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WASTEWATER TREATMENT AND EXCRETA DISPOSAL IN DEVELOPING COUNTRIES

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Wastewater Treatment and Excreta Disposal in Developing Countries

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PREFACE

It is a matter of fact that about two thirds of the population of the developing nations are living in municipal or rural shantytowns.

Day by day around 25,000 people are losing their lives as a result of poor or non-existent water hygienics, millions of others are becoming unfit for work every year and making a bare living,are pinched with hunger and misery. For the most part, infectious diseases caused by poor hygienic environmental conditions appear to be the cause.

Up to now, attempts to solve the waste water problems in the Third World countries, especially in the large overcrowded areas, have usually been made by introducing sewerage systems in connection with sewage treatment plants, the technologies of the industrialized countries.

As a rule, such methods will not be appropriate for rural districts, small municipalities and outskirts of cities. Here, the shortage of capital, scarcity of water and time restrictions call for more simple and adapted solutions.

What kind of system under what conditions may be defined as "adequate" is determined by a number of factors which are, among other things, the prevailing social and cultural circumstances, the willingness of the population to participate, the potential, various technologies for a reutilization of the raw products like waste water and faecal substances, the planning required or questions of material procurement.

Even this brief insight into the multitude of decisive factors makes it evident that it is barely possible to offer any "set remedies".

Many of the technologies in this manual have been developed and have proved to be succesful in developing countries. But the simple transfer to other social patterns, countries or continents has caused a lot of problems. For this reason it seems essential that engineers, economists, planners and sociologists cooperate in the preparation of projects for the treatment of waste water and excreta in developing countries.

The planning manual is the result of a scientific research project initiated by GATE. In particular we thank Mr. Schneider M.D. and Mr. Stiehler for their assistance. The manual is based on the analysis of the literature dealing with this topic, on discussions with experts of various organizations for scientific research and development aid, on project travels and the collection of data in developing countries.

This manual presents a wide selection of installations, starting from the very simple pit latrines up to compact sewage plants, and gives general planning and practical technical advice.

March 1980 Prof.H.-J. Karpe, M.D.

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1 Necessity for the treatment of wastewater and faecal substances in developing countries

1. Necessity for the treatment of wastewater and faecal substances in developing countries

- Scope of the study -

On the occasion of the water and sanitation conference of the UN held in 1977, the decade 1981 - 1990 was declared the "International Drinking Water and Sanitation Decade". The fundamental principles are a campaign to supply the population living in urban and rural settlements with potable water and the treatment of wastewater. Priority has been given to the rural regions and urban shantytowns which had been neglected up to this time and where about two thirds of the population of the developing countries in question are living. The manual is intended to be applied mainly in these regions. The statistics of the World Health Organization (WHO) - see also Table 1 - show that only 15 per cent of the rural population are connected to sewage treatment plants.

	Population connected to sewage treatment plants in 1977	Population without adequate sewage treatment plants in 1977
Urban areas	437 million (75 per cent)	145 million (25 per cent)
Rural areas	209 million (15 per cent)	1,190 million (85 per cent)

Table No. 1: Statistics of the World Health Organization regarding the treatment of fecal substances and wastewater in developing countries (1) - China excluded -

The unsatisfactory living and working conditions in the rural areas are deteriorating more and more (2). The prospects that the developing countries could counteract this process by their own efforts and to achieve an improvement in the standard of living depend on economic development in such countries as shown for example by a research study of the World Health Organization dealing with the disposal of faecal substances (3) - see also Table 2 -.

The World Bank has estimated that every day about 25,ooo people (9.1 million per year) lose their lives as a consequence of diseases which can be directly attributed to contaminated water, lack of hygienic disposal of faecal substances, or unsanitary conditions in development areas - in connection with undernourishment (4).

Until recently the industrialized countries have regarded the collection of waste water in sewerage systems as the customary and ideal procedure. In the meantime, however, we have come more and more to the conclusion that especially for the prevailing conditions in the developing countries more simple procedures have to be developed and propagated in order to achieve the objectives set by the Water Conference of the UN up to the year 1990 (5).

There are a number of reasons why in most of the developing countries the conventional sewage treatment method cannot find general acceptance, i.e.:

1. Shortage of capital. The costs per capita for conventional sewage treatment plants reach 150 to 650 US $ which is too high compared to an annual income of 100 to 200 US $ (4). On the other hand it should be taken into consideration that the necessary expenditures in rural areas will be somewhat higher than the stated costs of 650 US $ because many rural communities have a lower population density which would require an over-proportionally large drainage system.

2. Shortage of water. Only 13 per cent of the population in developing countries are directly connected to water networks. But even in these areas seasonal, climatic or operational supply problems are found. The conventional sewage network, however, needs a minimum quantity of water to keep the waste effluent in suspension.

3. Time restrictions. The projecting and design of a sewage discharge system requires a considerable period of time. Conditioned by the high birth-rates, the rapidly progressing development in the countries of the Third World calls for steps which could be realized and achieved within a shorter period.

4. Servicing and maintenance. The problem of operating and maintaining conventional sewage and treatment systems could hardly be solved in developing countries because the necessary manpower and working funds are not available.

In accordance with the World Bank and other international welfare and credit organizations special emphasis should be put on so-called appropriate technologies which are independent of sewerage systems. Low cost and simple technological solutions are necessary to solve the sewage and waste problems in countries of the Third World (4).

The intention of the manual is to describe and assess simple and practicable procedures for the sewage treatment and disposal of faecal substances. This manual should enable the planner and self-help groups to build plants which could be cheaply and quickly constructed and are suited to the conditions prevailing in the different countries. Owing to the fact that the stated restrictions are especially marked for rural areas, the technologies described in the manual should be limited to small (2,000 inhibitants) and medium-sized (20,000 inhibitants) settlements in developing countries.

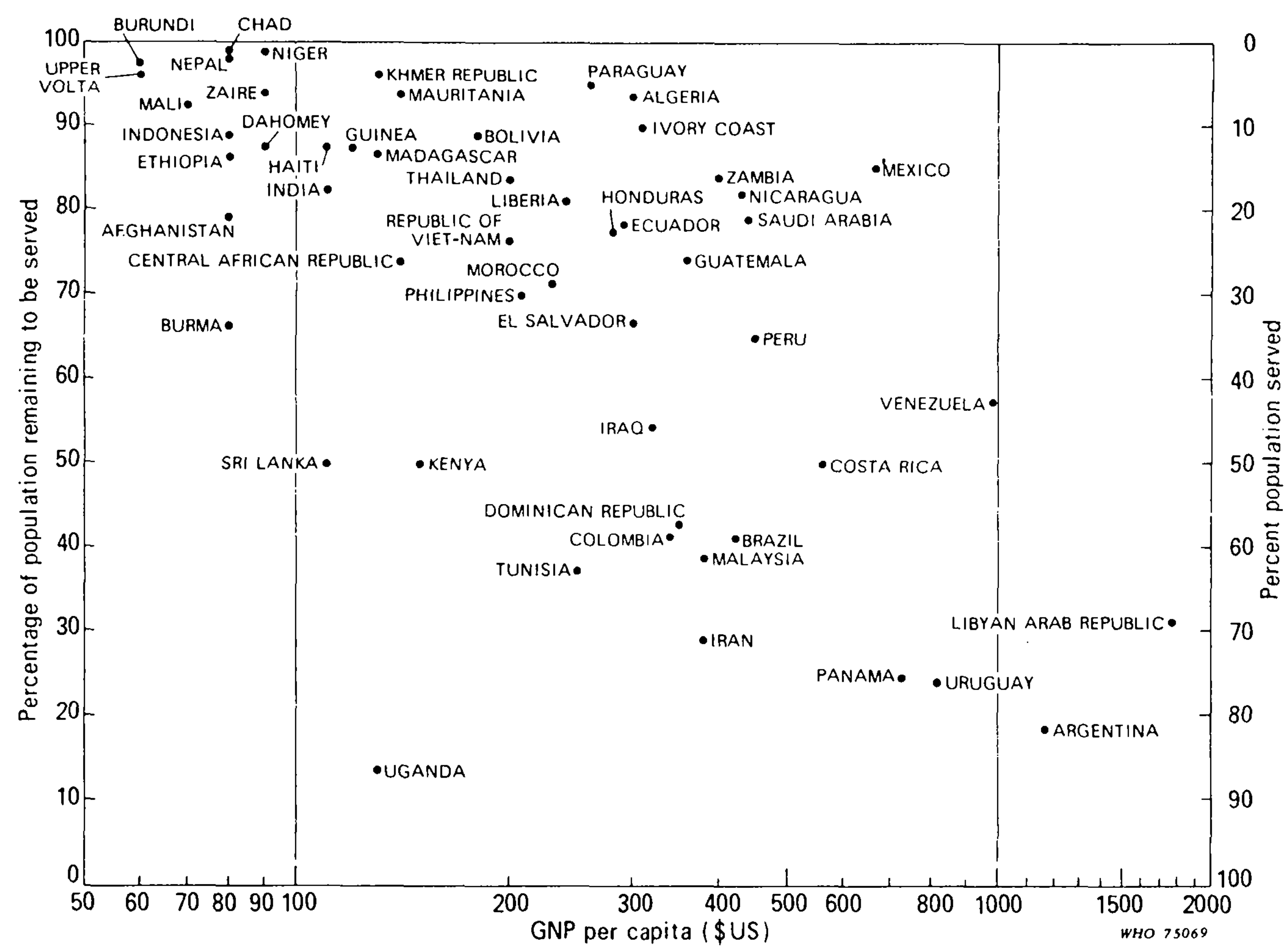


Fig. 2 EXCRETA DISPOSAL SERVICES IN RELATION TO ECONOMIC LEVEL (1970)

INFU

The results contained in the manual are based on extensive studies of standard literature, on discussions with experts and on our own investigations made on the spot in India, Thailand, Malaysia, Egypt, Kenya and Tanzania. Experiences gathered in other developing countries supplements the data obtained.

