A Project Report on

BIOGAS PRODUCTION FROM AGRICULTURAL AND OTHER WASTES AND ITS PURIFICATION

Submitted as a part of course work in
M. Tech (Gas Engineering)

By

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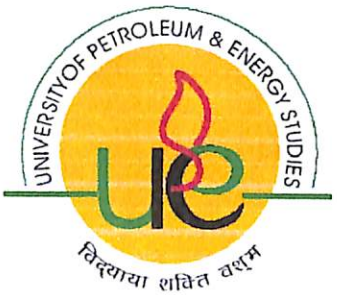

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CERTIFICATE

This is to certify that the project work entitled **"BIOGAS PRODUCTION FROM AGRICULTURAL AND OTHER WASTES AND ITS PURIFICATION"** being submitted by **Mr.Sunny Choraria.L**,in partial fulfillment of the requirement for the award of the degree of Master of Technology in Pipeline Engineering in University of Petroleum and Energy Studies-Rajahmundry, is bonafide project work carried out by him under my guidance.

Mr.A.Aravind Kumar, Assistant Professor fulfills all the requirements of the regulations laid down for the award of the degree of Master of Technology.

The content of this report has not been submitted to any university or institution by me or him for the award of any degree or diploma.

Place: Rajahmundry

Date:

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(Sunny choraria.L)

ABSTRACT

It's been a wild, exciting ride... but our blindly wasteful squandering of the planet's fossil fuels will soon be a thing of the past.

If we continue burning off petroleum at only this rate -- which isn't very likely since population is climbing and the big oil companies remain chained to "sell-more-tomorrow" economics -- experts predict the world will run out of refineable oil within (are you ready for this?) next 30 years.

So where does that leave us? Well, number one, we obviously must get serious about population control and per capita consumption of power and, number two, if we don't want to see brownouts and rationing of the power we do use, we'd better start looking around for ecologically-sound alternative sources of energy. And there are alternatives. One potent reservoir that's hardly been tapped is methane gas.

The various sources of biogas, the ways of production of biogas ,the purification process and calculation procedure is done in the following mini project.

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BIOGAS PRODUCTION FROM AGRICULTURAL AND OTHER WASTES AND ITS PURIFICATION

INTRODUCTION

What is biogas?

Biogas originates from bacteria in the process of bio-degradation of organic material under anaerobic (without air) conditions. The natural generation of biogas is an important part of the biogeochemical carbon cycle. Methanogens (methane producing bacteria) are the last link in a chain of micro-organisms which degrade organic material and return the decomposition products to the environment. In this process biogas is generated, a source of renewable energy.

Biogas and the global carbon cycle

Each year some 590-880 million tons of methane are released worldwide into the atmosphere through microbial activity. About 90% of the emitted methane derives from biogenic sources, i.e. from the decomposition of biomass. The remainder is of fossil origin (e.g. petrochemical processes). In the northern hemisphere, the present tropospheric

methane concentration amounts to about 1.65 ppm.

Biology of methanogenesis

Knowledge of the fundamental processes involved in methane fermentation is necessary for planning, building and operating biogas plants. Anaerobic fermentation involves the activities of three different bacterial communities. The process of biogas-production depends on various parameters. For example, changes in ambient temperature can have a negative effect on bacterial activity.

Substrate and material balance of biogas production

In principle, all organic materials can ferment or be digested. However, only homogenous and liquid substrates can be considered for simple biogas plants: faeces and urine from cattle, pigs and possibly from poultry and the wastewater from toilets. When the plant is filled, the

excrement has to be diluted with about the same quantity of liquid, if possible, the urine should be used. Waste and wastewater from food-processing industries are only suitable for simple plants if they are homogenous and in liquid form. The maximum of gas-production from a given amount of raw material depends on the type of substrate.

Composition and properties of biogas

Biogas is a mixture of gases that is composed chiefly of:

Methane, CH_4	40 - 70 vol. %
Carbon dioxide, CO_2	30-60 vol. %
Other gases	1 - 5 vol.%, including
Hydrogen H_2	0-1 vol. %
Hydrogen sulfide, H_2S	0-3 vol. %

Like those of any pure gas, the **characteristic properties** of biogas are pressure and temperature-dependent. They are also affected by the moisture content. The factors of main interest are:

· change in volume as a function of temperature and pressure,

· change in calorific value as a function of temperature, pressure and water-vapor content, and

· change in water-vapor content as a function of temperature and pressure

The **calorific value** of biogas is about 6 kWh/m3 - this corresponds to about half a litre of diesel oil. The net calorific value depends on the efficiency of the burners or appliances. Methane is the valuable component under the aspect of using biogas as a fuel.

Utilization

The history of biogas utilization shows independent developments in various developing and industrialized countries. The European biogas-history and that of Germany in particular, as well as developments in Asian countries form the background of German efforts and programmes to promote biogas technology worldwide. Normally, the biogas produced by a digester can be used as it is, just in the same way as any other combustible gas. But it is possible that a further treatment or conditioning is necessary, for example, to reduce the hydrogen-sulfide content in the

gas. When biogas is mixed with air at a ratio of 1:20, a highly explosive gas forms. Leaking gas pipes in enclosed spaces constitute, therefore, a hazard. However, there have been no reports of dangerous explosions caused by biogas so far. A first overview of the physical appearance of different types of biogas plants describes the three main types of simple biogas plants, namely balloon plants, fixed-dome plants and floating-drum plants.

The Benefits of Biogas Technology

Well-functioning biogas systems can yield a whole range of benefits for their users, the society and the environment in general:

· production of energy (heat, light, electricity) ;

· transformation of organic waste into high quality fertilizer;

· improvement of hygienic conditions through reduction of pathogens, worm eggs and flies;

· reduction of workload, mainly for women, in firewood collection and cooking.

· environmental advantages through protection of soil, water, air and woody vegetation;

· micro-economical benefits through energy and fertilizer substitution, additional income sources and increasing yields of animal husbandry and agriculture;

· macro-economical benefits through decentralized energy generation, import substitution and environmental protection

Thus, biogas technology can substancially contribute to conservation and development, if the concrete conditions are favorable. However, the required high investment capital and other limitations of biogas technology should be thoroughly considered.

The Costs of Biogas Technology

An obvious obstacle to the large-scale introduction of biogas technology is the fact that the poorer strata of rural populations often cannot afford the investment cost for a biogas plant.This is despite the fact that biogas systems have proven economically viable investments in many

cases. Efforts have to be made to reduce construction cost but also to develop credit and other financing systems. A larger numbers of biogas operators ensures that, apart from the privateuser, the society as a whole can benefit from biogas. Financial support from the government can be seen as an investment to reduce future costs, incurred through the importation ofpetrol products and inorganic fertilizers, through increasing costs for health and hygiene andthrough natural resource degradation.

Fuel and Fertilizer

In developing countries, there is a direct link between the problem of fertilization and progressive deforestation due to high demand for firewood. In many rural areas, most of theinhabitants are dependant on dung and organic residue as fuel for cooking and heating.Such is the case, for example, in the treeless regions of India (Ganges plains, centralhighlands), Nepal and other countries of Asia, as well as in the Andes Mountains of South America and wide expanses of the African Continent. According to data published by the FAO, some 78 million tons of cow dung and 39 million tons of phytogenic waste were burnedin India alone in 1970. That amounts to approximately 35% of India's totalnoncommercial/nonconventional energy consumption. The burning of dung and plant residue is a considerable waste of plant nutrients. Farmers in developing countries are in dire need of fertilizer for maintaining cropland productivity. Nonetheless, many small farmers continue to burn potentially valuable fertilizers, even though they cannot afford to buy chemical fertilizers. At the same time, the amount of technically available nitrogen, pottasium and phosphorous in the form of organic materials is around eight times as high as the quantity of chemical fertilizers actually consumed in developing countries. Especially for small farmers, biogas technology is a suitable tool for making maximum use of scarce resources: After extraction of the energy content of dung and other organic waste material, the resulting sludge is still a good fertilizer, supporting general soil quality as well as higher crop yields.

Public and Political Awareness

Popularization of biogas technology has to go hand in hand with the actual construction of plants in the field. Without the public awareness of biogas technology, its benefits and pitfalls, there will be no sufficient basis to disseminate biogas technology at grassroots level. At the same time,

awareness within the government is essential. Since impacts and aspects of biogas technology concern so many different governmental institutions (e.g. agriculture,environment, energy, economics), it is necessary to identify and include all responsible government departments in the dissemination and awareness-raising process.

