Organic Fertilizer from Biogas Plants

Organic substances in fertilizers

While there are suitable inorganic substitutes for the nutrients nitrogen, potassium and phosphorous from organic fertilizer, there is no artificial substitute for other substances such as protein, cellulose, lignin, etc.. They all contribute to increasing a soil's permeability and hygroscopicity while preventing erosion and improving agricultural conditions in general. Organic substances also constitute the basis for the development of the microorganisms responsible for converting soil nutrients into a form that can be readily incorporated by plants.

Nutrients and soil organisms

Due to the decomposition and breakdown of parts of its organic content, digested sludge provides fast-acting nutrients that easily enter into the soil solution, thus becoming immediately available to the plants. They simultaneously serve as primary nutrients for the development of soil organisms, e.g. the replenishment of microorganisms lost through exposure to air in the course of spreading the sludge over the fields. They also nourish actinomycetes (ray fungi) that act as organic digesting specialists in the digested sludge. (Preconditions: adequate aeration and moderate moisture).

Reduction of soil erosion

The humic matter and humic acids present in the sludge contribute to a more rapid humification, which in turn helps reduce the rate of erosion (due to rain and dry scatter) while increasing the nutrient supply, hygroscopicity, etc. The humic content is especially important in low-humus tropical soils. The relatively high proportion of stable organic building blocks such as lignin and certain cellulose compounds contributes to an unusually high formation rate of stable humus (particularly in the presence of argillaceous matter). The amount of stable humus formed with digested sludge amounts to twice the amount that can be achieved with decayed dung. It has also been shown that earthworm activity is stimulated more by fertilizing with sludge than with barnyard dung.

Digested sludge decelerated the irreversible bonding of soil nutrients with the aid of its ion-exchanger contents in combination with the formation of organomineral compounds. At the same time, the buffering capacity of the soil increases, and temperature fluctuations are better compensated.

Reduction of nitrogen washout

The elevated ammonium content of digested sludge helps reduce the rate of nitrogen washout as compared to fertilizers containing substantial amounts of more water-soluable nitrates and nitrites (dung, compost). Soil nitrogen in nitrate or nitrite form is also subject to higher denifrication losses than is ammonium, which first requires nitrification in order to assume a denitrificable form. It takes longer for ammonium to seep into deeper soil strata, in part because it is more easily adsorbed by argillaceous bonds. However, some of the ammonium becomes fixed in a non-interchangeable form in the intermediate layers of clay minerals. All aspects considered, it is a proven fact, that ammonium constitutes the more valuable form of nitrogen for plant nutrition. Certainly, the N-efficiency of digested sludge may be regarded as comparable to that of chemical fertilizers.

In addition to supplying nutrients, sludge also improves soil quality by providing organic mass. The porosity, pore-size distribution and stability of soil aggregates are becoming increasingly important as standards of evaluation in soil-quality analyses.

Effects on crops

Crop yields are generally aknowledged to be higher following fertilization with digested sludge. Most vegetable crops such as potatos, radishes, carrots, cabbage, onions, garlic, etc., and many types of fruit (oranges, apples, guaves, mangos, etc.), sugar cane, rice and jute appear to react favorably to sludge fertilization.

In contrast, crops such as wheat, oilseed, cotton and baccra react less favorably. Sludge is a good fertilizer for pastures and meadows. The available data vary widely, because the fertilizing effect is not only plant-specific, but also dependent on the climate and type of soil. Information is still extensively lacking on the degree of reciprocity between soil fertility, type of soil and the effect of fertilizers (particularly N-fertilizers) in arid and semi-arid climates. Thus, no definitive information can be offered to date. Nor, for the same reason, is it possible to offer an economic comparison of the cost of chemical fertilizers vs. biogas sludge. The only undisputed fact that can be stated is that biogas sludge is better from an ecological point of view.

Figure 15: Fertilisation with slurry: Transportation of slurry by a modified wheelbarrow and buckets
Photo: Kellner (TBW)

The Contribution of Biogas Technology to Conservation and Development

Conservation

The conversion of waste material into fertilizer and biogas helps protect the environment in five principal ways:

- The generated biogas can replace traditional energy sources like firewood and animal dung, thus contributing to combat deforestation and soil depletion.
- Biogas can contribute to replace fossil fuels, thus reducing the emission of greenhouse gases and other harmful emissions.
- By tapping biogas in a biogas plant and using it as a source of energy, harmful effects of methane on the biosphere are reduced.
- By keeping waste material and dung in a confined space, surface and groundwater contamination as well as toxic effects on human populations can be minimized.
- By conversion of waste material and dung into a more convenient and high-value fertilizer ('biogas slurry'), organic matter is more readily available for agricultural purposes, thus protecting soils from depletion and erosion.

Development

Farmers, industrial estates, municipalities and governments have diverging concepts of development. They can use biogas technology in different ways to contribute to their own development objectives.

Farmers may want to substitute inputs such as fertilizers, household and engine fuels by biogas slurry and the biogas itself. A biogas system can relieve farmers from work that they have formerly spent on dung disposal or dung application on their fields. By using biogas for cooking, lighting and heating, life quality for the whole family can improve. Improved stables, if they are part of the biogas system, can increase the output of animal husbandry. Improved farmyard manure may raise the yields of plant production.