Each technology has been assessed on the basis of:

- technological requirements
- possibility of realizing the project
- hygienic effects
- financial expenditure
- institutional and socio-cultural effects.

In the course of the study it became apparent that financing and implementation problems have a decisive influence on the introduction of any new technologies. The lack of funds demands the design of plants that as far as possible only require local building materials, which on the other hand will also make possible the cooperation of the concerned population.

Because of the fact that in rural areas almost exclusively organic waste materials have to be treated, re-use is called for to improve agricultural yields, the hygienic treatment of faecal substances and the development of new sources of energy, which will have two basic advantages, namely:

- the improvement of hygienic living conditions by a proper treatment of faecal substances and waste water
- the development of new sources of funds, which will at the same time directly or indirectly have a positive influence on nutrition and health (through the production of fertilizers, the production of biogas or the breeding of fish).

The decision, however, what system might be appropriate under what conditions is largely dependant on the prevailing social and cultural conditions.

The cooperation and the proper training of the users must, for every stage of a building project, be regarded as a prerequisite for the success of all hygienic measures and will later assure independent maintenance of the plants.

A number of the technologies examined have been developed in Third World Countries and have gone through thorough local tests. But a simple transfer to other social structures, other countries or other continents has created problems. For this reason more than sixty typical examples have been chosen for complementary exposition in the manual and are intended to serve as a practical guideline and enable the user to select appropriate technologies. An additional paper including these examples can be ordered from GTZ/Eschborn - Germany.

2 Technologies

2. Technology

2.1 Excreta disposal in single stage plants

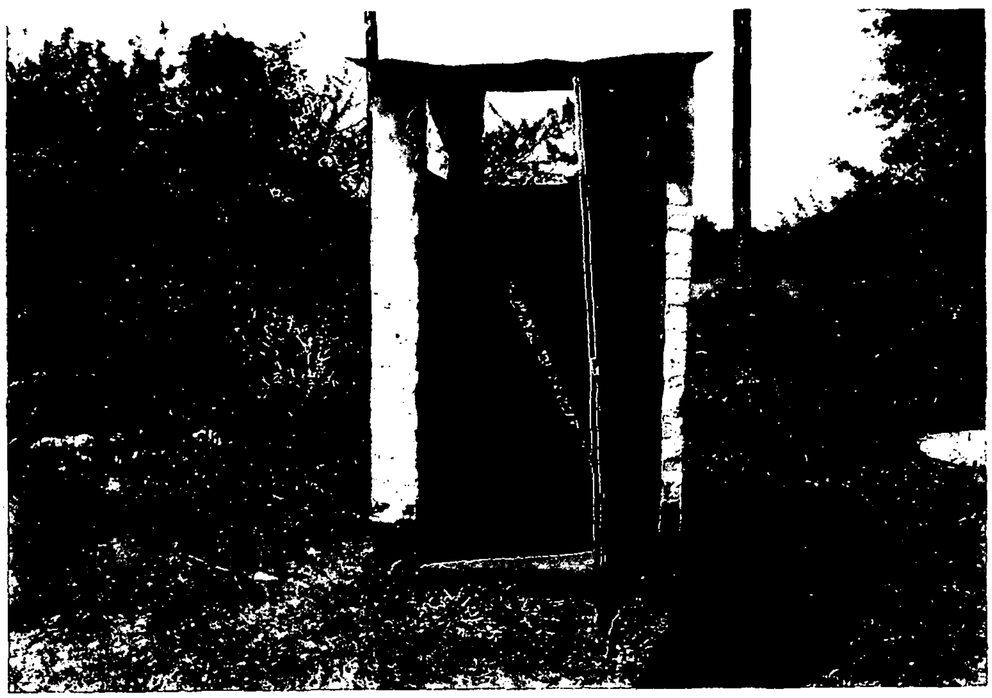
Only few of the rural settlements in developing countries have a communal drinking water supply. This means that excreta have to be cleared away, collected or re-used at the point where they occur. This may be achieved in an economic and simple way in latrines used by a complete family - the socalled single units. In general, such units are made in a very simple way and could, depending on the type of unit, be installed by a self - help - system with material available locally.

The following descriptions will give an idea of what kind of plant is the most suited under given environmental conditions.

2.1.2 Pit Latrines

The pit latrines are the simplest and most widely distributed disposal plants for excreta. They can be utilized not only in rural/rustic areas, but also in municipal districts. These plants are at the same time the cheapest systems for any self-help programs.

Figure 3 shows a simple pit latrine. The excreta falls directly into an excavated pit which normally is neither consolidated nor lined with brickwork. All liquids like urine, cleaning water, etc. can seep into the subsoil. The solid substances are retained and will gradually fill up the pit. As soon as two thirds of the pit is reached, it either has to be emptied or a new pit has to be excavated.



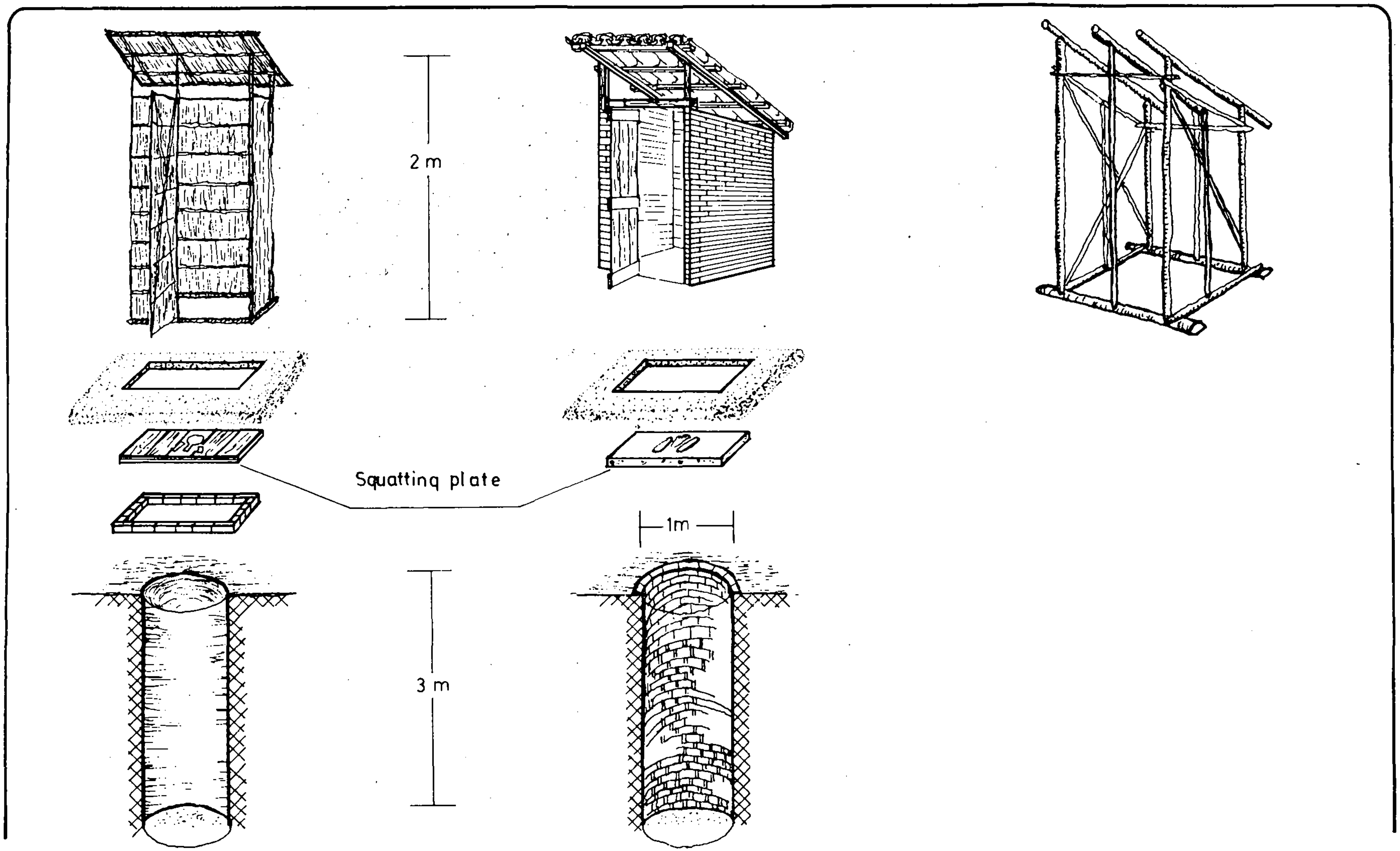


Fig. 3 PIT LATRINES

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Technological description

Construction system of the latrine

The pit and the base slab are covered by a superstructure. In general, the same building materials are used as for the construction of the local houses. Fig. 4 shows some examples.

The construction should satisfy at least the following prerequisites (6):

SIZE

The latrine superstructure should have an area of at least 90 x 100 cm. This also determines the minimum area of the base slab. The height of the roof at the level of the entrance should be not less than 2 m.

VENTILATION

The roof structure should not rest directly on top of the walls. It is necessary to have a gap of 10 to 15 cm in order to assure an efficient ventilation.

ILLUMINATION

Sunlight should be able to illuminate the interior.

