to contributing to energy resources, would solve an important environmental problem in crowded populated areas such as Dakhliya Governorate. Also, the problem of offensive smell would be solved.

The production, transport and use of fossil and renewable energy sources raises a number of important environmental issues. Resource depletion, multiple uses of resources, and environmental pollution are often specific for local needs, local resources and local constraints. Viable solutions to sustainable development are equally specific for particular rural areas. Dakhliya Governorate is considered as one of the governorates which has no industrial activities concerning the production of fossil fuels. Most of the energy resources needed for the governorate are transported from different distant areas (Cairo - Alexandria - Suez etc.). Many times the shortage of gas cylinders for domestic uses is considered as a big problem for both people and authorities.

The development and dissemination of energy technologies has a variety of social and environmental implications. Such technologies are to be thoroughly evaluated and selected. Furthermore, the development of potential small scale energy production affects a number of operational sectors as well as regional development objectives. Decentralized energy planning will, therefore, need to be built on multi-objective analysis and planning techniques.

Sustainable rural development will shape both the energy policy and the economic growth policy. Policies for rural energy and environment are to be integrated within, on one hand, a framework for overall rural development and, on the other hand, sustainable national energy policies. Such policies need additional efforts in decentralized planning and management of local rural resources and the environment.

The growing interest for energy resources alternatives to fossil fuels has generated a renewed interest in anaerobic fermentation. The wide interest in this technology is due not only to the prospect of getting energy but to the fact that it allows a remarkable reduction in environmental pollution, due to agricultural as well as industrial wastes.

The disposal or utilization of livestock farming waste can give rise to practical and economic problems especially on big modern intensive units. The presenters of this paper communicated personally with some owners of large scale poultry farms in Dakhliya Governorate who complained about the problem of the liquid manure produced from their farms. These problems include the following:

- (a) Large areas are needed for spreading the manure for drying.
- (b) Air pollution and offensive odor creates a big problem with the environmental and hygienic authorities in the council.
- (c) Low demand and low prices offered for this manure as fertilizer
- (d) Causing a significant hygienic problems to the flock itself due to dumping of the solid manure behind the farm.

Sewage sludge is a byproduct from waste water treatment plants, it amounts to less than 1%. It is largely a biological material consisting of solids which settle out during the treatment of sewage waste water. These solids (sludge) also undergo additional treatment, most commonly anaerobic or reducing the quantities of easily-decomposable organic, and eliminating the undesirable odors associated with raw sewage, in addition to obtaining reasonable quantities of biogas. Sewage sludge contains nutrients essential for plant growth, but it may also contain other nonessential elements toxic to plants and potentially hazardous to the food chain. Sewage sludge applied to crop land should be digested and stabilized.

## OBJECTIVES

### A-GENERAL OBJECTIVES:

The general objective of such study is the evaluation of the biogas, produced by biofermentation of agricultural, and animal wastes and sewage sludges, for either electricity production or direct combustion. Also, the sludge produced from biofermentation is to be evaluated as a fertilizer or fodder additives.

### B-SPECIFIC OBJECTIVES:

The possibility of utilizing liquid as well as solid effluent of anaerobic digestion as fertilizers in agriculture instead of both chemical fertilizers and raw solid animal wastes shows several advantages [3,4]:

- Increasing organic substance and microbic loads.
- It contains some elements indispensable for the growth of plants.
- It includes stimulating substances.
- Activity of microbic colonies of soil is increased.
- Inorganic phosphorus and all micro elements of the soil are stabilized, to the advantage of root absorption.
- It does not alter the content in fertilizing elements, like nitrogen, phosphorus and potassium.
- It makes easier the conversion of organic nitrogen into ammoniacal nitrogen.
- It increases the fertilizing power of liquid and solid effluent.

Table (2) lists the approximate nutrient contents of various substrates [5], whereby it should be remembered that the actual values may show a wide range of scatter depending on the type of fodder eaten by the animal.

The feeding value of biogas sludge for goats is more pronounced, and thirty percent substitution of rice bran with sludge has given excellent results. Broilers can be fed with rations substituted with from ten to twenty percent sludge. Ducks can accept up to fifteen percent sludge in their food. These results are attributed to the fact that vitamin B12 is synthesized in the slurry during anaerobic fermentation [6].

The well-aimed, direct disposal of organic waste, i.e., its use as a source material for biogas production, has the effect of eliminating breeding places for disease spreading flies, gnats and mosquitoes. Moreover, the mild odor of biogas sludge makes it unattractive to scavenging flies (blow flies).