HISTORY

Europe/Germany

1770 The Italian Volta collected marsh gas and investigated its burning behavior.

1821 Avogadro identified methane (CH4).

1875 Propoff states that biogas is produced under anaerobic conditions.

1884 Pasteur researched on biogas from animal residues. He proposed the utilization of horse litter to produce biogas for street-lighting.

1906 First anaerobic wastewater-treatment plant in Germany.

1913 First anaerobic digester with heating facility.

1920 First German sewage plant to feed the collected biogas into the public gas supply system.

1940 Addition of organic residues (fat) to increase sewage gas production.

1947 Research demonstrates that the dung of one cow can give a hundred times more gas than the feces of one urban inhabitant.

Establishment of the first working group on biogas in Germany.

1950 Installation of the first larger agricultural biogas plant.

1950s Nearly 50 biogas plants are built, fed by litter mixed with water and dung. Low oil prices and technical problems lead to the shutdown of all but two plants.

1974 After the first 'energy crisis', increased promotion of research on and implementation of agricultural biogas technology by the EC and federal departments.

1985 75 biogas plants are listed (built or planned). Biogas slurry is increasingly used asli quid manure.

1990 Progress due to guaranteed prices for biogas-generated electricity. Progress in optimizing the mixture of substrates, the use of biogas for different purposes and technology details.

1992 Foundation of the German biogas association 'Fachverband Biogas'

1997 More than 400 agricultural biogas plants exist in Germany.

China and India

The history of biogas exploration and utilization in China covers a period of more than 50 years. First biogas plants were build in the 1940s by prosperous families. Since the 1970s biogas research and technology were developed at a high speed and biogas technology waspromoted vigorously by the Chinese government. In rural areas, more than 5 million smallbiogas digesters have been constructed and,currently, over 20 million persons use biogas currently as a fuel. In India, the development of simple biogas plants for rural households started in the 1950s. A massive increase in the number of biogas plants took place in the 1970s through strong government backing. Meanwhile, more than one million biogas plants exist in India. The historical experiences in Germany, China and India demonstrate clearly, how biogasdevelopment responds to favorable frame conditions. In Germany, biogas dissemination gained momentum through the need for alternative energy sources in a war-torn economy and during an energy crisis or later by the change of electricity pricing. In India and China it was a strong government program that furthered the mass dissemination of biogas technology.

MICROBIOLOGY

The three steps of biogas production

Biogas microbes consist of a large group of complex and differently acting microbe species, notable the methane-producing bacteria. The whole biogas-process can be devided into three steps: hydrolysis, acidification, and methane formation (Figure 2). Three types of bacteria are involved.

Hydrolysis

In the first step (hydrolisis), the organic matter is enzymolyzed externally by extracellular enzymes (cellulase, amylase, protease and lipase) of microorganisms. Bacteria decompose the long chains of the complex carbohydrates, proteins and lipids into shorter parts. For example, polysaccharides are converted into monosaccharides. Proteins are split into peptides and amino acids.

Acidification

Acid-producing bacteria, involved in the second step, convert the intermediates of fermenting bacteria into acetic acid (CH3COOH), hydrogen (H2) and carbon dioxide (CO2). These bacteria are facultatively anaerobic and can grow under acid conditions. To produce acetic acid, they need oxygen and carbon. For this, they use the oxygen solved in the solution or bounded-oxygen. Hereby, the acid-producing bacteria create an anaerobic condition which is essential for the methane producing microorganisms. Moreover, they reduce the compounds with a low molecular weight into alcohols, organic acids, amino acids, carbon dioxide, hydrogen sulphide and traces of methane. From a chemical standpoint, this process is partially endergonic (i.e. only possible with energy input), since bacteria alone are notcapable of sustaining that type of reaction. Acid-producing bacteria, involved in the second step, convert the intermediates of fermenting bacteria into acetic acid (CH3COOH), hydrogen (H2) and carbon dioxide (CO2). Thesebacteria are facultatively anaerobic and can grow under acid conditions. To produce acetic acid, they need oxygen and carbon. For this, they use the oxygen solved in the solution or bound oxygen. Hereby, the acid-producing bacteria create an anaerobic condition which is essential for the methane producing microorganisms. Moreover, they reduce the compoundswith a low

molecular weight into alcohols, organic acids, amino acids, carbon dioxide, hydrogen sulphide and traces of methane. From a chemical standpoint, this process ispartially endergonic (i.e. only possible with energy input), since bacteria alone are not capable of sustaining that type of reaction.

Methane formation

Methane-producing bacteria, involved in the third step, decompose compounds with a low molecular weight. For example, they utilize hydrogen, carbon dioxide and acetic acid to form methane and carbon dioxide. Under natural conditions, methane producing microorganisms occur to the extent that anaerobic conditions are provided, e.g. under water (for exemple in marine sediments), in ruminant stomaches and in marshes. They are obligatory anaerobic and very sensitive to environmental changes. In contrast to the acidogenic and acetogenic bacteria, the methanogenic bacteria belong to the archaebacter genus, i.e. to a group of bacteria with a very heterogeneous morphology and a number of common biochemical and molecular- iological properties that distinguish them from all other bacterial general. The main difference lies in the makeup of the bacteria's cell walls.

Symbiosis of bacteria

Methane- and acid-producing bacteria act in a symbiotical way. On the one hand, acidproducing bacteria create an atmosphere with ideal parameters for methane-producing bacteria (anaerobic conditions, compounds with a low molecular weight). On the other hand, methane-producing microorganisms use the intermediates of the acid-producing bacteria. Without consuming them, toxic conditions for the acid-producing microorganisms would develop.In practical fermentation processes the metabolic actions of various bacteria all act in concert. No single bacteria is able to produce fermentation products alone.

Parameters and process optimisation

The metabolic activity involved in microbiological methanation is dependent on the following factors:

· Substrate temperature

· Available nutrients

· Retention time (flow-through time)

· pH level

· Nitrogen inhibition and C/N ratio

· Substrat solid content and agitation

· Inhibitory factors

Each of the various types of bacteria responsible for the three stages of the methanogenesis is affected differently by the above parameters. Since interactive effects between the various determining factors exist, no precise quantitative data on gas production as a function of the above factors are available. Thus, discussion of the various factors is limited to their qualitative effects on the process of fermentation.

Substrate temperature

Temperature range of anaerobic fermentation

Anaerobic fermentation is in principle possible between 3°C and approximately 70°C.

Differentiation is generally made between three temperature ranges:

· The psychrophilic temperature range lies below 20°C,

· the mesophilic temperature range between 20°C and 40°C and

· the thermophilic temperature range above 40°C.

Minimal average temperature

The rate of bacteriological methane production increases with temperature. Since, however, the amount of free ammonia also increases with temperature, the bio-digestive performance could be inhibited or even reduced as a result. In general, unheated biogas plants perform satisfactory only

where mean annual temperatures are around 20°C or above or where the average daily temperature is at least 18°C. Within the range of 20-28°C mean temperature,gas production increases over-proportionally. If the temperature of the bio-mass is below 5°C, gas production will be so low that the biogas plant is no longer economically feasible.

Changes in temperature

The process of bio-methanation is very sensitive to changes in temperature. The degree of sensitivity, in turn, is dependent on the temperature range. Brief fluctuations not exceeding the following limits may be regarded as still un-inhibitory with respect to the process of fermentation:

· psychrophilic range: ± 2°C/h

· mesophilic range: ± 1°C/h

· thermophilic range: ± 0,5°C/h

The temperature fluctuations between day and night are no great problem for plants built underground, since the temperature of the earth below a depth of one meter is practically constant.

Available nutrient

In order to grow, bacteria need more than just a supply of organic substances as a source of carbon and energy. They also require certain mineral nutrients. In addition to carbon, oxygen and hydrogen, the generation of bio-mass requires an adequate supply of nitrogen, sulfur, phosphorous, potassium, calcium, magnesium and a number of trace elements such as iron, manganese, molybdenum, zinc, cobalt, selenium, tungsten, nickel etc. "Normal" substrates such as agricultural residues or municipal sewage usually contain adequate amounts of the mentioned elements. Higher concentration of any individual substance usually has an inhibitory effect, so that analyses are recommended on a case-to-case basis to determine which amount of which nutrients, if any, still needs to be added.