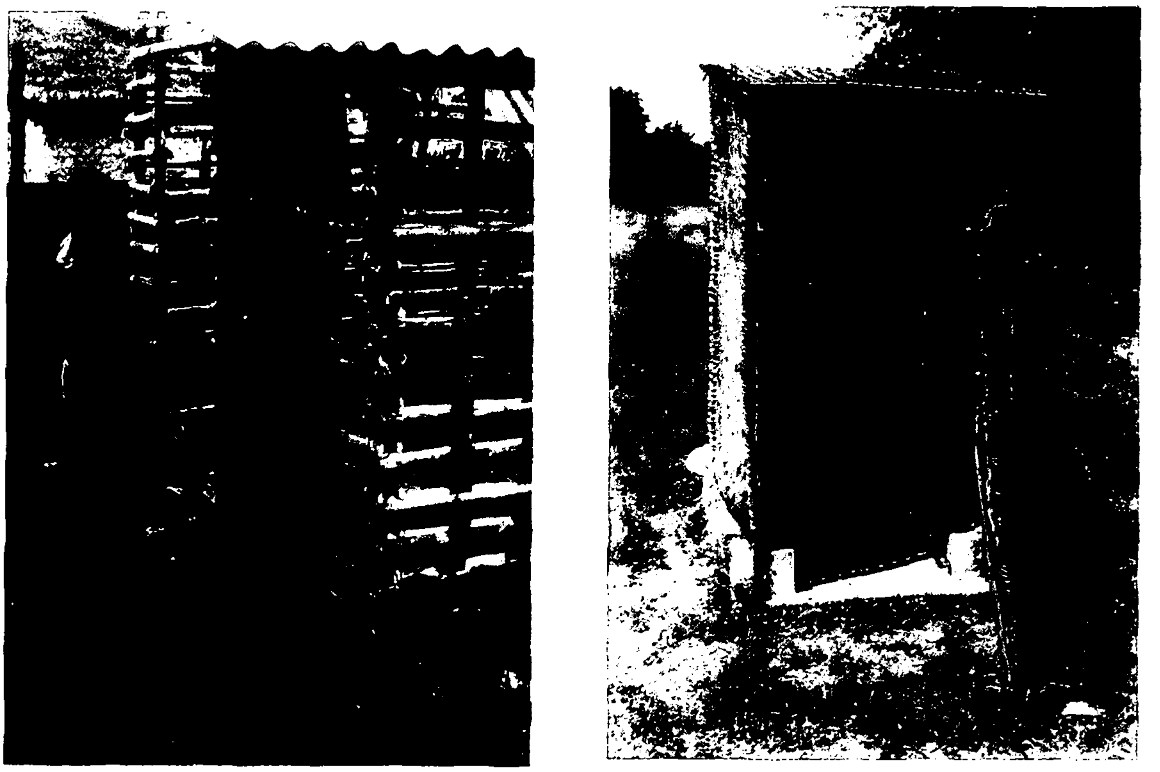


Fig. 4 Toilet superstructure design with local materials

- The base slab

The base slab covers the pit and should have at least twice the diameter of it. Like the superstructure, the slab is made of building materials available locally and should have a smooth and easy-to-clean surface. The supporting surface on the right and left side of the soil opening should be elevated. Examples of typical soil constructions are given in Fig.3. As for all other latrines described in this manual, we recommended not installing seats, which reduce hygiene as they are difficult to keep clean.

- The pit

The pit normally has a depth of up to 3 m and a diameter of about 1 m. Because an increasing of depth increases the danger of collapse, the following principles have to be observed by laymen:

1. Do not excavate pits to a depth of more than 3 m
2. Round pits are better than rectangular ones.

The degradation of the wastes takes place faster in wet pits, which also has the advantage of a prolonged period of utilization (compare below). But the contents should not be allowed to rise above a level of two metres below the ground plate, otherwise ideal breeding grounds for insects are created.

For the calculation of the size of the pit, we can take the following standard formula as a basis:

> The volume required for excreta per year and per capita is 0.06 m^3 in the case of dry pit latrines and 0.04 m^3 for wet ones. This means that a dry pit with a diameter of 1 m and a depth of 3 m could be used by a five person family for a period of six years.

The resulting quantities will naturally vary very much from country to country, in accordance with food habits and the quantities of water available.

As a general rule it can be said that in those countries where vegetarian food is predominantly consumed, the weight of excreta is higher than in other territories because the water content of vegetable food is higher. There, values of 500 grams per day with a water content of 90 per cent are nothing out of the ordinary as compared to the average value in the United States of 150 grams with a water content of 75 per cent. With an increase of the weight of the excreta, however, the frequency of use of the latrine also increases. This means that in many developing countries the latrines are frequented two or three times more often than in Europe or in North America.

Fig. 5 Pan production for a ROEC (Reed Odorless Earth Closet) in Poona/India

- Modifications

a) Ventilated and off-set pit latrines

As an example, the so-called Reed Odorless Earth Closets (ROEC) has been chosen. In principle, the method of operation is the same as the common pit latrines. It offers, however, the decisive advantage that the pit is off-set and can, therefore, have a substantially higher volume and be easily emptied.

The pit is ventilated by a 2 metre pipe. For ventilation, the following conditions should be met:

- The ventilation pipe should be installed on the side exposed to the sun because the air in the pipe is then

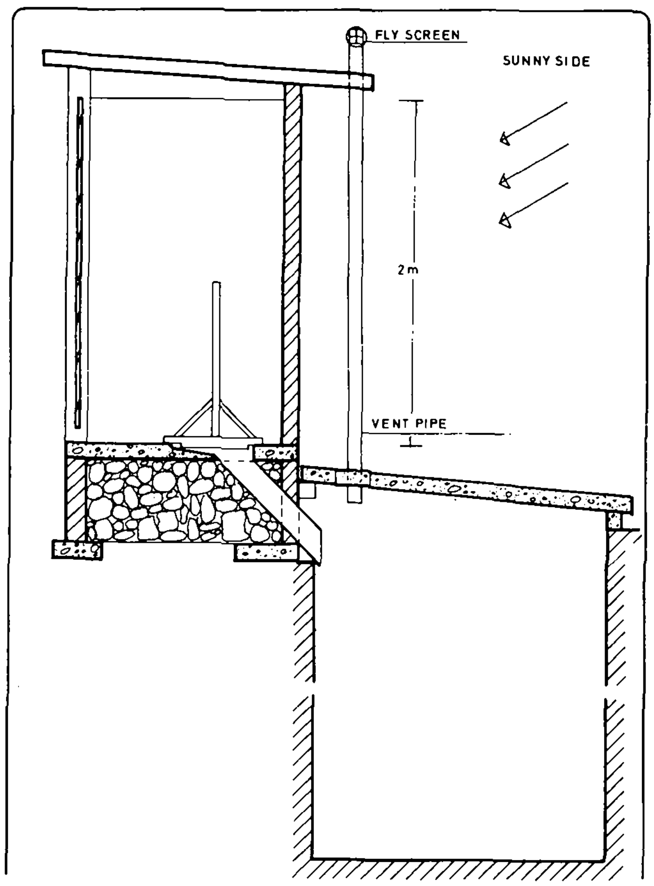


Fig. 6 VENTILATED LATRINE WITH DISPLACED PIT ("ROEC")

warmed up and then rises better.

- The colour of the pipe should be black in order to achieve higher heat absorption.
- The opening of the pipe should be covered by a fly net in order to avoid the formation of breeding grounds.
- The diameter of the pipe should be 150 to 200 mm (compare Figs. 5, 6 and 7) (7).

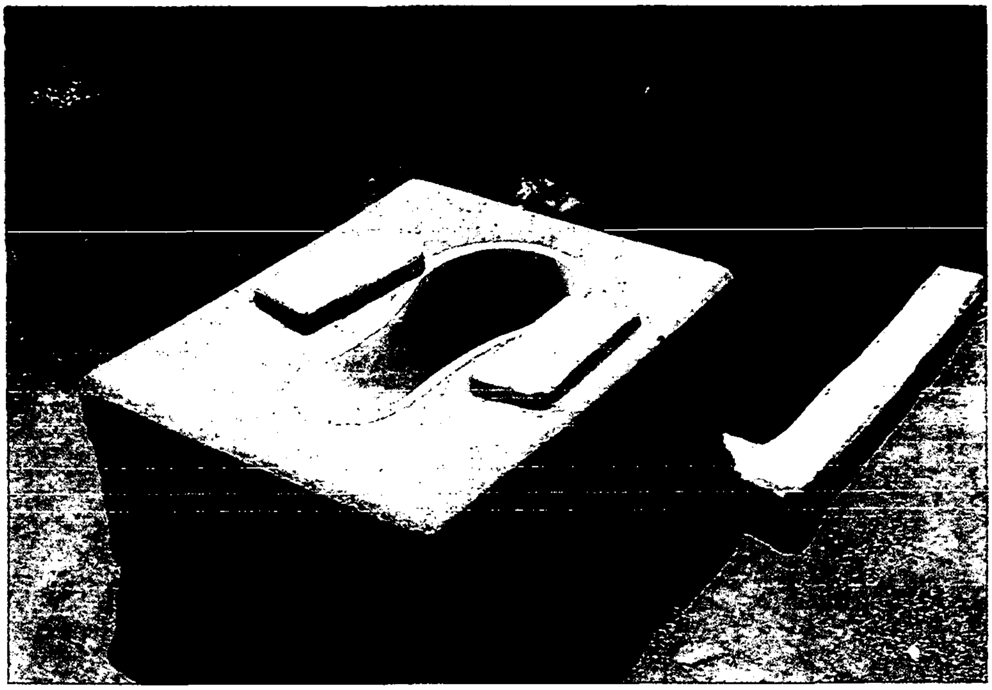


Fig. 7 Squatting plate, pan and soakage pit of an ROEC (Reed Odorless Earth Closet)

b) Water flush latrine (in the Anglo-Saxon literature defined as "Pour-Flush Toilet") (8)

In Figure 8 the setup of such a toilet is shown. The pit is off-set as explained above and separated from the latrine by a siphon filled with water. This system has various advantages:

1. The arrangement of the system allows the installation of the latrine inside houses because of the absence of insect breeding and odour problems.
2. The possibility of alternating pit utilization, as a second pit may be connected when the first one is full (and vice versa).