Industrial estates can, by processing their waste in a biogas plant, fulfill legal obligations of waste disposal. They can, at the same time, generate energy for production processes, lighting or heating.

Municipalities can use biogas technology to solve problems in public waste disposal and waste water treatment. The energy output of biogas digestion is usually not a priority, but may respond to public energy demands such as street lighting, water pumping and cooking in hospitals or schools.

National Governments have macro-economic interests that may render biogas technology an interesting option in overall development plans. On a national scale, a substantial number of working biogas systems will help reduce deforestation, increase agricultural production, raise employment, and substitute imports of fossil fuels and fertilizers. If macro-economic benefits are obvious and quantifiable, a government may even consider to subsidize biogas systems to bridge a micro-economic profitability gap.

Craftsmen, engineers and maintenance workers have long been overlooked as a target group for biogas promotion. Not only does biogas technology open market niches for masons, plumbers, civil engineers and agronomists, they are often the most effective promoters of biogas technology.

Under which conditions can biogas technology contribute to development and conservation?

Mature technology: A positive contribution of biogas technology can only materialize, if the technology works. The development of biogas technology has passed the experimental stage. Trials with uncertain outcome can only be accepted if the costs of failure are not to be paid by the end-users. Whatever the chosen design of the biogas plant may be, those in charge for its dissemination bear the responsibility to deliver a reliable, durable and user-friendly product.

Appropriate Design: Only appropriate designs will perform satisfactory and will have a favorable cost-benefit ratio. Existing basic designs of biogas systems have to be adapted to the following framework conditions:

- climatic and soil conditions;
- the quality of substrate to be digested;
- the quantities of substrate;
- the prioritization of expected benefits;
- the capital available;
- the availability of skills for operation, maintenance and repair.

Official Policy Support: The policies of governments and donor organizations cannot turn immature technologies and inappropriate designs into success stories, nor can they create an artificial demand for alternative energy or improved fertilizer. But where a national need for energy alternatives exists and the increasing burden of water pollution, deforestation and soil depletion is felt, governments can asupport biogas dissemination by a legal framework against unsustainable use of natural resources and in favor of green technologies.

Donor organizations can provide take-off funding and initial technical assistance where biogas technology is hitherto unknown.

The ’Critical Mass’ of Biogas Systems: For small and medium scale farmers, the investment in a biogas system is a considerable risk. Besides the confidence in the technology itself, they need reassurance from neighbors and colleagues. Farmers believe what they see. The more working biogas systems are around, the more they will be willing to invest. In addition, professional (commercial) advice, maintenance and repair will only evolve, if a sufficient number - the ’critical mass’ - of biogas systems are established in the area.

Limitations of Biogas Technology

Currently, there is no doubt anymore that biogas systems all over the world are functioning under a variety of climatic conditions. They respond successfully to needs of poor rural populations, urban communities and industrial estates. However, a widespread acceptance and dissemination of biogas technology has not yet materialized in many countries. One main reason, often mentioned, is the required high investment capital. But often the reasons for failure were the unrealistically high expectations of potential users. Biogas technology cannot solve every problem of a farm, a village or a big animal production unit. If disappointment is to be avoided, the limitations of biogas technology should be clearly spelt out. If from the below listed guiding questions one or more cannot be answered with 'YES', the success of biogas technology is questionable or even unlikely.

Is there a real problem that biogas technology can address?

e.g. Is there a problem with the affordability and availability of energy?

Is the substrate to be bio-degraded an environmental hazard?

Is the lack of high-quality fertilizer a serious problem in the farming system?

Can a permanent supply of bio-degradable material be guaranteed at low cost?

e.g. Are animals kept in a stable, connected to the biogas plant?

Would filling the biogas plant reduce the workload of the farmer?

If necessary, is transport capacity for the substrate guaranteed permanently?

Will the biogas plant be connected reliably to the sewage system?

Can the financing of biogas systems realistically be solved?

e.g. Do potential users have access to credit?

Can a substantial subsidy be expected from private or public sources?

How realistic is the optimism of the biogas plant owner-to-be?

For unheated biogas plants: does the climate allow bio-digestion for most of the year?

Under arid conditions: Is the availability of water secured and affordable?

Is the use of human feces as substrate and fertilizer culturally acceptable?

Is the use of biogas, generated from human waste, acceptable for cooking?

Are there allies among government and institutional decision makers with a certain degree of awareness of environmental problems?

Is in the region a sufficient number of skillful craftsmen available who can be upgraded to be 'biogas technicians'?

e.g. Is good quality masonry work known in the region?

Is plumbing a trade that is practiced in the region?

Does the number of potential biogas users in the region justify a 'biogas project' or the establishment of private 'biogas business'?

Biogas technology is not a universally accepted technology such as the transistor radio. A biogas plant has to fit into existing farming-, production- or waste disposal systems. Attempts to make the system fit to the biogas plant will result in expensive and frustrating failures.