Retention time

Batch-type and continuous plants

The retention time can only be accurately defined in batch-type facilities. For continuous systems, the mean retention time is approximated by dividing the digester volume by the daily influent rate. Depending on the vessel geometry, the means of mixing, etc., the effective retention time may vary widely for the individual substrate constituents. Selection of a suitable retention time thus depends not only on the process temperature, but also on the type of substrate used.

Cost efficiency

Optimizing the process parameters retention time - process temperature - substrate quality - volumetric load determine, among others, the cost efficiency of the biological processes. But as each m3 digester volume has its price, heating equipment can be costly and high quality substrates may have alternative uses, the cost-benefit optimum in biogas production is almost always below the biological optimum.

Substrate

For liquid manure undergoing fermentation in the mesophilic temperature range, the following approximate values apply:

· liquid cow manure: 20-30 days

· liquid pig manure: 15-25 days

· liquid chicken manure: 20-40 days

· animal manure mixed with plant material: 50-80 days

If the retention time is too short, the bacteria in the digester are "washed out" faster than they can reproduce, so that the fermentation practically comes to a standstill. This problem rarely occurs in agricultural biogas systems.

pH value

The methane-producing bacteria live best under neutral to slightly alkaline conditions. Once the process of fermentation has stabilized under anaerobic conditions, the pH will normally take on a value of between 7 and 8.5. Due to the buffer effect of carbon dioxide-bicarbonate (CO2 - HCO3-) and ammonia-ammonium (NH3 - NH4+), the pH level is rarely taken as a measure of substrate acids and/or potential biogas yield. A digester containing a highvolatile-acid concentration requires a somewhat higher-than-normal pH value. If the pH value drops below 6.2, the medium will have a toxic effect on the methanogenic bacteria.

pH	7-7.2	Optimum
pH	<6.2	Acid Inhibition
pH	>7.6	Ammonia Inhibition

Nitrogen inhibition and C/N ratio

Nitrogen inhibition

All substrates contain nitrogen. Tabelle 1 lists the nitrogen content of various organic substances and the C/N ratio. For higher pH values, even a relatively low nitrogenconcentration may inhibit the process of fermentation. Noticeable inhibition occurs at a nitrogen concentration of roughly 1700 mg ammonium-nitrogen (NH4-N) per liter substrate. Nonetheless, given enough time, the methanogens are capable of adapting to NH4-N concentrations in the range of 5000-7000 mg/l substrate, the main prerequisite being that the ammonia level (NH3) does not exceed 200-300 mg NH3-N per liter substrate. The rate of ammonia dissociation in water depends on the process temperature and ph value of the substrate slurry.

C/N ratio

Microorganisms need both nitrogen and carbon for assimilation into their cell structures. Various experiments have shown that the metabolic activity of methanogenic bacteria can be optimized at a C/N ratio of approximately 8-20, whereby the optimum point varies from case to case, depending on the nature of the substrate.

Substrate solids content and agitation

Substrate solids content

The mobility of the methanogens within the substrate is gradually impaired by an increasing solids content, and the biogas yield may suffer as a result. However, reports of relatively high biogas yields from landfill material with a high solids content may be found in recent literature. No generally valid guidelines can be offered with regard to specific biogas production for any particular solids percentage.

Agitation

Many substrates and various modes of fermentation require some sort of substrate agitation or mixing in order to maintain process stability within the digester. The most important objectives of agitation are:

· removal of the metabolites produced by the methanogens (gas)

· mixing of fresh substrate and bacterial population (inoculation)

· preclusion of scum formation and sedimentation

· avoidance of pronounced temperature gradients within the digester

· provision of a uniform bacterial population density

· prevention of the formation of dead spaces that would reduce the effective digester volume.

In selecting or designing a suitable means of agitation, the following points should be considered:

1. The process involves a symbiotic relationship between various strains of bacteria, i.e. the metabolite from one species can serve as nutrient for the next species, etc. Whenever the bacterial community is disrupted, the process of fermentation will remain more or less unproductive until an equivalent new community is formed. Consequently, excessive or too frequent mixing is usually detrimental to the process.Slow stirring is better than rapid agitation.

2. A thin layer of scum must not necessarily have an adverse effect on the process. Forsystems in which the digester is completely filled with substrate, so that any scum always remains sufficiently wet, there is little or no danger that the extraction of gascould be impeded by the scum.

3. Some types of biogas systems can function well without any mechanical agitation at all. Such systems are usually operated either on substrates with such a high solid content, that no stratification occurs, or on substrates consisting primarily of solute substances. Since the results of agitation and mixing are highly dependent on the substrate in use, it is not possible to achieve a sufficiently uniform comparative evaluation of various mixing systems and/or intensity levels. Thus, each such system can only be designed on the basis of empirical data.

Inhibitory factors

The presence of heavy metals, antibiotics (Bacitracin, Flavomycin, Lasalocid, Monensin, Spiramycin, etc.) and detergents used in livestock husbandry can have an inhibitory effect on the process of bio-methanation. The following table lists the limit concentrations (mg/l) for various inhibitors.

SUBSTANCE	DISRUPTIVE EFFECTS BEGINNING (mg/l)
Copper	10-250
Calcium	8000
Magnesium	3000
Zinc	200-1000
Nickel	350-1000

The Physical Appearance of Different Types of Biogas Plants

The three main types of simple biogas plants are shown in Figure 4:

· balloon plants

· fixed-dome plants

· floating-drum plants

More information about the different types of biogas plants is provided under digester types.

Balloon plants

The balloon plant consists of a digester bag (e.g. PVC) in the upper part of which the gas is stored. The inlet and outlet are attached directly to the plastic skin of the balloon. The gas pressure is achieved through the elasticity of the balloon and by added weights placed on the balloon.

Advantages are low cost, ease of transportation, low construction sophistication, high digester temperatures, uncomplicated cleaning, emptying and maintenance.

Disadvantages can be the relatively short life span, high susceptibility to damage, little creation of local employment and, therefore, limited self-help potential. A variation of the balloon plant is the **channel-type digester**, which is usually covered with plastic sheeting and a sunshade . Balloon plants can be recommended wherever the balloon skin is not likely to be damaged and where the temperature is even and high.

Fixed-dome plants

The fixed-dome plant consists of a digester with a fixed, non-movable gas holder, which sits on top of the digester. When gas production starts, the slurry is displaced into the compensation tank. Gas pressure increases with the volume of gas stored and the height difference between the slurry level in the digester and the slurry level in the compensation tank.

Advantages are the relatively low construction costs, the absence of moving parts and rusting steel parts. If well constructed, fixed dome plants have a long life span. The underground construction saves space and protects the digester from temperature changes. The construction provides opportunities for skilled local employment.

Disadvantages are mainly the frequent problems with the gas-tightness of the brickwork gasholder (a small crack in the upper brickwork can cause heavy losses of biogas). Fixed-dome plants are, therefore, recommended only where construction can be supervised by experienced biogas technicians. The gas pressure fluctuates substantially depending on the volume of the

stored gas. Even though the underground construction buffers temperature extremes, digester temperatures are generally low.

Floating-drum plants

Floating-drum plants consist of an underground digester and a moving gas-holder. The gasholder floats either directly on the fermentation slurry or in a water jacket of its own. The gas is collected in the gas drum, which rises or moves down, according to the amount of gas stored. The gas drum is prevented from tilting by a guiding frame. If the drum floats in a water jacket, it cannot get stuck, even in substrate with high solid content.

Advantages are the simple, easily understood operation - the volume of stored gas is directly visible. The gas pressure is constant, determined by the weight of the gas holder. The construction is relatively easy, construction mistakes do not lead to major problems inoperation and gas yield.

Disadvantages are high material costs of the steel drum, the susceptibility of steel parts to corrosion. Because of this, floating drum plants have a shorter life span than fixed-dome plants and regular maintenance costs for the painting of the drum.

Suitability of climatic zones

Tropical Rain Forest: annual rainfall above 1.500 mm, mean temperatures between 24 and 28°C with little seasonal variation. Climatically very suitable for biogas production. Often animal husbandry is hampered by diseases like trypanosomiasis, leading to the virtual absence of substrate.

Tropical Highlands: rainfall between 1.000 and 2.000 mm, mean temperatures between 18 and 25°C (according to elevation). Climatically suitable, often agricultural systems highly suitable for biogas production (mixed farming, zero-grazing).