As a rule it can be said that every time the latrine is used, about 2 to 3 litres of water are required for flushing, which corresponds to an amount of about 10 litres per person per day

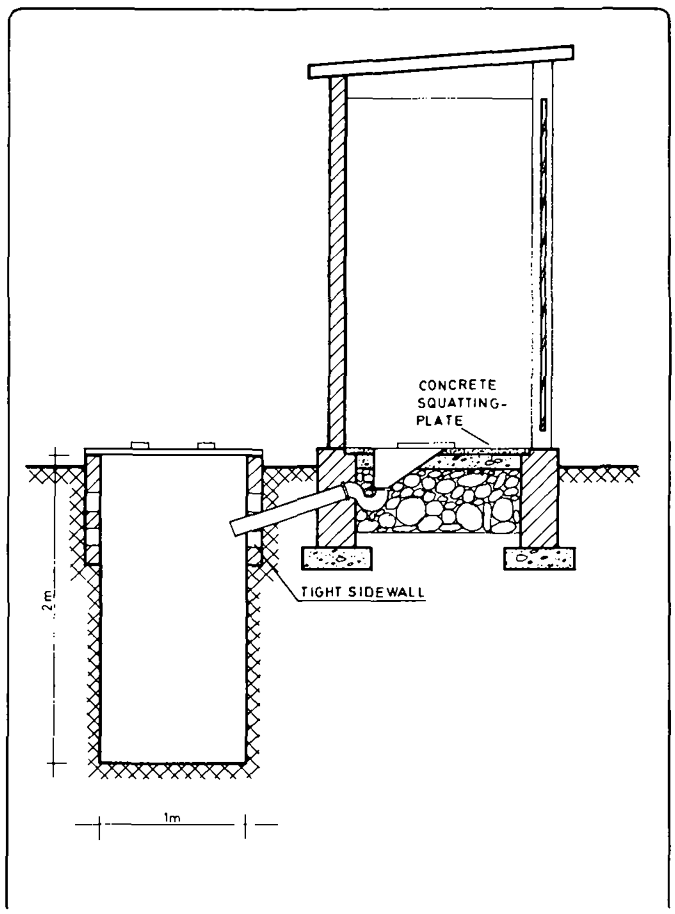


Fig.8 "Pour-Flush"-Toilet INFU (8)

Planning aspects

The following factors have to be taken into consideration when designing pit latrines:

- population density
- ground water level
- consistancy of the subsoil
- water pollution

- Population density

Pit latrines are suitable for low and medium population densities of up to approximately 150 inhabitants per hectare. In such residential districts there are normally one-storey houses and also enough space for two pits one of which is in use while the other serves as a reserve. Under certain circumstances, if the pit can be designed large enough and if provisions are made for the discharge of water, such installations may be built for population densities of up to 500 inhabitants per hectare.

- Ground-water level

If the level of the ground-water is too high, the building of pits will present difficulties. During the rainy season the water may rise rapidly resulting in a collapse of the pits. In such areas it is advisable to refrain from the building of latrines. Where other solutions are not possible, the pits have to be lined with open brickwork (cf. Figure 3). Strict attention should be paid to avoiding flooding of the pits during the rainy season. The consequences of flooding can be illustrated by the following example:

> In the course of a sanitation project, a pit latrine was installed close to the house of one family. During the rainy season the pit was flooded and all the excrement spread around the house. At the same time the region was afflicated by a cholera epidemic and the family suffered the death of one child. Thanks to the financial and technical intervention of the government, a septic-tank system (cf. Section 2.1.4) was installed in such a way as to avoid any future flooding. As a result of the bad experience with the first latrine the new system was not accepted by the family and they emptied all the accumulated excreta, collected in buckets, into a nearby pond which served as their water supply. The consequences were frequent diarrhoea for all members of the family.

- Consistancy of the subsoil

In the presence of rocky subsoils, the idea of installing a pit latrine has to be abandoned. On the other hand, nor is it feasible to excavate simple pits in sandy subsoil because of the danqer of collapse. In this case, a reinforcement has to be provided (cf. Figure 3).

- Water pollution (cf. Figure 9)

The installation of pit latrines will always involve the risk of contaminating the ground-water or neighbouring surface waters. The following two basic requirements must be met when determining the location of pits:

- The pit should not be installed within a radius of 30 m from any well or any drinking-water reservoir.

- In order to avoid the contamination of drinking water due to ground-water flow, pits should never be placed uphill of any drinking-water well.

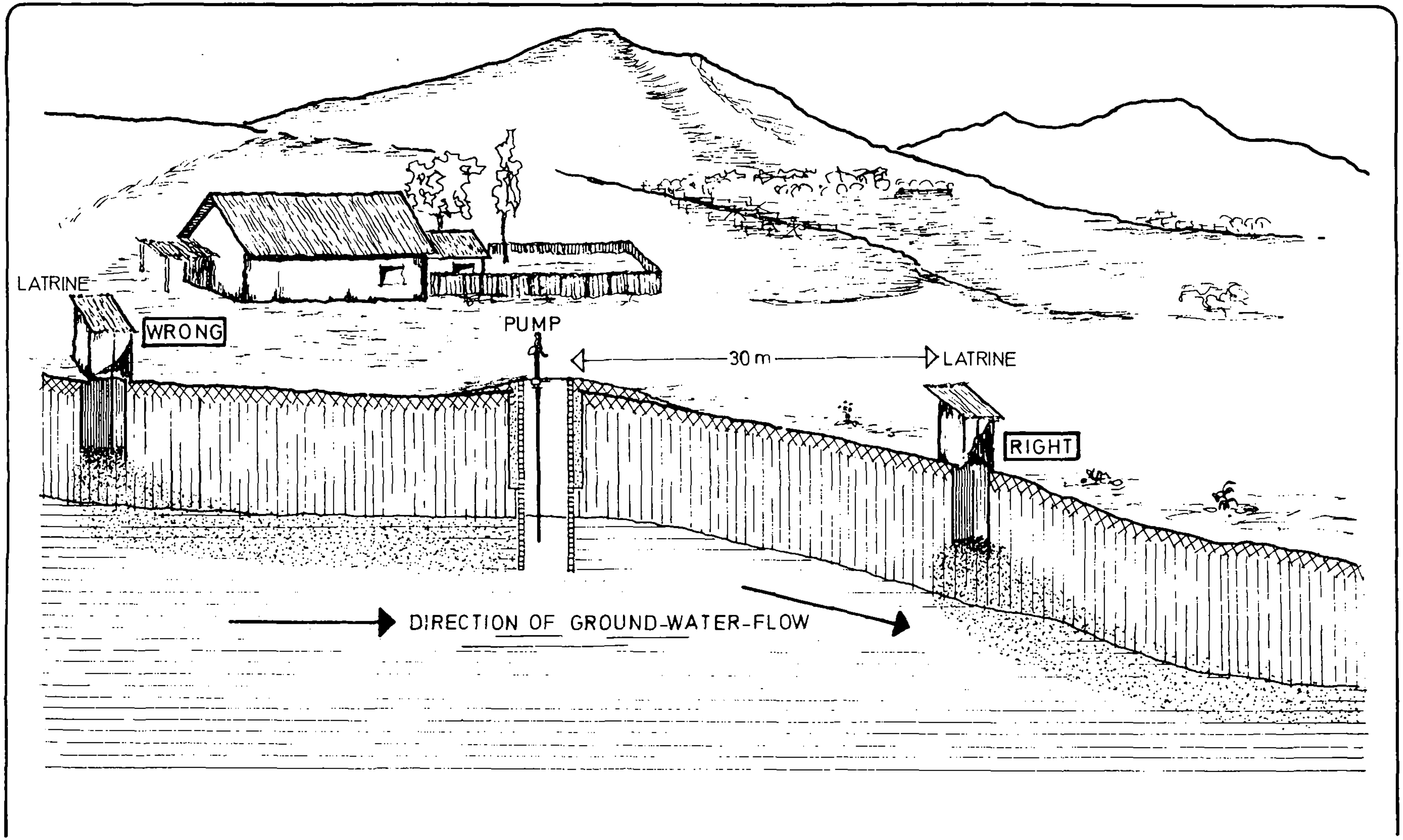


Fig. 9

GROUND-WATER-FLOW AS CRITERION FOR LATRINE POSITION

INFU (6)

Health aspects

Keeping latrines clean is of the utmost importance for hygienic conditions. The consequences of improper care are dirty and malodorous basins or, in the case of water-flush latrines, clogged basins. The main cause of such conditions may be attributed to the fact that latrines have been installed in regions where the population was accustomed to using the open fields and no instruction was given about the use of the latrines. Very often it happens that the overall hygienic situation changes for the worse after the installation of latrines due to an increase of contact with excreta. Pit latrines without any ventilation can spread evil-smelling odours with the result that they are avoided.