### DETAILED DESCRIPTION AND TECHNICAL APPROACH

To perform such a study, the following phases are suggested:

- 1- Data collection and area survey.
- 2- Evaluation of biogas and sludge.
- 3- Comprehensive technical, economic, environmental and social assessment.
- 4- Design criteria.

The details of every phase will be as follows:

#### 1- DATA COLLECTION AND AREA SURVAY

This phase include the following:

- (a) Number and kinds of animal farming in different locations in the Dakhlia Governorate as given in Fig.(1).
- (b) Evaluation of the quantity and kind of animal and agricultural wastes.

This may be performed for animal wastes using the following relation:

$$Q = A \times M \quad \dots\dots\dots(1)$$

Where:

- Q = quantity of waste produced in a certain location/time.
- A = number of animal in this location.
- M = mass of nominal waste produced per head per time, such as given in Table (3), [5,7].

The data obtained from different locations and from different animals are displayed in table (4).

- (c) Survey for sewage treatment plants and determining the capacity of these plants and the expected quantity of sludge produced. Concerning this item, it would depend upon the census of different locations. Assuming that the service of sanitary sewage treatment will cover the central cities in near future (next 5 years). The quantity of sludge from sewage treatment plants may be found, using the following relation:

$$Q = R \times F \quad \dots\dots\dots(2)$$

Where:

- Q = quantity of sludge produced, ( $m^3$ /day).
- R = quantity of sludge produced per unit volume of municipal waste water (1-2%) [8,9]
- F = Sewage flow rate = NC ( $m^3$ )
- N = Sewage volume per capita/day ( $m^3$ ) (200-350 liter/capita/day) [10]
- C = census (capita).

Concerning the sludge which may be produced from sewage emanating from rural areas, there is no clear plane to estimate the number and distribution of sewage treatment stations. Therefore, the sludge produced from rural areas may be estimated parametrically as follows:

$$Q = (RF) f \psi \quad \dots\dots\dots(3)$$

Where:

- f = factor of population growth.
- $\psi$  = factor representing the proportion of sewage treatment service cover the rural areas.

## 2-EVALUATION OF BIOGAS AND SLUDGE

### (a) Evaluation of fertilizing values of sludge and raw waste:

This activity includes the evaluation of the fertilizing value for both raw animal waste and untreated sewage sludge against the sludge produced from biofermentation, to include the following determination:

- 1- The content of macro nutrients (N, P, K, ..... ) and micro nutrients (Fe, Mn, Zn, ..... ) as well as total carbon in the composite and undecomposed materials.
- 2- Some crops will be cultivated in a pot experiment, by adding these material to the soils.
- 3- Yield, growth and chemical composition of the plants will be estimated.

### (b) Application of sludge for animal fodders:

As a part of the nutritional evaluation, feeding trials, using either poultry waste, animal waste or sludge have been evaluated by different researchers [5]. Proximate analysis including dry matter, crude protein, ether extract, fiber fractions and crude ash, in addition to, fine analysis involving minerals, digestibility trials on sheep, and voluntary feed intake factors would be undertaken to evaluate such animal wastes. Technical experiments involving an economic evaluation of all the processing on these wastage to be suitable as an animal feeds can provide the evaluation of the

qualitative and quantitative changes in their nutritive values in these animal wastes.

(c) Evaluation of biogas for various gas appliances:

In principle, biogas can be used in practically any commercial-type or traditional gas-burning appliance, whereby various combinations of heat, refrigeration, light, electricity and mechanical power can be generated and exploited. Fig.(3) illustrates the various options, and in Table (5) the typical gas consumption values and appliance efficiency rating are given [5].

Gas stoves/cookers are easy to modify for biogas operation merely by installing the proper gas jets. A wide variety of commercial type gas cookers are available in developing countries. Gas lanterns (with simple incandescent mantles) are very inefficient (3-5% light efficiency). The higher the pressure, the better the light efficiency. Proper heat removal must be insured. Therefore, this alternative would be suitable for dual purposes of lighting and heating in poultry farms. Radiant heaters of the type used quite frequently in animal husbandry can also be operated by biogas, as shown in Fig. (4). Such systems may operate with a useful energy efficiency of nearly 100%. Several manufacturers of radiant heaters have modified certain models for biogas operation and are marketing them in numerous countries

3- Comprehensive technical, economic, environmental and social assessment:

The process of economic evaluation is generally quite difficult, since it involves the gaging of numerous parameters, the future development of which will be influenced by a multitude of imponderable. Nevertheless, such evaluation often demanded by planners, politicians etc., can still serve as a very valuable tool in planning and implementing biogas programs. The economic evaluation her in would imply the evaluation of the raw waste in one hand and after biofermentation in the other hand. The different alternatives of waste sidposal would be economically analyzed on the cost/benefit basis. It should be borne in mind that, while the primary purpose of a cost/benefit analysis is to compare the relative appropriateness of various approaches, it is always very difficult to reach a definitive statement on a system's absolute economic worth, i.e. its profitability over various periods of time.