Biogas technology has many competitors. Energy can be produced by fuelwood plantations (with other positive side-effects), by solar systems, micro-hydro-power and other renewable energy technologies. Producing high quality fertilizer can be done in other, cheaper ways such as composting which are even closer to traditional techniques.

What makes biogas an attractive option is the fact that this technology can provide solutions to a variety of problems simultaneously. That is, if this variety of problems exists.

Biogas - Framework Conditions

The implementation of biogas projects and programs, even on a small-scale level, must take into account the underlying socio-cultural, political, economic and ecological conditions. As an appropriate technology, mainly for rural areas, the realization of economically viable and sociologically and ecologically beneficial biogas projects heavily relies on social and political acceptance. Benefits of biogas as well as major obstacles depend on the specific and complex relationships between social organization, economic premises, environmental problems and political intentions.

Social aspects in the planning process

Participation of the local population is a key issue in the project planning phase. People should be involved as early as possible. The basic facts about biogas technology should be made clear beforehand, so that possible problems of biogas technology are transparent to the actors involved. Obstacles can arise from religious and/or social taboos in the following respects:

- prohibitions in the use of gas primarily for the preparation of food
- prohibitions in the use of the slurry
- social prohibition of work involved in running a biogas unit, either due to the separation of classes, sexes, age groups or due to ethnic or religious affiliation.

In order to deal with these obstacles in a way that considers local conditions as well as requirements of the project, the assistance and attitude of ruling or generally recognized institutions is of major importance. Class structure and barriers have to be taken into account for as well. General features of the society’s class structure and comparison with neighboring areas and/or similar projects can serve for a preliminary analysis. The concrete conditions in the project area have to be investigated based on this "general model" focusing on the social position of the target group. For the delegation and organization of tasks during the project, the existing social regulations on the division of labour represent a framework, that is often difficult to determine. Women are often kept out of decision-making processes even though they are usually the primarily affected group regarding household energy issues. Their participation can, for instance, be encouraged by integration into authoritative bodies or by forming special female committees.

Social and political aspects in the dissemination process

For the dissemination of biogas technology certain social and cultural convictions and norms can act as impediments:

- Ethical barriers
- Sociocultural taboos
- Denfense mechanisms, (specifically aginst the use of human excrements as fertilizer)
- Lack of regularity in the attendance and maintenance of biogas systems
- Fertilization

The implementation of biogas programmes is also linked to a number of political and administrative factors that have to be considered.

Specific regional developments

Specific developments in the region can, positively or negatively, impact a biogas dissemination program. They can occur, for example, as the result of:

- *Regional (energy) development:* a dam is built in a region and the population is resettled. In many aspects the resettlement villages would be ideally suited for community biogas plants. The villages are to be newly constructed and can be designed accordingly. Moreover, social mobility is increased by resettlement. On the other hand the dam is being erected to produce electricity. Biogas will have to compete with (possibly cheap) electric energy.

- *Emergencies:* a village has had to be resettled because of a natural disaster. Similar planning advantages apply as in the first example. Care must be taken here to ensure that biogas is not misunderstood as an "emergency measure" but as a development initiative arising out of an emergency situation.
- *Changes in infrastructure:* an all weather road is to be constructed to link a previously remote area to the urban center. This will change the prices for building materials, for charcoal and labor. The cost-efficiency of biogas plants may increase as a result.
- *Conservation policies:* the area in question will soon be part of a large national park. The collection of firewood will be largely restricted, the road infrastructure improved and access to development funds made easier.
- *Other technology innovations* in the area which have led to disruptions within the social structure, or which have evoked the fear of disruptions. The result can be a negative attitude towards technological innovation.

National energy & fertilizer supply strategies

Chemical fertilizer

For developing countries, the production of biogas and bio-fertilizer holds the promise of substituting increasing amounts of imported fossil fuels and mineral fertilizers. On an economic scale, the importance of digested sludge as a supplementary source of fertilizer is gradually gaining recognition. As populations continue to grow, there is a corresponding increase in the demand for food, fertilizers and energy. Consequently, for example in India, both the production and consumption of chemical fertilizers have been steadily expanding over the past decades.

According to a recent estimate by Indian experts, the national consumption of mineral fertilizers could be reduced by 30-35% through the use of digested biogas sludge as fertilizer.

Fertilizer policies, energy policies

For biogas programs, it is crucial,

- to be familiar with official government policies on fertilizers and fuel;
- to be familiar with the realities of implementation of these policies;
- to have a clear understanding of the possibilities and processes of policy change. This includes an intimate knowledge of persons and institutions involved in possible policy changes.

If national policies have a strong self-reliance character, involving high import taxation on mineral fertilizers and fossil fuel, biogas technology will have an easy start. If world market integration is high on the agenda of national planning, biogas technology will face stiff competition from imported fuels and fertilizers.

According to available economic data, it may be assumed that (at least in remote, sparsely settled areas) biogas programs are usually less costly than comparable energy & fertilizer supply strategies based on fossil resources, like electrification and the production or importation of chemical fertilizers. The latter strategies involve not only high transmission and transportation costs, but are also largely dependent on imports.