Another danger is caused by pits with a high ground-water level as these pits present an ideal breeding-place for insects that carry tropical diseases like filariasis. Remedies which may be applied are the installation of adequate ventilation and the construction of water-flush latrines (cf. Fig. 5).

It is common practice when pits are filled up to two third that they are closed and emptied after many years or not emptied at all. In this case the danger of pathogenic germs remains unimportant because all organisms will have died off in the meantime. In several countries it is common practice to utilize two pits alternatively. This has the advantage that one pit may be closed for one or two years whilst the other remains in use. After a minimum retention period of one year most pathogenic germ will have died but there is still the propability that the eggs of helminths (Ascaris) exist. Especially in the case of wet pit latrines, there should be a minimum detention period of 12 month before using the content as manure. In general we can say, that single-cell organisms and eggs of helminths will not play any decisive part because they will be retained very easily by the ground because of their size. On the contrary, viruses and bacteria have to be considered as organisms of sustantial influence. Bacteria can survive in groundwater up to 5 month, whereas viruses survive up to six month and more. An imminent danger to health exists, if the contaminated ground-water is then reused as drinking, washing or bath water.

In general the following rules should be observed:

Whenever pit latrines are in common use in densely populated areas (from 200 inhabitants per hectare onwards),care should be taken to fulfil the following three conditions:

1. Drinking water sources should always be sbjected to continous hygienic investigation;

2. drinking water should be supplied from unpolluted areas over a piping system;

or

3. other disposal plants for excreta should be built.

In general, the second possibility is the most economic and feasible one.

Institutional aspects

The construction of pit latrines is quite simple and should, therefore, be carried out as far as possible by self-help. The biggest problems are encountered in all regions where latrines had previously been unknown.
In all these cases the local administration should give a helping hand by the publication of measures regarding the design standards, credit terms and financing. In addition, the installations should be checked several times to inspect utilization and maintenance. If the filled up pits need to be emptied, the local administration should provide an adequate dumping area for the resulting sludge (cf. Section 2.2.3).

Summary and recommendations

Pit latrines are built and used all over the world. In view of this fact and, of course, the circumstance that the construction characteristics will only deviate slightly from one country to another, the following universally valid statements can be made:

1. Pit latrines should only be installed for a population density of up to 150 inhabitants per hectare of land.
2. The pit should be arranged at a minimum distance of 30 m from the next well.
3. The latrine should always be at a minimum distance of 10 m from the house.
4. In the case of a rocky subsoil the installation of pit latrines should not be taken into account.
5. In the case of a sandy subsoil, the pit has to be consolidated.
6. The pit should never be installed uphill of a drinking-water reservoir.
7. Every pit has to be ventilated by a pipe.
8. Superstructures should be provided with vent holes.
9. The pit should have a depth of 3 m and a diameter of about 1 m.
10. Round pits should be dug rather than rectangular ones.

2.1.3 Composting Toilets

Should it be intended to process excreta into compost, the following essential condition has to be met:

The compost must be free of pathogenic organisms.

The two most important factors influencing this are:

- the detention period and
- the temperature.

In contrast to pit latrines, all composting procedures require additional organic matter, for instance domestic wastes, sawdust or similar additives in order to obtain a favourable ratio for the reduction process; C : N should be between 20 to 30 : 1. The ratio for excreta and urine is, in general, between 6 to 10 : 1 which is also demonstrated by the following analysis (10):

Humidity:	95.0	per cent
Organic matter:	3.4	" "
Ashes:	1.6	" "
Nitrogen:	0.57	" "
Sulphur:	0.052	" "
Potassium:	0.22	" "
Sodium chloride:	1.02	" "

In principle, there are two different types of composting toilets, which are dealt with in some detail below.

Technological description

Batch composting (cf. Fig. 11) (9)

Batch composting toilets are usually built up with a two-pit system. As soon as one pit is filled up to two thirds, it is topped up with earth and closed, the second one is then used. When the second one is filled up, the first one has to be emptied and put into service. This type of toilet provides an anaerobic composting.

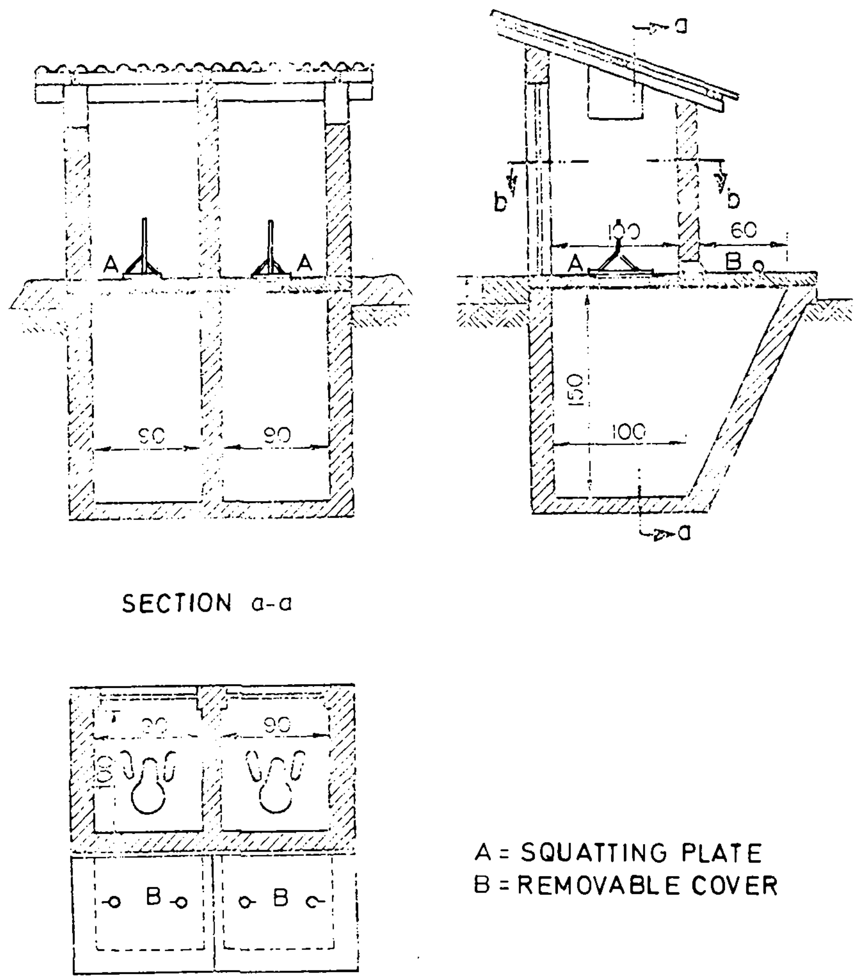


Fig.11 DOUBLE-VAULT COMPOSTING TOILET

INFU (9)

- The pit

The pits of a double-vault composting toilet are in principle comparable with those of pit latrines (cf. figure No. 11). The vaults, which are built next to one another, are alternately used. This allows longer composting periods. The vaults are accessible from outside and are emptied by hand.

The design capacity of the pit depends on the necessary quantity of compost and the number of persons using the toilet. To design the pit, the following standard formula should be used. A pit designed for a discharge period of one year should have the following capacity, assuming a waste volume of 0.3 m^3 per person per year:

$$V = 1.33 \cdot 0.3 \cdot P = 0.4 \cdot P \quad (m^3)$$

whereby

1.33 Factor considering that pit has to be emptied when it is 3/4 full

0.3 is the waste volume per person and year

P is the number of persons

Under these conditions, all the pathogenic organisms and some worm ova are killed.

Prior to the initial use, the ground of the pit has to be covered with a mixture of peat or humus and grass in order to "inoculate" the excreta for the subsequent composting process.

Continuous composting

For the continuous composting, only one pit is required. All the designs are based on a Swedish principle, the so-called "multrum toilet" (cf. Fig. 12).

In contrast to the batch composting toilets, the composting occurs by a thermophilic process, by the bacterial activity a heat is generated which develops temperatures of up to 60 °C in the digesting compartment. Because of the heat development all the pathogenic organisms and even the extremely resistant Ascaris ova are killed. It must be admitted that some investigations carried out in Tanzania and Botswana showed that the digestion temperature was only slightly higher than the open-air temperature. It can thus be concluded that in these toilets

a) the composting process was not aerobic and

b) that the composting process was incomplete.

- Superstructure of the toilet

The design and the materials to be used are identical with those of the superstructure described in Section 2.1.2.

- Base slab

For the design and material, please refer to Section 2.1.2.

- The pit

The pit of the continuous composting toilets is composed of the composting chamber and the humus pit.

The composting chamber has the same cross section as the superstructure, and the ground is inclined by about 20° (cf. Figure No. 12). The vault which has to be completely bricked up has a depth of 90 to 150 cm and is traversed by grates with the shape of an inverted U or V. All the excreta, grass, straw, sawdust, ashes, etc. fall onto the grates, which are spaced by narrow slits and compost there. The digested materials finally fall into the humus pit and have to be removed at regular intervals. The moisture of the humus depends on the nature of the organic materials and the quantity of water used for cleaning the latrines and should be approximately 40 to 60 per cent.