The annuities method is regarded as the most suitable one for evaluating the economic viability of biogas systems and programs. This method, compared to other approaches, is more suitable for assessing absolute economic efficiency and for comparing various investments with very divergent projected lifetimes. Basically, the annuities method converts the investment into fixed annual costs suitable for direct comparison with the annual benefits, according to the following relation [11].

$$AN = B - C - I \cdot CR(i, T) = R - AN_1 \dots \dots \dots (4)$$

Where:

- AN = annuity, i.e. the annual gain, calculated for the first year (year 0)
- AN<sub>1</sub> = annuity of the investment,
- B = annual benefits (savings and/or returns on investment), calculated for year 0.
- C = annual costs, calculated for the year 0.
- R = annual reflux (R = B - C).
- I = total initial investment volume, calculated for the year 0.

- CR = capital recovery factor.  
 i = assumed interest rate.  
 T = projected service life or time required for amortization of the investment.

In the last expression the annual benefits (B), comprise the monetarily evaluated returns, savings, etc. yielded by the investment. These may derive from:

(1) Power generation: Naturally, only the net energy gained be counted, i.e. the process energy fraction (for agitators, pumps, heating and any outside energy input) must be subtracted from the total gas yield. If the generated power is sold, the returns are included in the calculation.

(2) The substitution of digested sludge for chemical fertilizer or instead of direct application of animal dung as fertilizer can often yield savings. Accurate monetary evaluation will be based on laboratory investigation of the fertilizer values for the different alternatives taking into consideration the influence of the type of storage, climate, the techniques employed in spreading and working into the soil, etc.

(3) Savings attributable to the superior properties of the digested sludge: These may result from the improved fertilizing effect of the sludge, its hyponitization, reduced odor nuisance and more advantageous handling properties such as reduced viscosity, improved homogeneity, etc. it is normally quite difficult to attach a monetary value to such benefits. Legal regulations pertaining, for example, to reducing odors or improving hygiene can be of decisive influence.

The annual costs (C): are made up of the expenses incurred for:

(1) Maintenance and repair; usually 1-3% of the investment volume is generally accepted for this item.

(2) Plant operation; operating costs are largely attributable to the depletion of consumables (such as desulfurizer cleaning agents) and to outside energy requirements, e.g. electricity for running agitators and mixers.

(3) Inspection fees, etc. usually arise in connection with pressurized biogas systems.

(4) Expenses in connection with system attendance are usually variable, whereby the hourly wage and time expenditure are subject to wide variance.

#### Sensitivity analysis:

The results of cost-efficiency analysis for investment projects naturally include a number of uncertainties, because some of the data upon which they are based reach far into an uncertain future. With this in mind, those results should always be examined with regard to their sensitivity to potential changes in their hypothetical foundation. On the basis of the most-probable model formulation, at least the following parameters should be varied:

Capital expenditure, gas yield, energy cost increase, assumed interest rate and service life.

The results of such model variations can then be plotted for purpose of comparison and better recognition.

#### Questionnaire for Technical, Economic, Environmental and Social Assessment:

The questionnaire outlines a summary of facts and data that may be of value and/or interest in connection with the implementation of biogas technology. The questionnaire implies the following:

##### 1 - Local factors:

- Which building materials (cement, sand, lime, bricks, natural stone, steel sheets/plates, pipes, PE-tubing, plastic sheeting,.....)