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.

Environmental aspects

Biogas technology is feasible in principle in most climatic zones under all climatic conditions, where temperature or precipitation are not too low.

Using biogas technology is, besides direct thermal or photovoltaic use and hydropower, a form of using solar energy, mediated through the processes of photosynthesis (for build-up of organic material) and anaerobic decomposition. As such it is a renewable energy source. In many regions of the world, the consumption of firewood exceeds natural regrowth. This leads to deforestation and degradation of forests and woodlands with adverse effects on climate, water budget, soil fertility and natural products supply. Biogas is one of the solutions to this problem, because it substitutes firewood as a fuel and helps sustaining favourable soil conditions. It is also an important contribution to the mitigation of the global greenhouse effect.

The potential contribution of biogas technology to combat deforestation, soil erosion, water pollution and climate change is undisputed. But how much support biogas dissemination will receive from government institutions will depend largely on the role of environmental considerations in government decision making.

The success of biogas technology also depends on the influence of potential allies in the environmental NGO scene. Biogas programs can, if environmental policies are favorable, be perceived as "status projects" for environmental authorities.

Socio-Cultural Aspects of Biogas Projects

Participation

The basic principle of any planning should be to involve those concerned in the planning process as early as possible. This principle applies even more if the pre-feasibility studies have revealed a considerable amount of problems. In any case it is better to discuss these quite openly with those concerned and seek mutual solutions rather than to rely on the method "it will all work out in the end".

The point in time when participation is started is decisive. It is too early to expect full participation before the technology has reached a certain technical maturity and the conditions for it's dissemination are fully explored. It is, on the other hand, just as wrong to confront people with 'final solutions'. In this case there is the risk of obtaining verbal agreement without effective consequence. The ideal time for introducing concept and technology is during the last phase of the investigation, when preliminary results can be shown to those concerned as a basis for discussion. These discussions serve as a first test of the preliminary results. Furthermore, the structures of leadership and decision making can be observed clearly in such situations.

That does not mean that each of the proposals by the community should be accepted blindly. The fact that biogas technology requires a specific technical and economical organization should be stressed. A breakdown of planning would be preferable to unfeasible compromises. In view of this it is often advisable to invite the local technician to take part in these negotiations. His technically based arguments tend to be well accepted in situations of disagreement.

Religious and social taboos

Taboos, as a rule, are always of an overall social character. Violation of taboos is sanctioned (penalized), the extent and form of penalty being determined socially. Sanctions can vary from a direct 'punishment' to social disrespect. In many cases an immediate punishment (corporal punishment, exile from the village etc.) is no longer possible nowadays as state legislation claims a monopoly for punishment. This does not simplify the problem but makes it even more difficult. Instead of an official, foreseeable punishment, social exclusion occurs now in many cases and can be just as serious for those concerned but becomes practically inaccessible for a project or for authorities. As 'social punishment' is forbidden the 'sanctions' are not spoken about, especially when they target a program desired and aided by the state. An exclusion of participants by the community with all its negative consequences is not declared as such by the community and therefore rarely directly accessible.

On the other hand, from these 'sanctions' arises the opportunity to overcome resentments. In general, sanctions are governed by a 'ruling instance' or 'authority' who watches over these taboos and proclaims the punishment when they are violated. But this authority also determines possible exceptions. A general misconception is that taboos basically 'cannot be broken'. No society is inflexible to the extent that regulations do not allow for changes and modifications. In any case, exceptions have to be agreed upon by a recognized instance.

Authorities

Authorities can be:

- ***for religious taboos***: priests or members with a religious function, for instance the elders of the community.
- ***for social taboos***: social leaders, e.g. the elders, traditionally or modern politically leading groups or personalities etc. Often older women play a more important role than the outside observer would see.
- ***or general***: especially recognized members (key persons), either in the sense of traditional structures of leadership or people of certain professions like teachers or local bank managers.

Disregard of taboos

For the acceptance of exceptions a person or group of persons has a greater effect the more the taboo and the system behind it is generally recognized. If the system and its leaders have been accepted they become the only instance to be consulted concerning exceptions. Any opposition to this group will result in resistance even if individuals within the group are prepared to disregard the regulations.

It should not be assumed that any recognized leader can disregard taboos or suspend them and remain unpunished. These people are also part of the system and have to observe the rules of the system. It is quite right to start lobbying for technical innovations with recognized leaders, but is also necessary, if they can be won, to leave them with the initiative and allow them to decide on the procedure of technology introduction.

Just as the general extensive survey provides the basis for the problem analysis and the starting point of a project, it is essential to recognize that local application cannot be structured according to a general method but has to be integrated in the local context. To mention one example, priests are generally seen as religious leaders but this does not mean that their influence is equal in all localities. Cooperation with priests for local programs should depend on the quality of their local status.