Wet Savanna: rainfall between 800 and 1.500 mm, moderate seasonal changes in temperature. Mixed farming with night stables and day grazing favor biogas dissemination.

Dry Savanna: Seasonal water scarcity, seasonal changes in temperatures. Pastoral systems of animal husbandry, therefore little availability of dung. Use of biogas possible near permanent water sources or on irrigated, integrated farms.

Thornbush Steppe and Desert: Permanent scarcity of water. Considerable seasonalvariations in temperature. Extremely mobile forms of animal keeping (nomadism). Unsuitable for biogas dissemination.

Reduction of the greenhouse effect

Last but not least, biogas technology takes part in the global struggle against the greenhouse effect. It reduces the release of CO2 from burning fossil fuels in two ways. First, biogas is a direct substitute for gas or coal for cooking, heating, electricity generation and lighting. Additionally, the reduction in the consumption of artificial fertilizer avoids carbon dioxideemissions that would otherwise come from the fertilizer producing industries. By helping tocounter deforestation and degradation caused by overusing ecosystems as sources of firewood and by melioration of soil conditions biogas technology reduces CO2 releases from these processes and sustains the capability of forests and woodlands to act as a carbon sink. Methane, the main component of biogas is itself a greenhouse gas with a much higher"greenhouse potential" than CO2. Converting methane to carbon dioxide through combustion is another co ntribution of biogas technology to the mitigation of global warming. However, this holds true only for the case, that the material used for biogas generation would otherwise undergo anaerobic decomposition releasing methane to the atmosphere. Methane leaking from biogas plants without being burned contributes to the greenhouse effect! Of course, burning biogas also releases CO2. But this, similar to the sustainable use of firewood, doesonly return carbon dioxide which has been assimilated from the atmosphere by growing plants maybe one year before. There is no net intake of carbon dioxide in the atmosphere from biogas burning as it is the case when burning fossil fuels.

Sizing a biogas plant

The size of the biogas plant depends on the quantity, quality and kind of available biomass and on the digesting temperature. The following points should be considered

Sizing the digester

The size of the digester, i.e. the digester volume **Vd**, is determined on the basis of the chosen retention time **RT** and the daily substrate input quantity **Sd**.

Vd = **Sd** × **RT** [m3 = m3/day × number of days]

The retention time, in turn, is determined by the chosen/given digesting temperature. For an unheated biogas plant, the temperature prevailing in the digester can be assumed as 1-2 Kelvin above the soil temperature. Seasonal variation must be given due consideration, however, i.e. the digester must be sized for the least favorable season of the year. For a plant of simple design, the retention time should amount to at least 40 days. Practical experience shows that retention times of 60-80 days, or even 100 days or more, are no rarity when there is a shortage of substrate. On the other hand, extra-long retention times can increase the gas yield by as much as 40%. The substrate input depends on how much water has to be added to the substrate in order to arrive at a solids content of 4-8%.

Substrate input (**Sd**) = biomass (**B**) + water (**W**) [m3/d]

In most agricultural biogas plants, the mixing ratio for dung (cattle and / or pigs) and water (**B**:**W**) amounts to between 1:3 and 2:1.

Calculating the daily gas production G

The amount of biogas generated each day **G** [m3 gas/d], is calculated on the basis of the specific gas yield **Gy** of the substrate and the daily substrate input **Sd**. The calculation can be based on:

The volatile solids content **VS**

G = **VS** × **Gy**(solids) [m3/d = kg × m3/(d×kg)]

The weight of the moist mass **B**

G = **B** × **Gy**(moist mass) [m3/d = kg × m3/(d×kg)]

Standard gas-yield values per livestock unit **LSU**

G = number of **LSU** × **Gy**(species) [m3/d = *number*× m3/(d×*number*)]

The temperature dependency is given by:

Gy(T,RT) = mGy × f(T,RT)

where

Gy(T,RT) = *gas yield as a function of digester temperature and retention time*

mGy = *average specific gas yield*, e.g. l/kg volatile solids content

f(T,RT) = *multiplier for the gas yield as a function of digester temperature T and*

retention time RT

As a rule, it is advisable to calculate according to several different methods, since theavailable basic data are usually very imprecise, so that a higher degree of sizing certainty can be achieved by comparing and averaging the results.

Establishing the plant parameters

The degree of safe-sizing certainty can be increased by defining a number of plant parameters:

Specific gas production Gp

i.e. the daily gas generation rate per m3 digester volume **Vd**, is calculated according to the following equation

Gp = G ÷ Vd [(m3/d) / m3]

Digester loading Ld

The digester loading **Ld** is calculated from the daily total solids input **TS/d** or the daily volatile solids input **VS/d** and the digester volume **Vd**:

LdT = TS/d ÷ Vd [kg/(m3 d)]

LdV = VS/d ÷ Vd [kg/(m3 d)]

Then, a calculated parameter should be checked against data from comparable plants in the region or from pertinent literature.

Sizing the gasholder

The size of the gasholder, i.e. the gasholder volume **Vg**, depends on the relative rates of gas generation and gas consumption. The gasholder must be designed to:

· cover the peak consumption rate **gcmax** (->**Vg1**) and

· hold the gas produced during the longest zero-consumption period **tzmax** (->**Vg2**)

Vg1 = gcmax × tcmax = vcmax

Vg2 = Gh × tzmax

with

gcmax = *maximum hourly gas consumption* [m3/h]

tcmax = *time of maximum consumption* [h]

vcmax = *maximum gas consumption* [m3]

Gh = hourly gas production [m3/h] = **G** ÷ 24 h/d

tzmax = maximum zero-consumption time [h]

The larger **Vg**-value (**Vg1** or **Vg2**) determines the size of the gasholder. A safety margin of 10-20% should be added:

Vg = 1.15 (±0.5) × max(**Vg1**,**Vg2**)

Practical experience shows that 40-60% of the daily gas production normally has to be stored.

The ratio **Vd ÷ Vg** (digester volume ÷ gasholder volume) is a major factor with regard to the basic design of the biogas plant. For a typical agricultural biogas plant, the **Vd/Vg**-ratio amounts to somewhere between 3:1 and 10:1, with 5:1 - 6:1 occuring most frequently.

TABLE - GAS YIELD AND METHANE CONTENT FROM VARIOUS SOURCES

SUBSTRATE	GAS YIELD (L/Kg)	METHANE CONTENT (%)
Pig Manure	340-550	65-70
Cow Manure	90-310	65
Poultry Droppings	310-620	60
Horse Manure	200-300	60
Sheep Manure	90-310	
Bamyard Dung	175-280	
Wheat Straw	200-300	50-60
Rye Straw	200-300	59
Barley Straw	250-300	59
Oats Straw	290-310	59
Corn Straw	380-460	59
Rape Straw	200	
Rice Straw	170-280	
Rice seed coat	105	
Flax	360	59
Hemp	360	59
Grass	280-550	70
Elephant Grass	430-560	60
Cane Trash(Bagasse)	165	
Broom	405	
Reed	170	
Clover	430-490	
Vegetable Residue	330-360	
Potato tops/Greens	280-490	
Sugar Beet Greens	400-500	
Sunflower Leaves	300	59
Agricultural Wastes	310-430	60-70
Seeds	620	
Peanut Shells	365	
Fallen Leaves	210-290	58
Water Hyacinth	375	
Algae	420-500	63
Sewage Sludge	310-740	

REMOVAL OF HYDROGEN SULPHIDE FROM BIOGAS

Hydrogen sulphide is particularly harmful when biogas is used in internal combustion engines. Its chemical reactions and those of its combustion product - sulphur dioxide, quickly lead to severe corrosion and wear on engines.

Properties of hydrogen sulphide

Physical and chemical properties

Hydrogen sulphide (H2S) is a colourless, very poisonous gas. It is inflammable and forms explosive mixtures with air (oxygen). H2S has a characteristic smell of "rotten eggs". This odour is only apparent in a small concentration range (0.05-500 ppm).
H2S is soluble in water forming a weak acid. A combustion product of H2S is SO2. This makes the exhaust gases very corrosive (sulphuric acid) and contaminates the environment (acid rain).

Toxicity

H2S is very poisonous (comparable to hydrogen cyanide).

Lower toxic limit 10 ppm H2S.

Lethal dose

1.2-2.8 mg H2S per lifer of air or 0.1% kills instantly.
0.6 mg H2S per lifer of air or 0.05% kills within 30 minutes to one hour.