- are locally available or can be easily produced on the home market?
  - Which local craftsmen (masons, plumbers, steel erectors, welders,...) are available, and how well qualified are they?
  - Are biogas experts available for the project? if so, from which organization, starting when? and for how long?
  - Are any other biogas projects presently under way or already at the operational stage in the near vicinity, or at least within the national bounds? if so, what is their "image"?
  - Which biogas appliances, if any, are available on the domestic market?
  - What is the local climate, i.e. mean ambient temperatures (winter, summer, rainy season, dry season), and ground temperatures (at a depth of ca. 1 m), precipitation, pan evaporation, and particular local weather characteristics?
  - What is the character of the local sociocultural setting (population structure, religion, hierarchical structures,...)?
  - Miscellaneous data of relevance?
- 2 - Operational factors:
- Name and address of prospective owner/user?
  - Size and location of farm (layout plans)?
  - Number of persons involved/affected?
  - Livestock inventory and management (broken down according to type(s) of animal(s), weight(s) and type of housing provided)?
  - Farmland (area, crops)?
  - Crop residues available for use in biogas generation (types and amounts according to season)?
  - Are means available for chopping such residues?
  - Fertilizer requirements, type(s) of fertilizer(s) presently used, storage of organic fertilizer?
  - Is enough fresh water in hand for diluting the fresh substrate (if necessary)?
  - Depth of ground water table?
  - How far away from the next shallow well will the envisioned biogas plant be located?
  - Type of soil (literate, black earth,...)?
  - Energy demand/consumption, broken down according to types of fuel (wood, dried cow dung, sundry organic materials, LPG,...)?
  - Consumers (list of fuel-consuming equipment, individual specific power ratings, type of fuel used)?
  - Cooking habits (how many times a day, for how long each time)?
  - To the relevant extent, various daily/seasonal fluctuations in energy consumption (except for lighting)?
  - Propagation aspects (model character of biogas plant or of the entire farm, social status of the prospective owner/user)?
  - Is there any possibility of installing a community biogas plant?
  - Miscellaneous data of relevance?
- 3 - Economic factors [11].
- Inflation rate, typical interest pro and contra or assumed interest rate?
  - Availability of loans (interest, credit periods, amounts)?
  - Subsidies, grants (national, International,...)?
  - Owner/user building capital?
  - Economic situation of owner/user (annual income, profit)?
  - Expenditures for other energy vehicles of relevance under the prevailing conditions?
  - Expenditures for chemical fertilizers?
  - Cost of labor?
  - Bought estimate of the cost of essential building materials?
  - Miscellaneous data of relevance?

#### 4 - DESIGN CRITERIA:

Biogas systems should be planned with due regard for local circumstances, particularly with regard to: potential installation sites, minimum pipe lengths, topographical situation (for exploiting any natural slope), exploiting any existing structures and equipment available, and the plant must be situated such that neither the ground water could become contaminated nor the neighbors will be exposed to an odor nuisance, i.e. prevailing winds should be taken into account.

The installation of the biogas system in Dakhliya Governorate should cope with the following objective:

- Production of biogas,
- Obtainment of superior fertilizer, and
- Hygienisation of the feed stock.

These objectives would be of major importance as design criteria with regard to shape, size, temperature range, process, etc.

The biogas system should be energetically adapted to achieve maximum gas load and commercial energy should be replaced by biogas as possible. Fig. (5) illustrates the flow of energy in a biogas system [5].

In attempting to calculate the potential savings on commercial energy, it is based on the amount of energy that remains available for use after the process energy fraction (heat and equipment operation) is deducted. Thus, all energetic considerations should begin with a rough estimate of potential gas production [5,7]. Applying this concept on the undertaken case study for the Dakhliya Governorate, the estimated net gas production from the biofermentation of the different solid wastes in the Governorate amounts to about  $1.67 \times 10^7 \text{ m}^3/\text{day}$ . Details of gas production from different wastes are displayed in Table (4).

The main objective leading to the installation of the biogas system in Dakhliya Governorate is to generate as much high-quality fertilizer as possible, therefore, the following would be considered in design criteria:

- (1) The system should be sized to accommodate all available feed stock.
- (2) The energetic aspects need not be optimized, i.e. no gas holder, less thermal insulation, etc. is required.
- (3) Adequate storage capacity must be provided for collecting effluent sludge until it can be used to the best advantage according to the soil conditions, climate, crop rotation, etc.
- (4) Efficient means of spreading and working in the fertilizer are recommended.
- (5) Biogas output would be monitored, (quality and quantity), for stability of the system which is an indicator for the quality of the effluent sludge.

The estimated fertilizing value of sludge produced from biofermentation of solid wastes in Dakhliya Governorate is displayed in Table (6).

Dakhliya Governorate is considered as one of the most crowded governorates in Egypt, therefore hygienisation of the feed stock is of major importance in design criteria, consequently special attention must be given to the following points:

- (1) Maximum process temperature (thermophilic is better than mesophilic).
- (2) Maximum retention time (generally exceeding 30 days).
- (3) Uniform real retention time for all substrate.