Social classes and class barriers

In their general features, social classes are the binding structure in each society and an important phenomenon which has to be reckoned with and included early enough in planning. It must be taken into account that class structures and class barriers exist in locally specific variations which have a considerable influence on implementation. Typical deviations are:

a) ***For hierarchical societies***:

- the absence of certain hierarchical groups in a village
- the shifting of the hierarchy on account of certain (changing) conditions
- a restructuring of the hierarchy for certain projects

b) ***For more egalitarian societies***:

- the abolition of egalitarian principles by specific village personalities
- the abolition of egalitarian principles by specialization

As these deviations cannot be foreseen, it is wise to compare the results of similar or comparable projects for the preliminary analysis. An essential preliminary analysis offers the following possibilities:

- the development of a general class model including test criteria to check its local application
- the potential for the allocation of individual functions
- the potential for the allocation of certain jobs

Development of a general model

If such a quite rudimentary model is enriched by additional material from other measures in neighboring areas, a series of check questions can be derived and applied in the target area or group. This preliminary model serves as a reference instrument for the main survey and also as a control for results gained. The latter is very important since over-optimistic statements can be made by target groups which are interested in project measures. This applies to the whole project as well as to the allocation of special functions to individual groups. The model is in no case a substitute for a local survey. Local deviations, possibly on account of personality, can be so great that they do not principally change the model but can very much affect the degree of functioning in an initial implementation.

Definition of position of the target group

Equally important to the development of question and control structures is the definition of position of the target group in relation to neighboring groups. The extensive observation of the whole society can provide a series of criteria for the initial analysis. Special importance is attached to this method in the following situations:

a) The proposed group or institution is not or only minimally self-sufficient in its biogas measures. It requires deliveries (material or service) from other groups, either a neighboring village or another enterprise.

> Such matters become relevant whenever certain regulations exist within the extensive class system but do not appear within the local system. In such cases an investigation has to take place, for example, whether neighboring groups who would have to deliver substrate, would accept this.
>
> This investigation is of great importance when within the target group a 'violation' of the class system is accepted. It is frequently found out afterwards that this 'violation' is not given because the essential suppliers do not accept their counterparts; now and again it can be seen that certain groups within the target group only give their approval because they are sure that the conditions negotiated would not be accepted by the partner groups.

b) The implementation takes place within the context of a more extensive program, possibly a pilot program. In this case it is not sufficient to obtain the acceptance only within the temporary target group but an investigation into whether this model is acceptable for later target groups has to be carried out.

> Although it is in principle practicable to keep the model variable for later adaptation to other target groups, it should not be overlooked that the interest of later target groups will be affected by the pilot model. 'Violations' against social norms which are acceptable for the initial target group could be rejected in neighboring communities and lead to a general rejection of the 'biogas project'. Consequently pilot models should avoid 'far-reaching' violations even if these are locally possible.

Social regulations for the division of labor

Reasons for regulations on the division of labor

Social regulations for the division of labor can arise for the following reasons:

- Privileges of certain groups in taking over specific jobs or being released from less desirable work. These privileges can stem from belonging to a social or ethnic group, age group or sex.
- Social and traditional allocation of specific work for specific groups. The division of labor among the sexes belongs here.
- 'Regulations' on the division of labor caused by political or economic dependency which means e.g. the necessity for the 'village rich' to carry out certain tasks in order to secure labor during agricultural seasons etc.

The regulations on the division of labor always prove to be an especially persistent phenomenon; 'leading' groupings frequently refuse to carry out socially or religiously 'banned' jobs (handling feces, heavy manual work etc.) as they are 'non-rank conform' and force socially or economically dependent groups to take over these tasks. This applies especially to the division of labor between sexes.

Difficulties in researching social regulations

To investigate in social regulations is difficult as their existence is often not admitted to 'strangers', however strong their influence on the later course of the measures may be. It is not an exception when, for example, in an interview a man agrees to take over a certain task - but means in saying this that his wife or a person dependent on him will carry out the task. For the interviewee this is no 'lie'; for him it is a matter of course that he means, by agreeing, that he will allocate the task. In individual interviews this leads to wrong interpretations which could have a considerable influence on the implementation model. Leaders in many societies assume that their statement will be valued as correct. Who would think that they carry out such jobs themselves? On the other hand, the purpose of the interview is accurately guessed and the answer given accordingly. The implementer would like an as even distribution of work as possible; he could consider the regulations of labor division to be 'bad'. And so, the answer is given accordingly, so that noone has to be 'ashamed'. Unfortunately this changes nothing as far as the later reality is concerned. Especially in the case of traditionally underprivileged groups, often including women, it has to be expected that the 'leaders' as well as the 'laborers' find it very difficult to give correct statements on the division of tasks.

Conclusions

It can be concluded that:

- On the one hand an extensive preliminary investigation which can often refer to literature is essential. If there are general strong tendencies towards division of labor within a target region, statements concerning the even delegation of jobs within the target group have to be treated with caution.
- The local interviewing of the target group does not initially refer to the future project, but to comparable, existent job routines. If there is a strict division of labor here, no promises of an egalitarian division of work within the proposed biogas project should be made.

Gender considerations

Women are kept out of many decision-making processes as far as they exceed the family, are connected with the allocation of finances or are concerned with 'technical measures'. On the other hand, women may be the main interested parties concerning biogas for cooking. Once a plant is constructed, they are the most affected by the malfunctioning of a plant.