Effect

H2S changes the red blood pigment; the blood turns brown to olive in colour. The transport of oxygen is hindered. The person suffocates "internally". The symptoms are irritation of the mucous membranes (including the eyes), nausea, vomiting, difficulty in breathing, cyanosis (discoloration of the skin), delirium and cramps, then respiratory paralysis and cardiac arrest. At higher concentrations immediate respiratory paralysis and cardiac arrest are the only symptoms. Even if a person survives poisoning, longterm damage to the central nervous system and to the heart remains.

First aid

Fresh air, artificial respiration; warmth, rest, transportation in an inclined position. There is a danger of suffocation if the patient is unconscious!

Medical care

Artificial respiration. Analeptics. Further observation of symptoms, particularly the function of the circulatory and pulmonary systems. Beware of oedema of the larynx. Codeine may be administered for bronchitis as soon as the asphyctic stage is past. Oedema of the lungs during the latent period: treat prophylactically with high doses of prednisolone i.v. In addition, infusions of altogether 0.5 g THAM/kg. Absolute rest, warmth, infection prophylaxis, keep breathing passages free. Only small quantities of morphine. Combat anhydremia by peroral administration of fluids or rectoclysis.

Chronic effects

Long-term exposure to very small amounts of H2S can lead to chronic poisoning. Symtoms: irritation of the mucous membranes, sensitivity to light, bronchitis, headaches, weariness, circulatory disturbances and loss of weight.

The origins of hydrogen sulphide in biogas plants

Formation

Hydrogen sulphide is formed in the biogas plant by the transformation of sulphur-ontaining protein. This can be protein from plants and fodder residues. However, when animal and human faeces are used, bacteria excreted in the intestines is the main source of protein. Inorganic sulphur, particularly sulphates, can also be biochemically converted to H2s in the fermentation chamber.

Amounts

Plant material introduces little H2S into biogas. On the other hand, poultry droppings introduce, on average, up to 0.5 vol. % H2S, cattle and pig manure about 0.3 vol. % H2S.

Protein-rich waste (e.g. swill, molasses etc.) can produce large amounts of hydrogen sulphide (up to 3 vol. %). Inorganic sulphates (from salty, stall rinse water or diluting water) also produce considerable H2S.

The effect of hydrogen sulphide on the biogas plant and the gas-utilization equipment

Fermentation inhibition

Dissolved H2S is contained in the fermentation slurry. An equilibrium is set up between the dissolved H_2S and the H_2S in the gas phase. The dissolved H_2S in high concentrations can be toxic to the bacteria in the slurry. It can inhibit the production of biogas and cause its composition to alter.
Remedies - put less sulphur-rich material in the plant, dilute with water. In less serious cases stir vigorously (to drive H_2S out of the slurry).

Corrosion by H_2S

The presence of H_2S gas in biogas makes it corrosive to metal parts. Iron is subject to surface attack, although not major corrosion. Galvanized parts are similarly subject to surface corrosion. The effect on non-ferrous metals in components, such as pressure regulators, gas meters, valves and mountings, is much more serious. They are very quickly corroded. These materials also corrode in gas engines (seals and valves).

Corrosion by SO_2 from H_2S

The combustion product SO_2 combines with water vapour and badly corrodes the exhaust side of burners, gas lamps and engines. Burning biogas in stoves and boilers can also result in damage to the chimney.

Engines

The acid which is formed corrodes engine parts in the combustion chamber, exhaust system and in various bearings. This is enhanced by frequent starts, short running times and the relatively low temperatures when starting up and after cutting off the engine. The water cooling system also provides the means (water needed to form sulphuric acid) for corrosion.

Service life

Running engines with H_2S -containing gas can reduce the service time to the first general overhaul by about 10-15%.

Engine oil changes

The suphur content of biogas used in gas engines shortens the time between oil changes. SO_2 from combustion and water vapour both dissolve in the lubricating oil. The oil becomes acidic and its properties change. It loses its ability to lubricate and sometimes corrodes metal components. Under continuous operating conditions the interval between oil changes is reduced to 200 - 250 hours.

Cooking stoves

If biogas is burned for cooking and lighting in poorly ventilated rooms' the occupants

Determination of the hydrogen sulphide content of biogas

The H_2S content of the purified gas can be measured to check the effectivity of the desulphurization process.

Laboratory method

In the laboratory the H_2S content of gases is usually measured iodometrically using cadmium acetate. However, the necessary techniques are too involved for an application here.

Lead acetate method

A simple way of determining the presence of H_2S in biogas is a test with lead acetate paper. A piece of paper soaked with lead acetate solution is held in the gas stream for a short time. The presence of H_2S colours the strip black. The difficulty with this method is its high sensitivity which means that even a very small amount of H_2S can be detected. A small amount of H_2S, however, is not an indication of greatly reduced efficiency of the desulphurization. Simple desulphurization plants may still posses an adequate purifying performance.

Detection with iodine solution

Another simple method for detecting H_2S is with an alcoholic solution of iodine, such as often available in first aid kits. A small amount of biogas is carefully introduced into the iodine solution. If H_2S is present the reddish brown solution will decolour. The formation of elementary sulphur causes a milky turbidity.

The test-tube method

The test-tube method is a very exact and simple method of determining the H_2S concentration in biogas. Suitable tubes are available for measuring the concentration in both raw and purified gas. The gas detector apparatus (ca. 450,- DM) and the individual test tubes (ca. 5,- DM each) are relatively expensive. Also, the test tubes can only be preserved for a limited time. This method is only expedient in the regional biogas extension service or similar advisory services. This apparatus could then be used to provide empirical field values for individual plants. The intervals for recharging the purifying agent can then be laid down.

As yet there is no simple, cheap, test method available. For this reason a close control of the desulphurization plant is strongly recommended.

Methods for removing hydrogen sulphide from biogas

General

Of the many processes traditionally and presently employed, that have been used for large-scale desulphurization of technical gases, only the so-called "dry" process is suitable on a smaller scale for biogas plants. They are acceptable from the point of view of technical complexity and maintenance and the degree of purification is satisfactory.

The desulphurization of biogas is based on a chemical reaction of H_2S with a suitable substance.

The lime process

The oldest process is the desulphurization of gases with quick lime, slaked lime in solid form or with slaked lime in liquid form. The process using quick or slaked lime has not been applied on a

large scale for a long time. The large amounts of odourous residue that are produced cannot be satisfactorily disposed of. The handling of large amounts of dissolved or suspended slaked lime requires elaborate equipment.

Large concentrations of CO_2 which are present in biogas make the satisfactory removal of H_2S difficult. The CO_2 also reacts with the quick and slaked lime and uses it up quickly. The $Ca(HCO_3)_2$ formed reacts with $Ca(SH)_2$ which is formed by the reaction of H_2S with $Ca(OH)_2$ thus resulting in the reoccurance of H_2S. However, a large scale biogas plant in Germany with the cogeneration of heat and power has recently been constructed using a lime purifier. The results of long term tests are not yet available.
In as far as enough lump, quick lime is available in the countries concerned, this process could be considered for desulphurization. The apparatus for utilizing quick lime corresponds in construction and function to that used for the desulphurization with iron-containing substances.

Ferrous materials

Ferrous materials in the form of natural soils or certain iron ores are often employed to remove H_2S.

Principle

The ferrous material is placed in a closed, gas tight container (of steel, brickwork or concrete). The gas to be purified flows through the ferrous absorbing agent from the bottom and leaves the container at the top, freed from H_2S.

Chemistry

The absorbing material must contain iron in the form of oxides, hydrated oxides or hydroxides. These react as follows:

$2\ Fe(OH)_3 + 3\ H_2S$ à $Fe_2S_3 + 6\ H_2O$ $Fe(OH)_2 + H_2S$ à $FeS + 2H_2O$

This process terminates, of course, after some time. The greater part of the iron is then present as a sulphide.

Regeneration

However, by treating the sulphidized absorbent with atmospheric oxygen, the iron can be returned to the active oxide form required for the purification of the gas:

$2\ Fe_2S_3 + 3\ O_2 + 6\ H_2O$ à $4\ Fe(OH)_3 + 3\ S_2$

$2\ FeS + O_2 + 2\ H_2O$ à $2\ Fe(OH)_2 + S_2$

The used absorbent can, therefore, be "regenerated". This regeneration cannot be repeated indefinitely. After a certain time the absorbent becomes coated with elementary sulphur and its pores become clogged. Purifying absorbents in gasworks (coke plants) acquire a sulphur content of up to 25% of their original weight, i.e. 40% sulphur by dry weight.