The required digester volume for biofermentation of solid wastes from Dakhliya Governorate may be calculated from the following

relation [9].

$$v = q \times t \quad \dots\dots\dots(5)$$

Where:

- v = the digester volume (m<sup>3</sup>).
- q = feed flow rate (m<sup>3</sup>/day)
- t = solids retention time (days)

as recommended above from the point of view of hygienisation, taking retention time of about 30 days and total feed stock produced from all solid wastes in Dakhliya Governorate to be about 1.44x10<sup>8</sup> Kg/day, (Table 4), diluted with water (average ratio 1:1), then the total volume of all digesters to be constructed for biofermentation of all solid wastes in Dakhliya Governorate would be about: 8.6x10<sup>8</sup> m<sup>3</sup>. Although true operational solid retention time for the different wastes would be calculated using the following relation [9]:

$$t = \frac{S_r}{X_v K S_e} \quad \dots\dots\dots(6)$$

Where:

- S<sub>r</sub> = achievable percent removal of COD.
- X<sub>v</sub> = Mixed liquor volatile suspended solids.
- K = reaction rate constant (lit/mg. day).
- S<sub>e</sub> = non achievable percent removal of COD.

The sludge yield is computed from the relationship [9]:

$$\Delta X_v = a S_r - b X_v \quad \dots\dots\dots(7)$$

Where:

- a = cell yield coefficient,
- b = cell endogenous rate (day<sup>-1</sup>).

#### CONCLUSIONS

In Dakhliya Governorate the production of biogas holds the promise of becoming an important contribution to the national energy and fertilizer balance.

According to the collected data, an estimated 5.2 million tons of solid waste is available annually in Dakhliya Governorate. If all the solid waste emanating from different sources be used as feed stock for biogas systems, the resultant energy yield could satisfy the cooking fuel needs of 4 million capita or roughly 100% of the whole population in Dakhliya Governorate. The biogas needed for this purpose amounts to 3.6x10<sup>8</sup> m<sup>3</sup> per year.

The energy yielded would far exceed the amount presently required for cooking purposes. In view of the fact that the number of poultry farms in Dakhliya Governorate amounts to about 2600 farms, the remaining biogas production, from cooking needs will exceed all the needs of these farms for lighting, (12 hours/day), which amounts to some 48 million m<sup>3</sup> of biogas per year. The remaining biogas from these needs amounts to about 5.7x10<sup>8</sup> m<sup>3</sup> of gas fuel per year, which could be utilized for electricity generation to about 1.14x10<sup>10</sup> KW.

On general economic scale, the importance of digested sludge as a supplementary source of fertilizer is generally gaining widespread recognition. As the population continued to grow, there is a natural corresponding increase in the demand for food and energy. In order to increase food-crop production, greater amounts of fertilizer must be employed. Consequently in Dakhliya Governorate, the consumption of chemical fertilizers have been steadily expanding over the past decade. According to the undertaken study, the sludge produced from biofermentation will satisfy the needs of Dakhliya Governorate from chemical fertilizers with an excess value of 134%, 367% and 195% from nitrogen, phosphorus and potassium fertilizers respectively.

In any comparison between biogas technology and traditional

nitrogen, phosphorus and potassium fertilizers respectively.

In any comparison between biogas technology and traditional approaches to the provision of energy and fertilizer, due consideration should be given to the fact that the continuation or expansion of the latter would surely magnify the ecological damage that has already been done and accelerate the depletion of natural resources required for the future. Thus, the question is: Which alternatives are likely to contribute the most to the preservation of natural resources in a measure comparable to that offered by biogas technology?

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Table (1): Animals distribution at different centers in Dakhliya Governorate (Agricultural ministry, Dakhliya Dept. 1992).

Center	Cows	Dairy cattle	Buffaloes	Sheeps	Goats
Al-Mansoura	3540	1804	18712	29119	3519
Aga	4803	4197	17611	11630	3399
Mit-Ghamr	20998	98	34169	16264	14513
Senbilawin	6244	538	14303	12689	4582
Temi-Al-Amidid	4698	zero	15600	6283	2865
Mit-Sewed	7443	822	8547	2813	478
Oikerns	10632	zero	11809	5723	1677
Menit El-Nasr	46125	zero	20170	19505	6251
Manzala	11348	572	19046	2872	665
Talkha	9496	1833	10540	10748	1849
Shirbin	9889	139	7026	11153	5410
Belkas	32113	zero	35832	17108	4060

Table (2): Annual manure nutrient content of cow and chicken excrements [5].