Forms of participation

Which form of participation is appropriate for women cannot be decided from outside. It is of little use to the women if they are 'forced' into a decision-making body without being truly accepted by other members. Their impact could be even less than by influencing of the husband. When there are problems with the plant, it is the women who can be a stabilizing element. As they are more affected by malfunctioning of the plant, they are more interested than men in, for example, a well functioning repair service.

Different models should be considered according to the standing of women in society:

- the careful integration of women into decision making bodies
- women committees for the regulation of consumer problems whilst matters of finance are left to the men
- specialized committees with a mixed central body

Special female committees

The impact of a female committee should not be underestimated. Even if it has no direct influence on decisions it embodies a greater confidence of the women and so indirectly influences decisions. This sort of special committee can also be an initial step towards full participation in the future.

It is necessary to take not only the women but also the men into consideration when discussing gender specific questions. A participation model which is not effective for these will also not help the women.

Social Problems Affecting the Propagation of Biogas Technology

Ethical barriers

Many religions have very strict laws with regard to cleanliness, especially in connection with human and, to a lesser extent, animal excrement. The suppression or bypassing of such laws is always a mistake. Every new case of illness would invariably be ascribed to the transgression of religious laws. It would be of little importance how much such an illness may actually have to do with the production of biogas.

Implementation strategies should be based on cooperation with appropriate domestic institutions that are looked upon as benign and "clean". The positions and attitudes of such institutions must always be clarified in advance, since it is not their general posture that is of decisive importance, but rather their attitudes with respect to the transgression of religious doctrine. For example: the socio-cultural expectation is that illness will result from the handling of human or animal excrement. Since, however, hospitals are generally accepted as the absolute "experts" in matters of health (or lack of it), it could have a beneficial model effect on the popularization of biogas technology to see that their local hospital or dispensary is operating a biogas system.

On the other hand, hospitals are also regarded as secular institutions; one accepts their services as a ’necessary evil’ without affording them a social rank. Seen in that light, religious taboos cannot be overcome by way of the hospital’s example. At best, the reaction would amount to: "They can get away with it. They have special defense powers. But we don’t!".

Socio-cultural taboos

Many socio-cultural taboos, though rooted in ancient religious beliefs, have gradually become altered by way of missionary activities and the extenuation of religious interests to "generally applicable" taboos, which are frequently more difficult to handle than "pure" religious taboos, since no priest or minister is able to exert any influence. The only way to overcome taboos is by way of example. Highly respected members of the community, approved educational institutions, etc. may be able to make inroads in a model function. Here, too, a preliminary study of the envisioned mediator is imperative. The question of individual acceptance must be clarified in advance. It is by no means a foregone conclusion that someone who is considered highly acceptable in a certain field or function, e.g. politics, will enjoy the same high standing in a different context, e.g. hygiene.

Of equal importance is the effective investigation of existing interrelations between, and relative influence of, the various taboos. For example, the socio-cultural cross-linkage between social behavior and illness must be expected to appear illogical to a Western implementer. Such associations must be heeded if the strategy being applied is to meet with success in generating acceptance for biogas and in instigating a (partial) breach of taboos. Often enough, the breakthrough may be easier to achieve indirectly (by way of the cross-links) than directly. In the Pacific region, for example, human feces were traditionally "disposed of" by pigs. This was a matter of general practice and no one considered it repulsive. The potential solution: a "three-in-one" system in which the human excrement "pass through" the pigs, so to speak, by being routed underneath the pigpen on their way to the digester. No one "sees" what actually takes place, or more precisely, what does not take place.

Defense mechanisms against the use of human excrements as fertilizer

In practical terms, this subject could be viewed as a subgroup of the socio-cultural taboos, the main distinction being that the use of night-soil for the production of biogas is regarded as acceptable, but the use of the digested sludge as fertilizer is not. This stance is particularly well-entrenched in regions where the use of fertilizers is relatively new, and mineral fertilizers have been introduced as a "clean" product, i.e. in regions where shifting cultivation is traditional.

It is unusual in such regions to find that the arguments against the use of manure have been generated, or at least amplified, by hygiene propaganda. In the Pacific Basin, for example, a region in which few epidemics have been known so far, but were belatedly infused by way of acculturation. A potential solution would be to conduct demonstrations in cooperation with institutions known for - and viewed as credible because of - their close involvement with matters of hygiene.

Figure 16: Toilet (under construction), directly connected to the plant
Photo: Kellner (TBW)

Irregular attendance and maintenance of biogas systems

This is a frequent problem in the tropics, where the climate dictates no particular sequence of agricultural activities. Applied to biogas systems, the connection between a process breakdown and irregular charging is not immediately recognizable, because there is a substantial time lag between the owner's forgetting to feed substrate into the system and the eventual, resultant decrease in gas production. Similarly, once the biogas system has stopped producing, it will take up to about 10 days of regular charging to get the gas production back to normal levels. Once again, the connection is blurred. The only possible solution would be to provide long-term intensive training aimed at instilling an appreciation for the need to ensure that the system is charged on a regular basis.