Process techniques

There are three different, dry desulphurizing processes available.

Without regeneration

The purification chamber consists of a box or drum. The absorbent is placed inside it on several, intermediate trays (sieve floors) to ensure that the depth of the absorbent is not more than 20-30 cm. Otherwise the absorbent would easily press together causing an increase in the resistance to the gas flow.

The biogas is fed in at the bottom of the box, flows through the absorbent and leaves the purification chamber at the top, freed from H_2S. When the absorbent becomes loaded with iron sulphides, the gas leaving the chamber contains increasingly more H_2S. The chamber is then opened at the top and the trays with the spent absorbent are removed. Then fresh absorbent is placed on the trays.

After the air in the purification chamber has again been displaced with biogas, the gas connection to the user is re-opened.

The spent absorbent is disposed of as described under the heading "Disposal of spent absorbent".

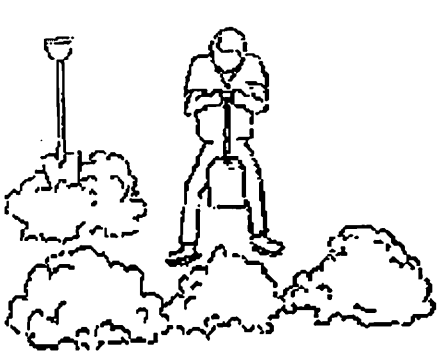
With regeneration

The spent, sulphide containing absorbent can also be regenerated by exposing it to oxygen. This can either be done by taking the used absorbent out of the chamber and exposing it to the air, or inside the purification chamber by simply sucking ambient air through it.
Since regeneration inside the chamber requires precautions against the formation of unwanted and dangerous air-gas mixtures and would require powerful fans, regeneration outside the chamber is usually preferred. The absorbent that is to be regenerated, is spread out on the ground in as thin a layer as possible. From time to time it is turned over with a shovel. After a few days it is ready for use again.
This regeneration process can be repeated up to ten times, after which the absorbent is finally spent.

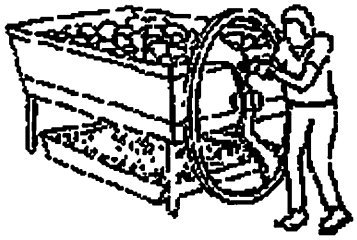
Simultaneous regeneration and loading

Simultaneous regeneration and loading of the absorbent is a special case. Here a certain, small amount of air is added to the biogas. Then sulphide formation and regeneration occur at the same time and place. As such, the absorbent acts effectively as a catalyst.
Expensive gas-measuring and mixing equipment is required for this process, however, so that it is not suitable for small biogas plants.

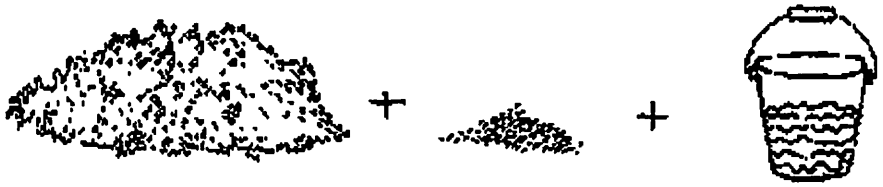
Preparation of the absorbent



Break up the lumps of soil



Grind the small pieces



55–70% finely ground soil

10–15% sawdust, peat, etc.

20–30% water

Mix the fine soil with the filler and the water

The desulphurizing apparatus

The absorbent described above must be brought into immediate contact with the gas. This takes place in closed purification chambers. They can be made of steel, gas-tight brickwork or concrete.

Size of the chamber

The area perpendicular to the gas-flow or cross section of the chamber is important. If it is too small, the gas will flow too quickly through the absorbent and the contact time is too short. If the gas flow is too fast channels will open in the absorbent. The gas then flows through these channels and is not properly purified.

The volume (if the cross section is fixed then the height) of the chamber is also important. The chamber must contain enough absorbent for the gas to be in contact with the absorbent over a sufficient distance. Apart from this the purification chamber must be large enough so that it does not constantly need to be refilled.

Dimensioning method

A method for calculating the required size of purification chambers is included at the end of this manual.

Intermediate trays

The purification chamber contains several intermediate trays. A layer of absorbent cat 20-30 cm thick is placed on each tray. This avoids compacting of the absorbent under its own weight.

The intermediate tray floors are permeable to the biogas. They are made from perforated steel sheet or wooden slats. Wickerwork can also be used.

The individual, intermediate trays do not rest upon the absorbent in the tray below, but are supported by small spacers attached to the tray underneath. The layers of absorbent that lie between should not be compacted.

Inserting absorbent

The absorbent should be placed on the trays in such a way that it is not compressed or packed down. It should be piled up higher at the chamber walls to avoid the preferable gas penetration at this position.

The chamber corer

The chamber cover should be designed to give access to the whole chamber cross section. This allows the removal of the intermediate trays from the chamber.

Sealing the cover

The cover must be sealed with the chamber. A rubber seal made from foam rubber' old bicycle inner tubes or a water hose would be suitable.

Fixing

The cover is fixed on to the chamber with clamps or bolts.

Control valves

Control valves are installed in the feed and exit pipes of the purification chamber. These are used to disconnect the chamber from the gas flow while the absorbent is being exchanged.

Scavenging vent

In addition, a scavenging vent is installed. It is used for flushing air out of the chamber with new biogas after exchanging the absorbent and sealing the chamber.

Caution: Danger of fire and explosion

When scavenging. the chamber there is a danger of fire and explosion, due to the gas emerging from the scavenging vent. For this reason the vent exit should be installed high up and away

from buildings. Open flames and smoking must be prohibited during all work on the purification chamber.

When scavenging is completed, that is, when two or three times the volume of the chamber has been vented, the valve to the user can be re-opened.

The H_2S content of the gas can also be checked via the scavenging vent even during plant operation.

Operation procedures for gas desulphurization

Filling

Remove the cover of the purification chamber. Put in the bottom tray, which has spacers attached both below and above. Spread a layer of absorbent 20 - 30 cm thick over it. The absorbent at the edge of the tray is "piled up" against the wall of the chamber.

The material should not be pressed and should be uniformly distributed.

The second, intermediate tray is then placed on the spacers of the bottom one and covered with absorbent. Then the rest of the intermediate trays, which are covered in turn with absorbent, are placed in position.

Sealing

Put the cover on the purification chamber together with the seal and screw it down tight.

Scavenging

Open both the feed valve in front of the chamber and the scavenging vent valve. Leave the control valve to the user closed. Let a volume of gas equivalent to three times the chamber volume escape from the scavenging vent (caution danger of fire and explosion!). Then close the scavenging vent and open the valve to the biogas user.

Emptying the chamber

When the H_2S concentration of the purified biogas begins to rise, the absorbent should be exchanged. See Section 5 for the determination of the H_2S of the gas.

Exchanging the absorbent

Close the control valves (feed and user valves) in front of and behind the purification chamber.
Remove the cover of the chamber. Caution - danger of fire and explosion!
Remove the absorbent layer after layer from the chamber. In some cases the individual intermediate trays can be removed together with the entire layer of absorbent. Check the trays for damage and, if necessary, repair or replace them. Then the purification chamber can be refilled with fresh absorbent.

What to do with the spent absorbent?

The sulphur-loaded absorbent can either be regenerated by exposure to the air (oxidation) or be discarded if there is an ample supply. See the next section for details.

Regeneration

The absorbent is regenerated by spreading it on the ground in a thin layer and turning it over periodically. It is oxidized again within a few days and can be re-used.
After it has been utilized and regenerated several times the absorbent finally becomes inactive and must be discarded. Spent material highly concentrated with powdered sulphur reacts under certain conditions with the oxygen in the air, to form sulphur dioxide - SO_2 - which irritates breathing passages and the eyes, as well as being harmful to the environment.

Self-ignition

It is only seldom that the heat of reaction is sufficient to cause spontaneous combustion. The spent absorbent should however be disposed of in a way to avoid these problems.