Substrate from	Nutrient ratio ( $P_2O_5=1$ )						
	$P_2O_5$		$K_2O$		N	$P_2O_5$	$K_2O$
	Kg/a	%	Kg/a	%			
Cow	34	0.2	54	0.5	2.3	1	2.5
Chicken (fresh dropping)	194	1.0	108	0.6	1.2	1	0.6
Chicken (dry dropping)	193	4.6	106	2.5	0.8	1	0.6

Table (3): Potential gas generation values [5,7]

Substrate from	Live weight (Kg)	Daily dung yield (Kg)	Daily urine yield (Kg)	Biogas produc. per animal and day (l)
1 Cow	200	10	7	360
1 Buffalo	300	15	10	540
1 Chicken	2	0.18	---	8
1 Adult person	60	0.40	1.0	28

Table (4): Solid waste produced in Dakhlia Governorate with the equivalent gas production.

Substrate from	Manure production (Kg/day)	Gas production (m <sup>3</sup> /day)
Cows and dairy cattles	1809320	65135.52
Buffaloes	3200475	115217.10
Sheeps	271794	13589.70
Goats	98536	4926.80
Chickens	7384895.8	3282175.90
Sewage sludge	1600000	112000.00
<b>Total</b>	<b>14365021</b>	<b>27813749.00</b>

\* Total net gas production = 60% of total gas production .....(8)  
 = 16688249 m<sup>3</sup>/day.

Table (5): Gas consumption and energy efficiency ratings of various gas appliances [5].

Appliance	Consumption kwh	Efficiency
Gas cooker	300-600 l/h	50-60 %
Gas lantern equiv. to 60 w bulb.	120-170 l/h	3-5 %
Refrigerator, 100 l, dep. on ambient temp.	30-75 l/h	2-3 %
Gas engine	0.5 m <sup>3</sup> /kwh <sub>mech</sub>	25-30 %
Burner, 10 kw	2.0 m <sup>3</sup> /h	80-90 %
Infrared heater 200 W	30 l/h	ca.100 %
Cogeneration	0.5 m <sup>3</sup> /KWH <sub>el</sub> (producing 1 KW <sub>el</sub> + 2 KW <sub>th</sub> )	up to 90%

Table (6): Estimated fertilizing values from biofermentation of solid wastes in Dakhliya Governorate against the actual needs.

Substrate from	Total nitrogen (N <sub>tot</sub> ) ton/year	Phosphate (P <sub>2</sub> O <sub>5</sub> ) ton/year	Potash (K <sub>2</sub> O) ton/year
<b>Gows:</b>			
dung	2641.5	2245.5	5151.2
liquid manure	5613.3	2311.5	5613.3
<b>Buffaloes:</b>			
dung	4672.7	3893.8	9111.9
liquid manure	10124.0	4049.7	10124.0
<b>Sheeps and Goats:</b>			
dung	676.0	845.0	676.0
liquid manure	2027.6	1013.6	743.5
<b>Chickens:</b>			
dung	34442.5	26954.9	16472.5
Human	10512.0	9629.1	1266.6
<b>Total production</b>	<b>70709.6</b>	<b>50943.1</b>	<b>49159.0</b>
<b>Needed</b>	<b>30226.2</b>	<b>10897.4</b>	<b>16672.8</b>
<b>Surplus</b>	<b>40483.4</b>	<b>40045.7</b>	<b>32486.2</b>

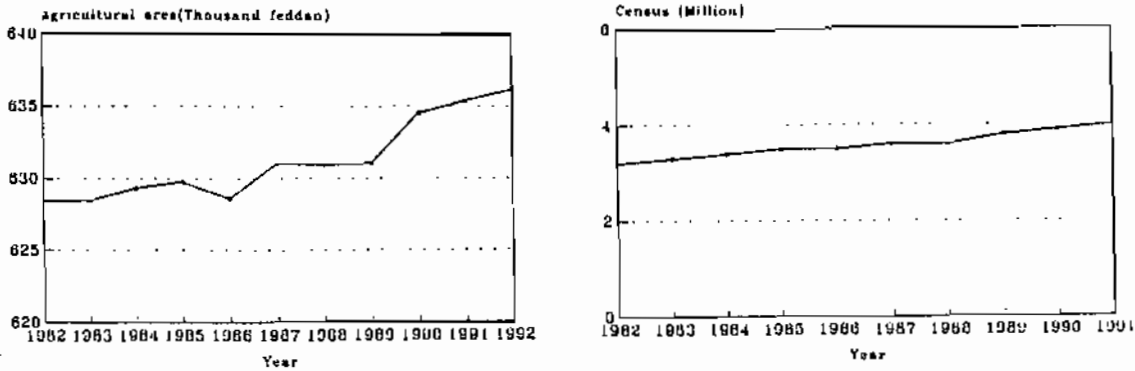
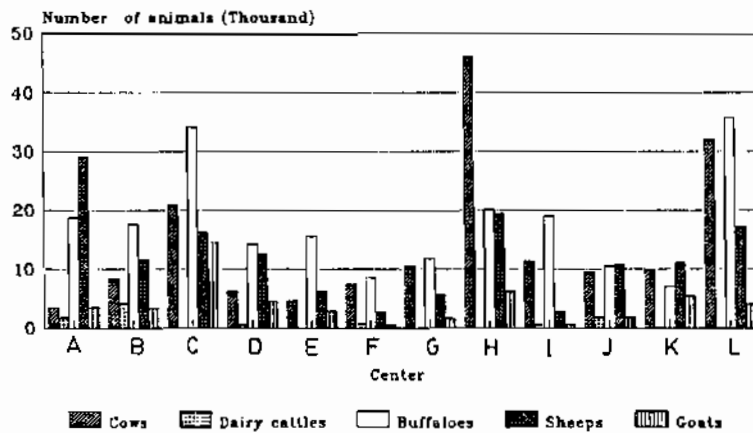