Fertilization

This problem stands in close relation to the ethical barriers, socio-cultural taboos, defense mechanisms and the lack of regularity in the attandance of biogas systems. Insufficient, untimely or otherwise improper fertilizing may be the result of a lack of familiarization with regard to the work involved, the type of fertilizer being used or the necessity of methodical regularity. To the extent that neither ethical barriers nor socio-cultural taboos are involved, the only workable approach is to provide intensive training for the owner-operators.

Political and Administrative Frame Conditions for Biogas Programmes

Political will and public opinion

The development of biogas technology depends on the political will of donor and recipient governments. It is the task of the governmental and administrative authorities to provide access to the technology and to secure and organize the requisite material, financial and legal basis. According to their political will to promote biogas, governments can play a more or less supportive role in biogas research, information dissemination and regulations for funding, subsidies or tax waving. The formation of a political will does not evolve in a vacuum. Political will and public opinion develop in interrelation. Successful practical examples, encouraging research findings, the use of media to spread information, all these are tools to influence both political will and public opinion.

Biogas programs should attempt to lobby for biogas at various entry points of the government system simultaneously. Creating a favorable climate for biogas dissemination depends almost always on a whole range of decision makers. For example:

- *The Ministry of Finance* will decide on subsidies and tax wavers for biogas users.
- *The Ministry of Energy* can propose laws regarding the feeding of biogas-produced electricity into the grid. It can also propose financial and other assistance.
- *The Ministry of Agriculture and Livestock* can include biogas in the training curriculum of extension officers and agricultural colleges.
- *The Ministry of Education* can include biogas in the curricula of high schools and promote the construction of bio-latrines for schools.
- *The Ministry of Health* can include biogas in the curricula of public health workers and encourage the building of bio-latrines for hospitals.

Simultaneously to political lobbying, PR work is important to influence public opinion:

- *Radio Programs* are an effective means in rural areas to familiarize the population with basics of biogas technology.
- *Articles in Print Media* usually reach members of the middle class, among whom are the most promising potential users: middle to large farmers.
- *Pilot Biogas Systems* must be located strategically to be easily accessible. The more these pilot plants have a 'real life character', i.e. be an operational part of a farm, the more convincing they will be for other farmers.
- *Visits in Agricultural Schools and Colleges* does not reach the decision makers of today, but lays the ground for biogas acceptance in the future.

Figure 17: Sign of the National Biogas Department/National Energy Board in Ghana
Photo: Kellner (TBW)

Program goals

Since the actual installation of a biogas plant is ultimately the decision of the individual investor, it is important that the program goals and the organizational environment is conducive to affirmative individual decisions. The prerequisites for this must be established at all planning stages by and for all sectors concerned. A biogas program which is part of a larger development program must harmonize with the other departments of the parent program. The introduction of biogas as an alternative source of energy affects various sectors, each of which functions within its own specific structural setting. These, of course, vary from one country to another. As a rule, the responsibilities within a biogas program should be distributed along the lines of existing contacts with the corresponding target groups. If, for example, certain farmers are considered the target group of an information campaign, it would be appropriate to have the ministry of agriculture be involved in the biogas program.

Administration

No new administrative bodies should be established for performing the above tasks. Instead, it is advisable to set up biogas promotion units or biogas contact persons within the existing departments and agencies. Within the framework of a well-established development program, particular importance should be attached to self-help groups, voluntary agencies and/or private foundations.

The authorities' efforts in favor of biogas promotion will be more effective, if sufficient detailed information is placed in the hands of the self-help groups. The concerned administrative bodies must disseminate the requisite information and provide inexperienced groups with a satisfactory explanation of how to best exploit the promotional options available to them. Practical assistance should be offered wherever possible. Active self-help groups will then become ideal multipliers.

Environmental Frame Conditions of Biogas Technology

Climatic conditions for biogas dissemination

Temperatures

Biogas technology is feasible in principle under almost all climatic conditions. As a rule, however, it can be stated that costs increase for biogas production with sinking temperatures. Either a heating system has to be installed, or a larger digester has to be built to increase the retention time. Unheated and un-insulated plants do not work satisfactory when the mean temperature is below 15 °C. Heating systems and insulation can provide optimal digestion temperatures even in cold climates and during winter, but the investment costs and the gas consumption for heating may render the biogas system not viable economically.