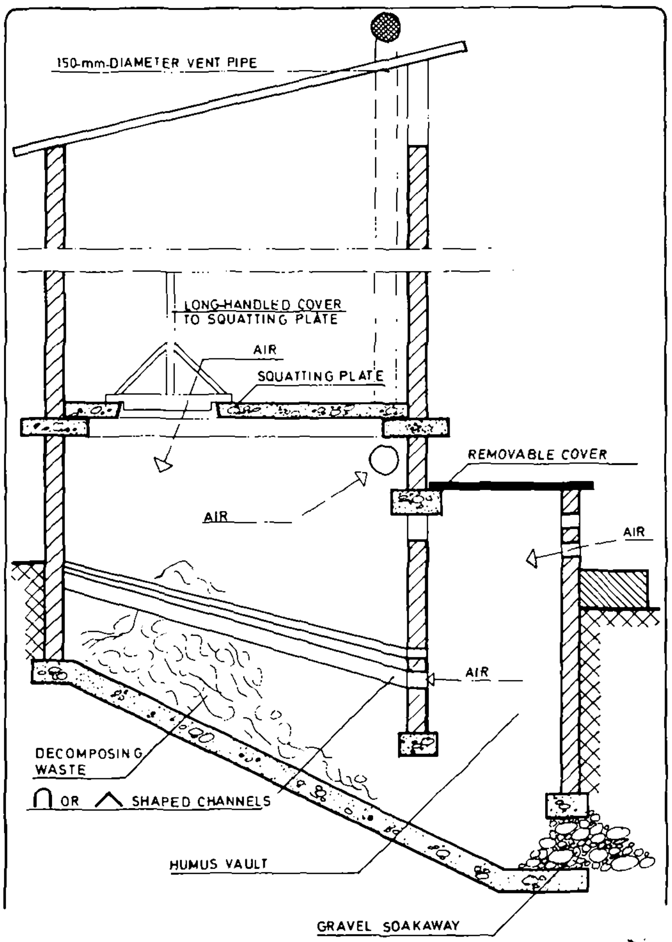


Fig.12 'MULTRUM' CONTINUOUS-COMPOSTING TOILET INFU

Planning aspects

When designing composting toilets, the following three points have to be taken into consideration:

1. Are there any culturally conditioned reservations against re-utilization of excrements ?

2. Are there sufficient possibilities for an appropriate use of the humus ?

3. Can an adequate maintenance be assured ?

The first question is conditioned by the religion and traditions of each single country or region. This question will be considered in detail in ection 3.1.

The possibilities of an utilization of the humus are to a large extent dependent on the population density. In case of a high density (more than 300 inhabitants per hectare) there are usually no gardens or only very small ones. In such cases the construction of these systems would be pointless.

On the other hand, preference should be given to batch composting rather than to pit latrines whenever difficult ground-water conditions have to be faced. This is the reason why Kilama et al. (11) recommends this type even for regions with high ground-water levels. But it is then advisible not to design the toilet for more than 8 people. It should also be taken into consideration that continous composting toilets demand high maintenance expenditure and that up to now it has not been established under what conditions the composting process could proceed in the best possible way.

For this reason the World Bank does not advise the construction of continuous composting toilets in the tropics (12).

Health aspects

The compost product of composting toilets is used as fertilizer. This presupposes that as far as possible all pathogenic organisms have been destroyed, for which temperature and retention period play a decisive part. The temperature itself is dependent on the C/N-ratio, the humidity and the atmospheric conditions. During an anaerobic process, which occurs during the composting by charges, temperatures of 35 ^{o}C are normally reached. During an aerobic process, as in the case of the continuous composting, temperatures ranging between 50 and 70 ^{o}C are reached, depending on the conditions prevailing.

Difficulties are encountered especially in those arid areas where only a few organic wastes can be added to the excrements. It should also be noted that in the case of false or insufficient servicing of the continuous composting toilets the digestion can proceed under anaerobic conditions as observed in the test installations in Botswana and Tanzania (12). The table No. 13 gives us a synopsis of the life duration of different pathogenic organisms under anaerobic conditions. It can be seen that the compost will be completely free of all infectious agents after three month; exceptions are some resistant worm ova. Owing to the fact that these can only partially be destroyed even after a period of ten month, the following possibilities should be taken into consideration in order to minimize the health risk as far as possible, i.e.:

1. The compost should be taken out onto fields at the latest three weeks before the harvest season.

2. As far as possible, the compost should be used for improving the soilbefore planting. Up to the harvest, enough time will pass.

PATHOGEN	Retention Time (Months)						
	1 mth	2 mths	3 mths	4 mths	6 mths	8 mths	10 mths
Enteric viruses	+	+	0	0	0	0	0
salmonellas	+	+	0	0	0	0	0
shigellas	+	+	0	0	0	0	0
Vibrio cholerae	+	0	0	0	0	0	0
Path. E. coll	+	+	0	0	0	0	0
Entamoeba	0	0	0	0	0	0	0
Ascaris	++	++	++	++	+	+	+
Trichuris	++	++	+	+	+	+	0
Hookworms	+	+	0	0	0	0	0
Schistosoma	0	0	0	0	0	0	0
Taenia	++	++	++	++	+	+	+

0 Probable complete elimination

\+ Probable low concentration

++ Probable high concentration

Fig. 13 PATHOGEN CONTENT ANTICIPATED IN FINAL PRODUCT OF ANAEROBIC COMPOSTING TOILETS

INFU (13)

3. The compost should be used as fertilizer for fodder crops.

4. The pit should be arranged in such a way as to make possible a minimum detention period of six months to assure that diseases due to contaminated fertilizers will only be found in exceptional cases.

Health hazards due to flies, or odour annoyances, can to a large extent be eliminated by proper ventilation and by keeping the base slab clean (cf. Section 2.1.2).

Institutional aspects

In general it may be said that the installation of composting toilets is too complicated to be carried out by any self-help programs. For this reason, the local administration has to place primary emphasis on assistance to the construction and servicing of toilets if it intends to build such units within its sphere of influence. Besides appropriate financing, a training program has to be carried out to guarantee faultless operation.

Before going into fundamental consideration on the questions of location, construction, etc. it is imperative to find out if the population concerned would be prepared to fertilize with humus produced by the composting of human excreta.

Summary and recommendations

Composting toilets which receive continuous attendance are not very common in developing countries because they are expensive, require a regular and frequent servicing and because proper running conditions depend on many other factors.

As opposed to the aerobic procedure, toilets for composting excreta and other wastes by charges can be built in a much simpler way and demand lower service expenditures. Usually two pits are built beside one another and used alternately year by year. In contrast to the continuous composting process, the composting is in this case an anaerobic process taking place at a temperature of about $36\ ^{o}C$.

It is recommended not to construct continuous composting toilets in any developing countries because the batch composting is simpler and safer from the hygienic point of view.

2.1.4 Aqua Privies and Septic Tanks

Beside simple pit latrines, septic tanks are the most common installation for simultaneous disposal of excreta and household waste water, in the absence of puplic disposal installations. These tanks have the decisive advantage that in principle they can be connected later on to any public network.The tank will then serve for a certain preliminar treatment preventing a large quantity of solids from flowing into the sewerage system, a very important point especially in hot climate zones (clogging risk, velocity of flow of about 1 m/sec.).

Fig 14 shows a toilet with practicable designs for septic tanks or aqua privies.

Technological description (14), (15)

- Superstructure of the toilet:

The design and the materials to be used are identical with those of the superstructure described in Section 2.1.2.

- Base slab

Depending on the type of the tank, a chute or a siphon basin are embedded in the base slab. Similar to the pit latrines there is a difference between tanks placed directly under the base slab (aqua privy) and off-set tanks connected by a pipe (septic tank).

a) If the tank is placed directly under the toilet, a chute with a diameter of 100 to 150 mm is inserted into the base slab. The end of the pipe should reach 10 to 15 cm below the water level. The level remains constant because the discharge pipe equalizes any rise in the water level.

b) If the septic tank is off-set - which is especially practical in those cases where the installation of a toilet inside the house is intended - a siphon basin has to be inserted in the base slab(cf. section 2.1.2).

- The tank

The method of operation and the design of the tank are completely independent of the way in which the excreta and/or waste water flows into the tank. The average detention period of the sullage is 1 to 3 days. During this period, the solid substances sink to the bottom of the tank where an anaerobic reduction process takes place. The very light substances float on the surface and form a layer which furthers the anaerobic process. Due to the biological activity a reduction of the sludge volume allows an operation period of many years without sludge removal, depending to the number of users. In order to make a rough estimate of the intervals for sludge removal, a quantity of sludge ranging between 0.03 and 0.04 m^3 per year and per capita may be assumed.