Figure (1): Census and agricultural lands in Dakahlia Governorate from 1982 to 1992. (Agric. Ministry Dept., Information Center, Dakahlia Governorate).



- A = Al-Mansoura                      B = Aga                                      C = Mis-Ghamr
- D = Senbilawin                      E = Temi-Al-Amdid                      F = Mit-Sewed
- G = Dikerns                              H = Menu El-Nasr                      I = Manzala
- J = Talkha                                  K = Shirbin                                  L = Belkas

Figure (2): Animals distribution at different centers in Dakahlia Governorate (Agric. Ministry Dept., Dakahlia Governorate).

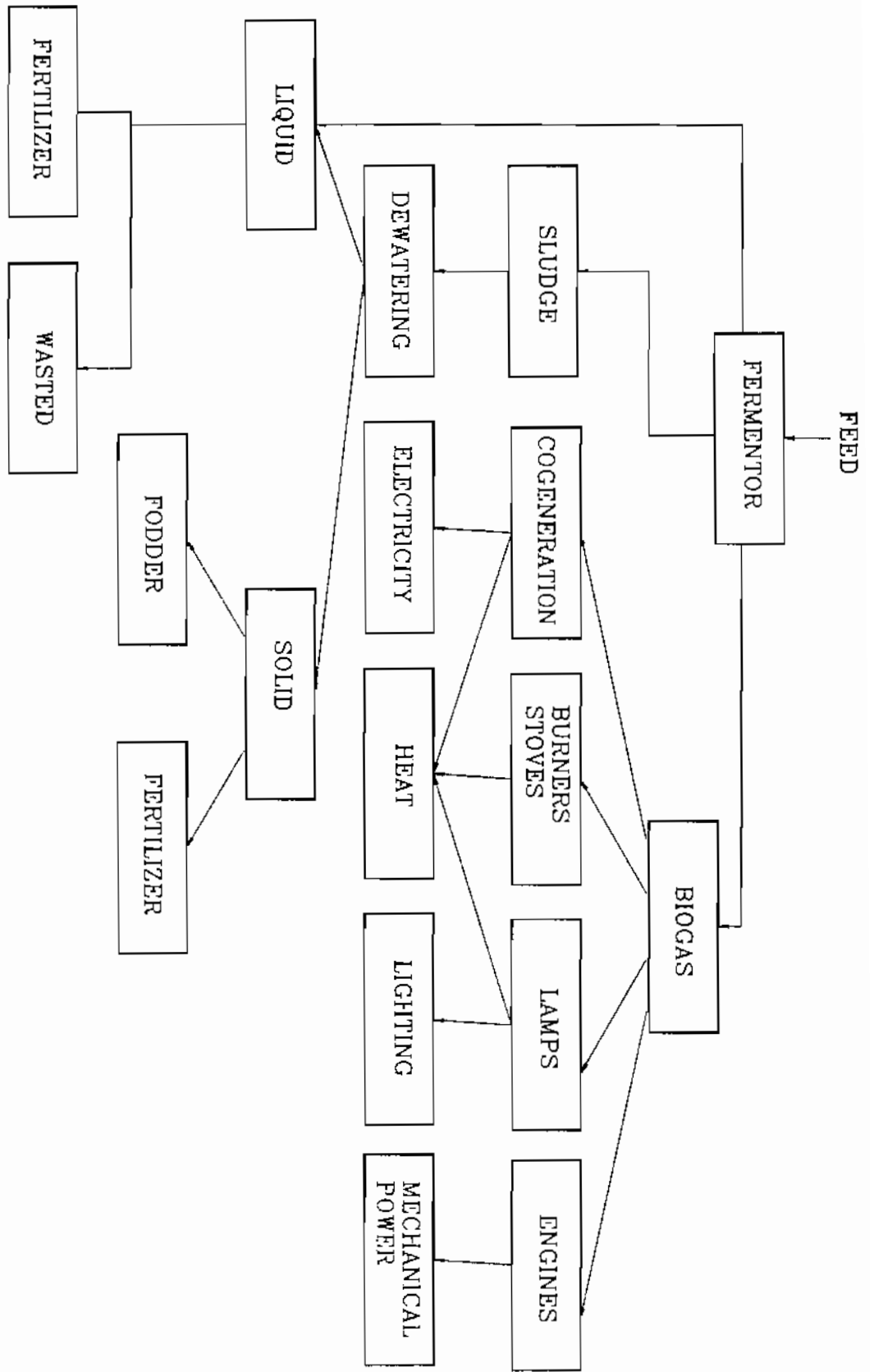


Figure (3): Different options of utilizing biofermentation effluents.



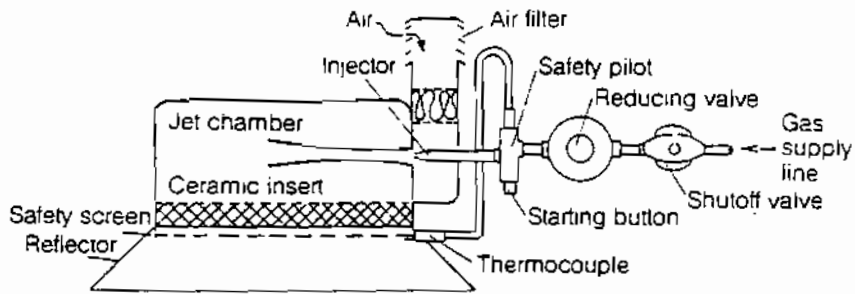


Figure (4): Sectional view of an infrared heater.

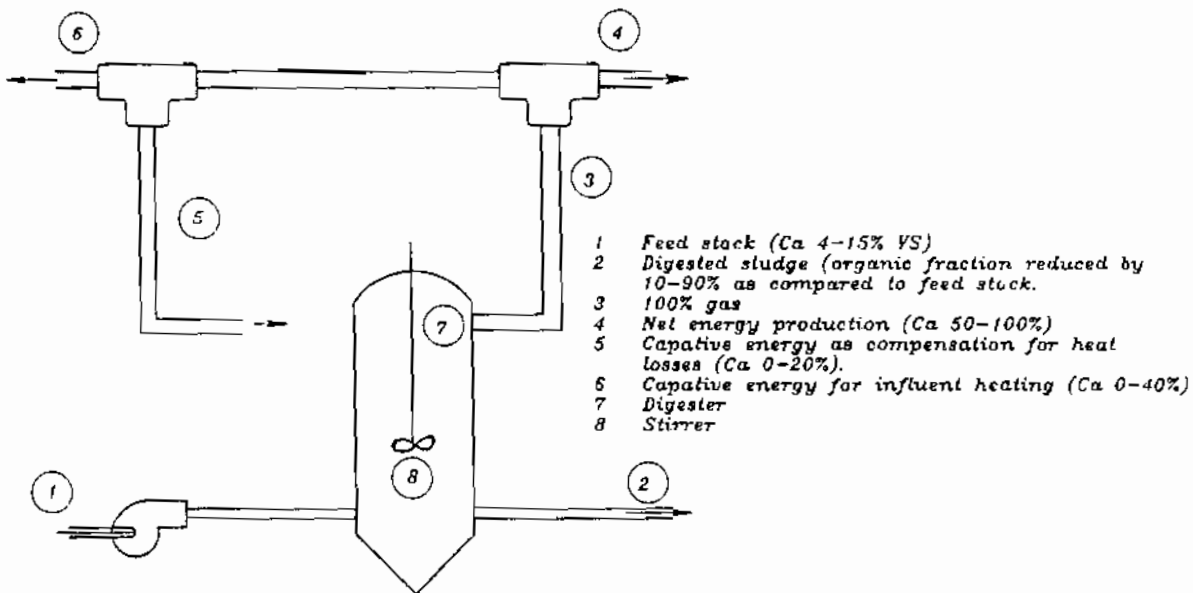


Figure (5): Flow of energy diagram in a biogas system.