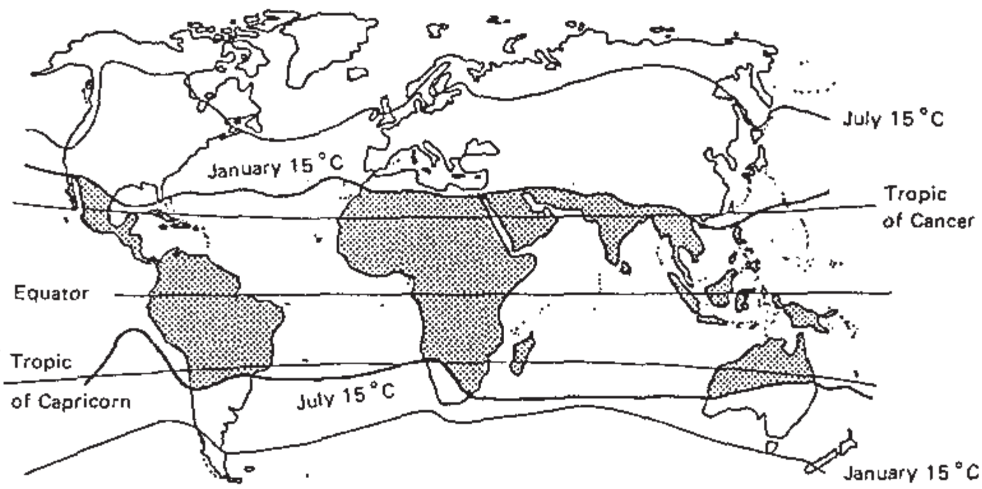

Figure 18: Global 15°C isotherms for January and July, indicating the biogas-conducive temperature zone
Source: OEKOTOP

Not only the mean temperature is important, also temperature changes affect the performance of a biogas plant adversely. This refers to day/night changes and seasonal variations. For household plants in rural areas, the planner should ensure that the gas production is sufficient even during the most unfavorable season of the year. Within limits, low temperatures can be compensated with a longer retention time, i.e. a larger digester. Changes of temperature during the course of the day are rarely a problem as most simple biogas digesters are built underground.

Precipitation

The amount of seasonal and annual rainfall has mainly an indirect impact on anaerobic fermentation:

- Low rainfall or seasonal water scarcity may lead to insufficient mixture of the substrate with water. The negative flow characteristics of substrate can hamper digestion.
- Low precipitation generally leads to less intensive systems of animal husbandry. Less dung is available in central locations.
- High precipitation can lead to high groundwater levels, causing problems in construction and operation of biogas plants.

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 seasonal variations in temperature. Extremely mobile forms of animal keeping (nomadism). Unsuitable for biogas dissemination.

Firewood consumption and soil erosion

A unique feature of biogas technology is that it simultaneously reduces the need for firewood and improves soil fertilization, thus substantially reducing the threat of soil erosion. Firewood consumption in rural households is one of the major factors contributing to deforestation in developing countries. Most firewood is not acquired by actually cutting down trees, but rather by cutting off individual branches, so that the tree need not necessarily suffers permanent damage. Nonetheless, large amounts of firewood are also obtained by way of illegal felling.

In years past, the consumption of firewood has steadily increased and will continue to do so as the population expands - unless adequate alternative sources of energy are developed. In many developing countries such as India, the gathering of firewood is, strictly speaking, a form of wasteful exploitation. Rapid deforestation due to increasing wood consumption contributes heavily to the acceleration of soil erosion. This goes hand in hand with overgrazing which can cause irreparable damage to soils. In the future, investments aimed at soil preservation must be afforded a much higher priority than in the past. It will be particularly necessary to enforce extensive reforestation.

Soil protection and reforestation

The widespread production and utilization of biogas is expected to make a substantial contribution to soil protection and amelioration. First, biogas could increasingly replace firewood as a source of energy. Second, biogas systems yield more and better fertilizer. As a result, more fodder becomes available for domestic animals. This, in turn, can lessen the danger of soil erosion attributable to overgrazing. According to the ICAR paper (report issued by the Indian Council of Agricultural Research, New Delhi), a single biogas system with a volume of 100 cft (2,8 m^3) can save as much as 0.3 acres (0,12 ha) woodland each year.

Taking India as an example, and assuming a biogas production rate of 0.36 m^3/day per livestock unit, some 300 million head of cattle would be required to produce enough biogas to cover the present consumption of firewood. This figure is somewhat in excess of the present cattle stock. If, however, only the amount of firewood normally obtained by way of deforestation (25.2 million trees per year) were to be replaced by biogas, the dung requirement could be satisfied by 55 million cattle. Firewood consumption could be reduced to such an extent that - at least under the prevailing conditions - a gradual regeneration of India's forests would be possible.

According to empirical data gathered in India, the consumption of firewood in rural households equipped with a biogas system is much lower than before, but has not been fully eradicated. This is chiefly attributable to a number of technical and operational short-comings. At present,

- many biogas systems are too small to handle the available supply of substrate;

- many biogas units are operated inefficiently;
- many of the existing biogas systems are not used due to minor mistakes;
- biogas users tend to increase energy consumption to the point of wastage, then requiring additional energy in the form of firewood.

A more serious problem, however, is the fact that a household biogas system program can only reach the small percentage of farmers who have the investment capital required. The majority of rural households will continue to use firewood, dried cow dung and harvest residues as fuel.

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 CO_2 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 dioxide emissions that would otherwise come from the fertilizer producing industries. By helping to counter deforestation and degradation caused by overusing ecosystems as sources of firewood and by melioration of soil conditions biogas technology reduces CO_2 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 CO_2. Converting methane to carbon dioxide through combustion is another contribution 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 CO_2. But this, similar to the *sustainable* use of firewood, does only 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.