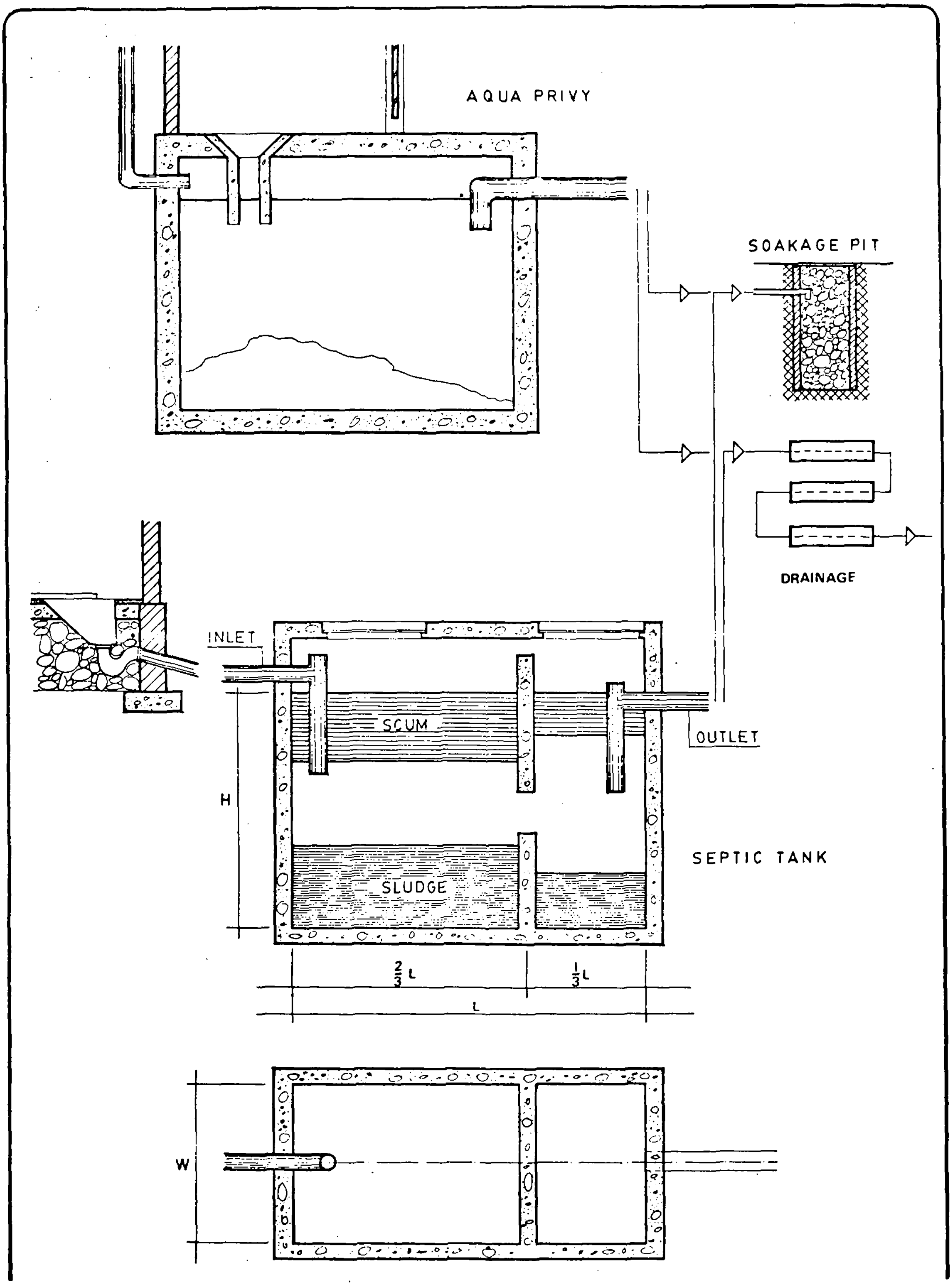


Fig. 14 SECTION AND PLAN OF AN AQUA PRIVY AND SEPTIC TANK

INFU
—

Dimensioning of a septic tank according to (16)

Construction of a septic tank for a twelve-person family with a water consumption of 100 litres per capita per day.

It is assumed that 80 per cent of the total water consumption will flow into the tank as sullage where it is expected to be retained for three days. The capacity of the tank should then be:

$$(0.08\ m^3 \text{ per capita per day}) \times (12 \text{ family members})$$
$$\times\ (3 \text{ days retention time}) = 2.9\ m^3$$

Knowing the design capacity V, the individual dimensions of the septic tank could be established on the basis of Fig. 15.

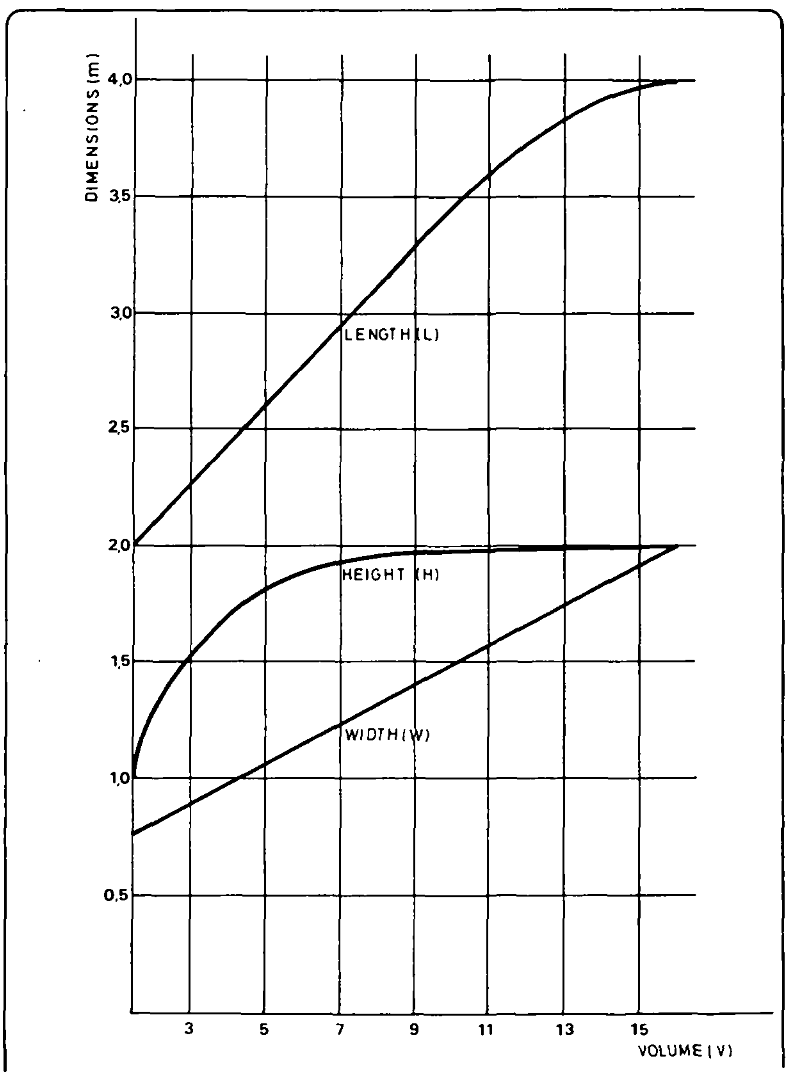


Fig.15 DIMENSIONS OF A SEPTIC TANK IN RELATION TO ITS VOLUME

INFU (17)

For the example in question, the following dimensions would apply:

1. Length (total): L = 2.30 m
2. Height of the sludge layer H = 1.50 m
3. Width of the tank: W = 0.85 m
4. Subdivision of the tank with L/3 = 0.75 m

Assuming a sludge volume of 0.04 m^3 per capita and year, the following sludge removal interval is reached:

(0.08 m^3 per capita per day) / (0.04 m^3 per capita per year) = 2 years

As shown in figure 14, preference is actually given to a tank divided into two parts. The first subsection has double the capacity of the second one and a depth of 1 to 2 metres. As soon as the tank is filled up to about one third with sludge it has to be emptied and cleaned.

Owing to the reduction process of the sludge, bubbles are formed which rise drawing with them light sludge particles. These accumulate at the floating sludge layer which may build up to such a height that the tank ceases to operate. This has lead to the recommendation to connect a second tank. All light particles then flow into this tank by the overflow and are deposited in calmer water.

Material:

All septic tanks should be made of concrete, reinforced concrete or clay bricks. It is advised not to use any materials , prone to corrosion.

Aeration:

As the reduction process takes place anaerobicly, tank ventilation is not necessary and it is sufficient to use the upper part of the inlet pipe as a pressure equalizer (cf. Fig. 14).

Servicing:

A manhole should be provided in the tank cover at both the inlet and outlet so that clogged pipes can be cleared and the necessary checks carried out.

Purification and disposal of the sullage:

The discharge from aqua privies or septic tanks must not be fed into surface or ground water because it may still contain some pathogenic organisms.

There are two possibilities for the purification of the sullage:

- purification in sewage treatment ponds (cf. section 2.2.2)
- disposal through soakaway pits or drainfields.

The use of drainage systems depends on three factors:

- the density of the population
- the risk of contaminating the ground water
- the quantity of waste water.

The quantity of the wastewater produced determines the demension and/or the necessary filter surface. If a soakaway pit is built according to the principles shown in Fig. 16, an infiltration rate of 50 litres per square metre, per day and per capita may be assumed for normal soil conditions. If the total quantity of sewage produced is known, the required dimensions for the tank can be read off from the graph.

If the daily effluent of waste water exceeds 2,000 litres, the only recommendation that can be made is to provide a drainage system with the values shown in Figure 17. The clarification is bacteriological. A biological slime forms on the stones in the tank or on the ground at the sides and decomposes all the sullage during infiltration into the ground. In the case of large-scale installations and a population of 100 inhabitants per hectare and more, it is advisable to provide communal installations, as for instance sewage clarification ponds (cf. Section 2.2.2).

Aqua privies

Aqua privies are very common installations, generally having, however, a lower purification capacity than septic tanks. They consist of one compartment (cf. Figure 14) which is dimensioned on the basis of 0.12 m^3 per user, with a maximum capacity of 1 m^3. This means a sludge removal in intervals of 2 to 3 years if the tank is emptied when filled up to two thirds. In the same way as with septic tanks the overflowing sullage is led into the subsoil, into stabilisation ponds or to filters. However, because the health risks are considerably higher, we can only recommend refraining from the construction of aqua privies. In certain countries, e.g. in Zambia and Nigeria, it is common practice to connect aqua privies to public sewerage systems, which in our opinion is not suitable in the case of new designs.

If there is a sufficient water supply and/or sewerage possibilities, for hygienic reasons preference should always be given to the septic-tank system. Should it be necessary, however, to procure the necessary amount of water first, the idea of building both types of toilets should be abandoned and more practicable systems, like aerated pit latrines (cf. Section 2.1.2), should be considered.