Disposal of spent absorbent

Discarded absorbent should thus be placed in pits and immediately covered with earth. When this is done the soil bacteria transform the sulphur and sulphides to relatively harmless sulphates. It might also be possible to mix the used absorbent with the digested sludge. In this way the sulphur, which had been removed, could be fed back through the soil to the plants, thus completing the natural cycle. A decision can only be made after tests under local conditions.

Degree of desulphurization

Since the desulphurization capacity drops with continued use, the efficiency is not constant during the service life of a charge of absorbent. As it becomes loaded with sulphur, that is as the sulphur concentration increases, the H_2S content of the purified gas also increases. Nearly complete desulphurization can only be achieved when the absorbent is regularly exchanged and then discarded. The absorbent is not completely utilized with this procedure and the time interval between refillings is considerably shortened.

Two chambers in series

Another way of producing a very low H_2S concentration is to use at least two purification chambers in series, that is one after the other.

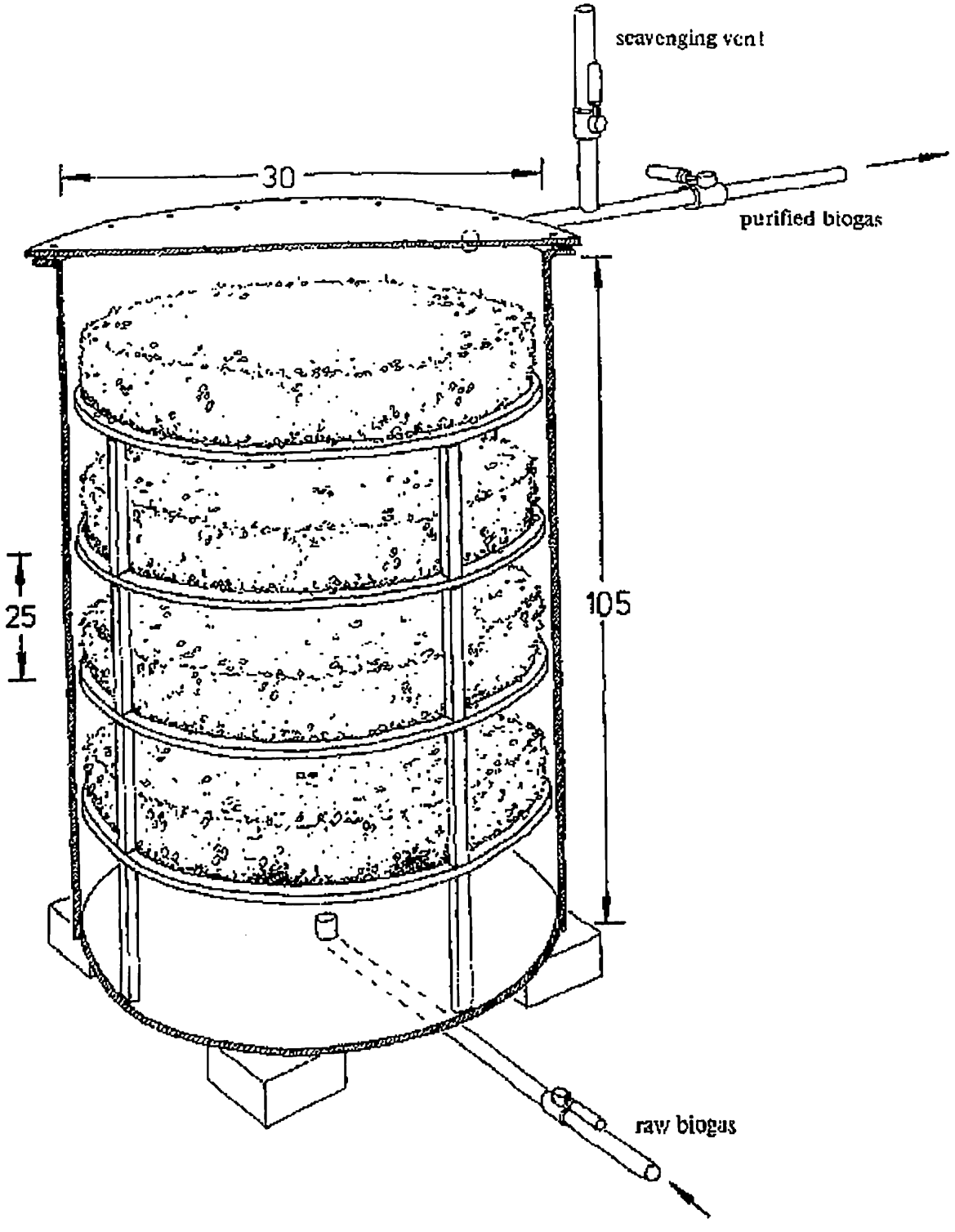
The first serves as a coarse purification chamber while the second serves as a fine filler chamber. Even when the first chamber allows considerable amounts of H_2S to pass through, the second is capable of reliably binding the remainder. The resulting purified biogas is almost completely free from sulphur.

The absorbent is almost completely utilized. As soon as the first chamber is unable to remove H_2S, its absorbent is exchanged. This chamber is now used as the fine filtering chamber. The second chamber which was the fine chamber is now used as the first, coarse purification chamber. That is, the order of the gas flow has been reversed.

Temperature during desulphurization

The temperature of the gas in the purification chamber should be held as constant as possible to prevent the absorbent from drying out or becoming moist. If necessary the purification chamber should be insulated. The chemical reactions in the purification process operate best at temperatures between 15-25 °C. A higher temperature is better than too low a temperature.

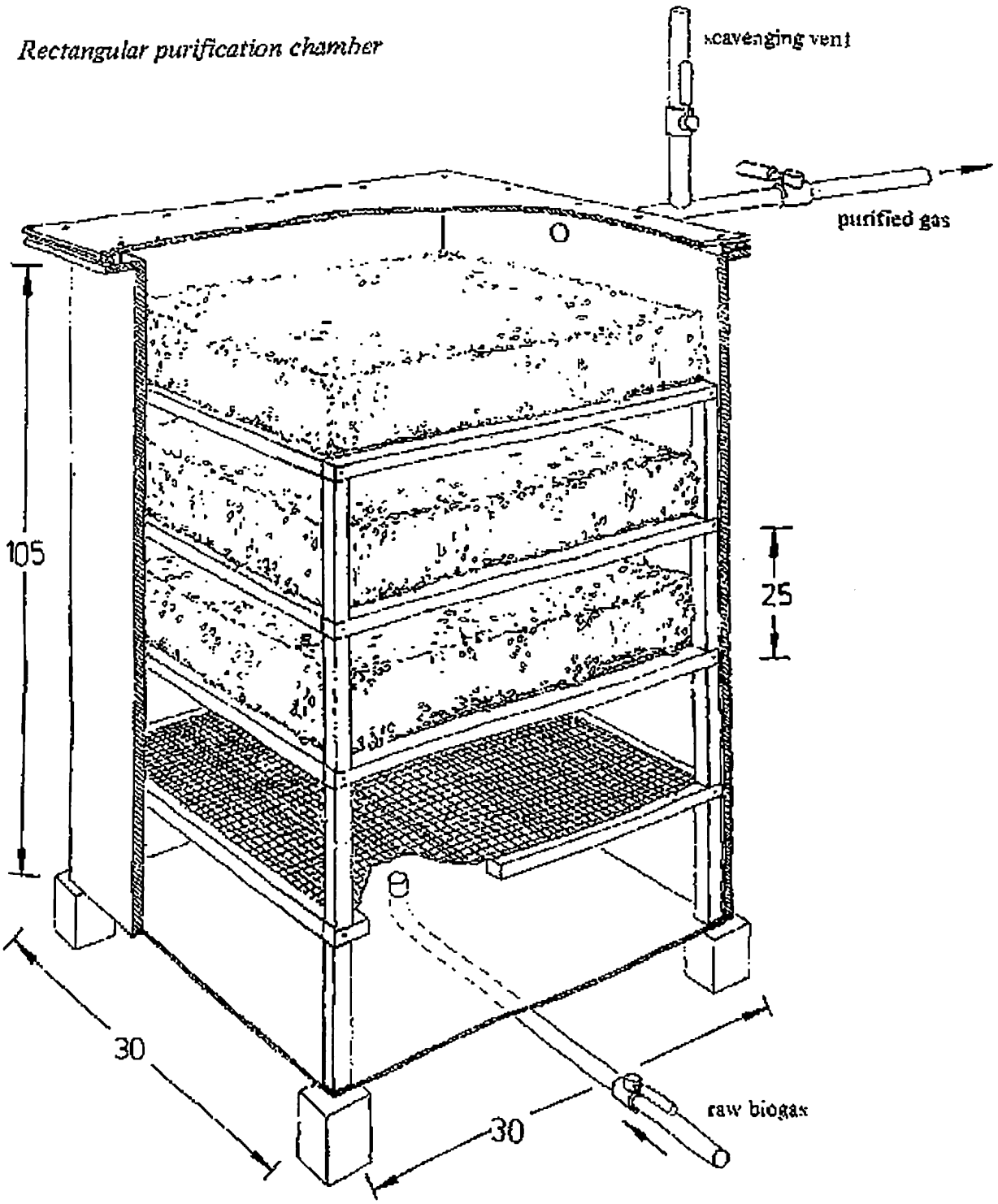
Cylindrical purification chamber



Example: 1.25 m^3/h (see dimensioning calculation)

dimensions in cm

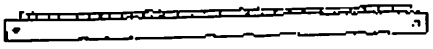
Rectangular purification chamber



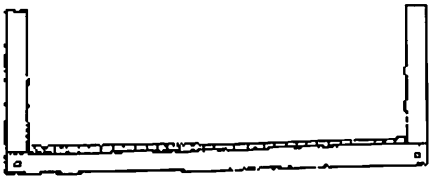
Example: 1.25 m^3/h (see dimensioning calculations)

dimensions in cm

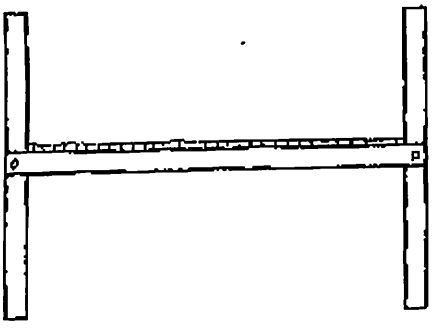
Construction of intermediate trays, cross section



The top tray is only a frame.

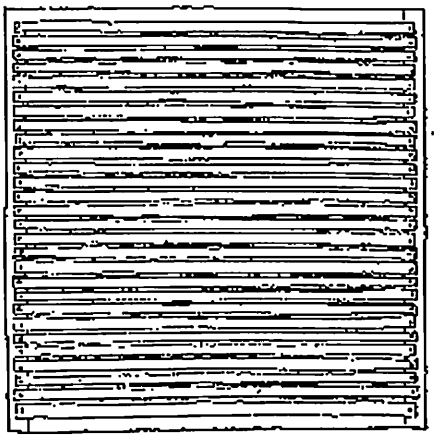


The intermediate trays have spacers extending upwards.

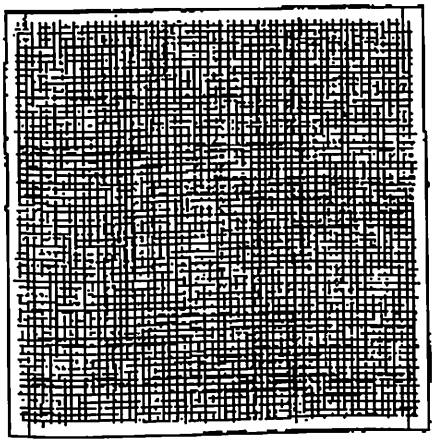


The bottom tray has spacers on the top and bottom.

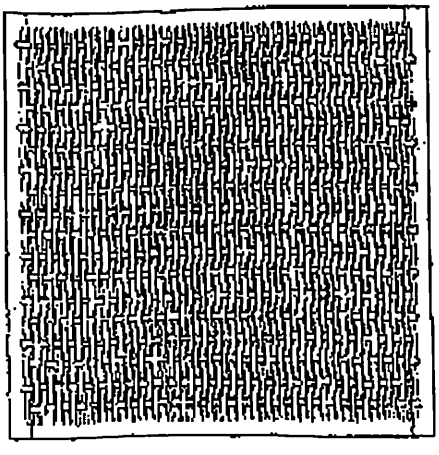
The intermediate trays can be made from



a frame covered with thin slats,



a frame covered with wire-screening,



– a frame covered with wickerwork made from rattan or similar material.

Calculation method for dimensioning biogas desulphurization units

Calculation of thr chamber cross section

(125 m^3gas/hour throughput x 1000 x 1000) ÷ 3600 = 3475 cm^3gas/s throughput.

The maximum flow rate in the chamber is 0.5 cm/s

(347.5 cm^3 gas/s throughput) ÷ (0.5 cm/s flow speed) = 695 cm^2 cross section of chamber

Length of the chamber side with the square cross section

$(\text{cross sectional area})^{0.5} = (695 \div 1000)^{0.5} = 26.4$ cm side – length

Radius of a chamber for a circular cross section

$(\text{cross sectional area} \div \pi)^{0.5} = (695 \div 3.14) = 14.9$ cm

Calculation of the height chamber

The height and cross sectional area of the chamber determine its volume. The volume determines the amount the absorbent that can be put into the unit. The amount in turn determines the operating time of the chamber between absorbent exchanges.

Refernence values for the amount of sulphur bound in the absobent:

Without regeneration 15g sulphur/kg absorbent

With regeneration 150g sulphur/kg absorbent.

The actual value depends on the absorbent used.

30m^3 biogas per day throughput

3.4 m^3 H_2S / m^3 biogas

60 number of operating days

30 x 3.4 x 60 = 6300 g H_2S/ operating period

(6300 g H_2S / operating period) ÷ (150 g H2S / kg absorbent) = 42 kg absorbent / operating period until exchange

Bulk density of absorbent = 0.8 kg / l

42/0.8 = 52.5 liters absorbent / operating period

Addition for dead volume = 25%

Chamber volume

(52.5 + 13.7) ÷ 1000 = 0.066 m^3

Chamber height

(0.066 / 0.0695) = 0.95 m

Number of intermediate trays

(0.95 / 0.25 m layer depth / tray) = 4 trays

CONCLUSION

The study of various aspects of biogas production was studied. The sizing parameter and sizing procedure was illustrated.

Hydrogen sulphide is a natural component of biogas. Its concentration depends on the sulphur content of the raw material being digested and lies in the range 1,500 ppm 5,000 ppm or 0,15-0.5 vol. % or 2.1-7 g H_2S/m^3. Hydrogen sulphide is responsible for corrosion of various parts of the plant equipment.

The use of biogas in an internal combustion engine causes uncontrollable corrosion problems. Engine components are very susceptible to corrosion by H_2S and its reaction product SO_2.

The experience of various manufacturers and users, as well as the (older) literature indicate that with the sulphur concentrations mentioned, the service life of the engines can be reduced by up to 15% of their normal value. Not only are the resulting repair and maintenance costs increased but also the costs for service materials such as spark plugs and lubricating oils. Even with special oils the oil change interval drops up to one-fifth of that under normal conditions. The oil becomes acidic from sulphur dioxide and thus loses its lubricating properties.

Acidic exhaust gases corrode the exhaust systems very severely.

Desulphurizing biogas with acceptable investment and operating costs is only possible employing the dry desulphurization method. Iron-containing materials of specified compositions are utilized as absorbing agents for H_2S. Alongside the traditional, commercially available absorbents, certain substitutes can be used. Various tropical and subtropical soils contain sufficient iron in a suitable form. They must be prepared, in order to obtain the proper purifying characteristics. The material must be loose, porous, moist and granular.

The raw soil has to be ground and mixed with a filler and water to obtain a homogeneous texture. The finished absorbent is placed on gas-permeable trays in a purification chamber. The raw biogas is fed in at the bottom and the desulphurized or partially desulphurized gas is extracted from the upper part of the chamber.

Eventually the absorbing agent is saturated with sulphur and can be regenerated either inside the chamber or outside through natural ventilation with air (oxygen). The absorbent material can, therefore, be re-used several times.

Using two or more purification chambers connected in series ensures a continual production of purified gas and allows a good capacity utilization.

The spent absorbent can be disposed of safely by burying it. Various factors must be considered when dimensioning the purification chambers. A certain maximum flowspeed should not be exceeded The gas volume to be purified per unit time determines the cross section of the purification chamber. The chamber volume and, hence, the amount of absorbent determine the operating time for the purification process up to regeneration or exhange of the absorbent.

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