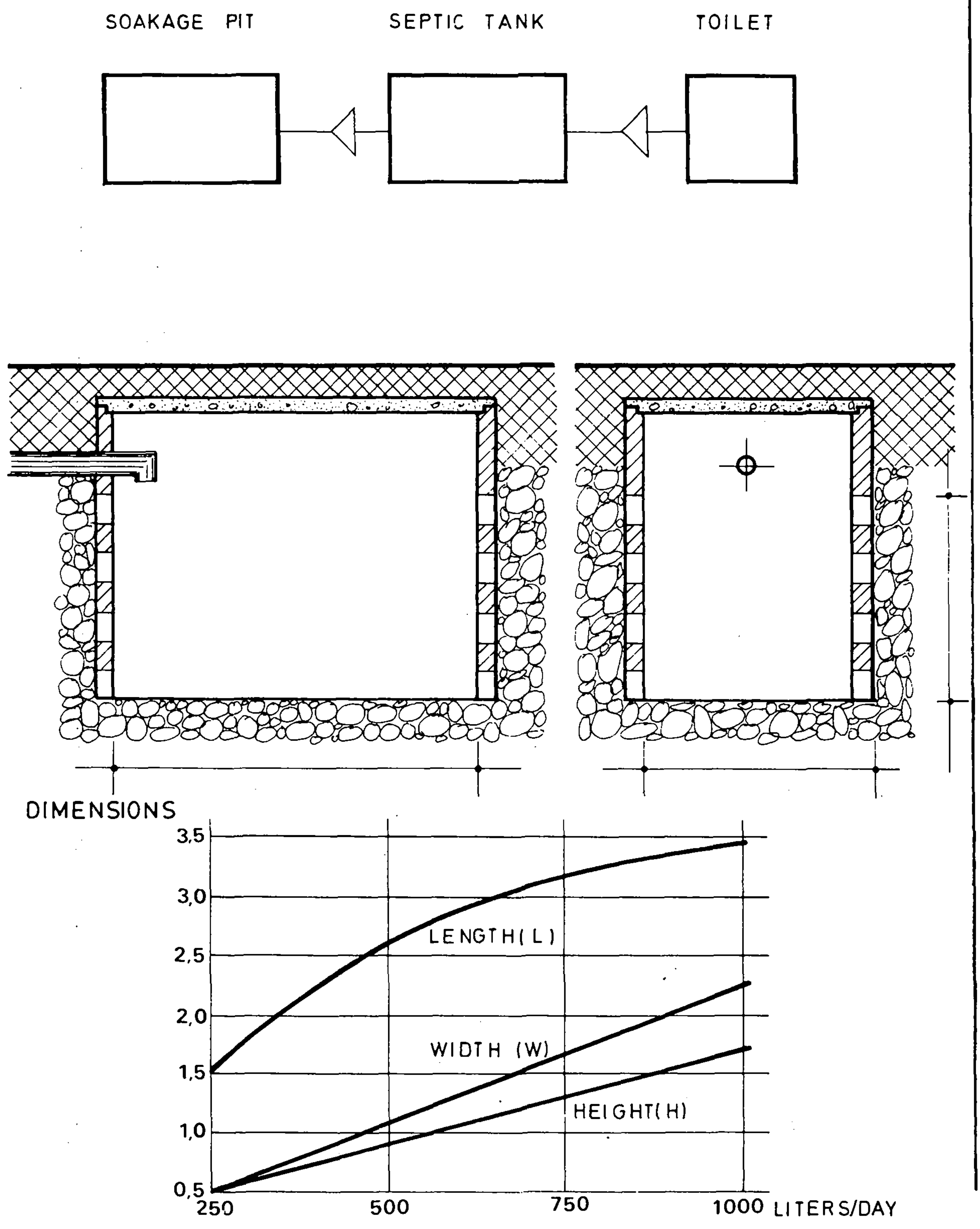


Fig.16 SIZE AND DESIGN OF A SOAKAGE PIT

INFU (17)

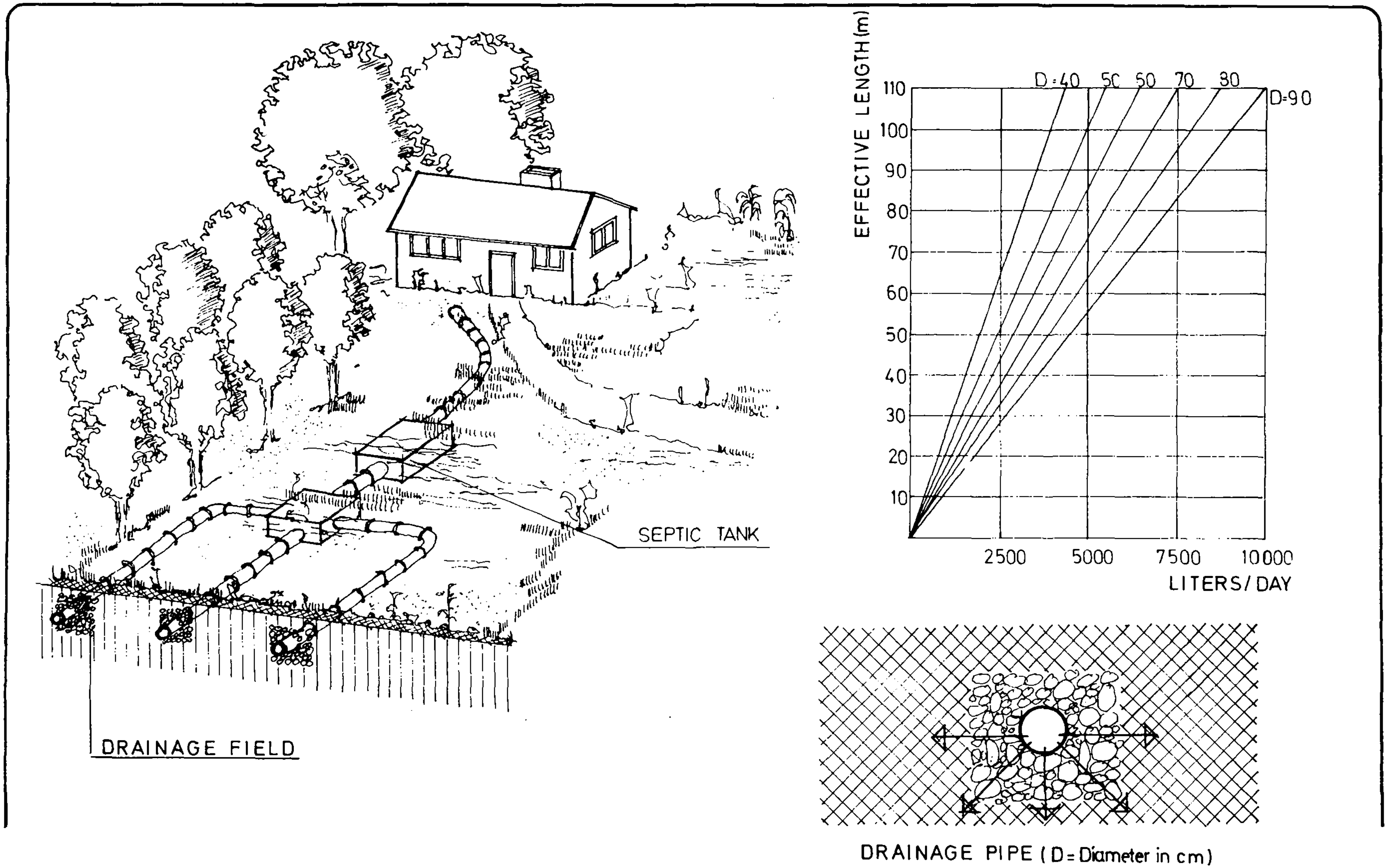


Fig.17

DRAINAGE SYSTEM FOR SEPTIC TANK EFFLUENT

INFU

Planning aspects

The installation of toilets with chutes (aqua privy) and septic tanks requires the following two things:

1. The existence of a sufficient water supply in the house.
2. A sufficient area for infiltration systems must be provided if a connection to a sewerage system cannot be envisaged from the outset (maximum population density: 200 inhabitants per hectare) (18).

As standard values for the distance to water cisterns, domestic buildings and other design fundamentals, the data given in Section 2.1.? for pit latrines should be taken as standard values. The position of the pit corresponds in this section to that of the soakaway pit.

Health aspects

The removal of microorganisms in septic tanks takes place by sedimentation of the sludge particles. For this reason the detention time in the septic tank is not only important to assure the necessary time for the sedimentation of the solid substances, but also for reducing the content of pathogenic germs.

A second criterion essential to hygiene is given by the design of the septic tanks. In this connection, special attention should be given to achieve calm and unturbulent zones which will enable sedimentation. As already explained, this could be achieved by a series of several connected tanks.

The detention time in aqua privies or septic tanks is decisively dependent on the amount of sludge in the tank (19). If the gradually accumulating amount is too high, the detention time is reduced too much resulting in an expectable increase of infectious germs in the outlet. If not enough waste water is added the water level drops so much that the down pipe is no longer submerged in the water which causes a very intense odour and fly nuisance.

Another health risk could crop up during desludging. As fresh sludge is normally recharged with pathogenic germs of every nature and kind, this fact calls for a careful handling and deposition.

Pathogenic germs contained in the sullage outlet of septic tanks have to be taken as a matter of fact which makes it indispensable to provide sufficient space for a second purification stage. Because of this we recommended not to feed the overflow of septic tanks directly into any ponds where a fish culture, a vegetable culture or other recycling processes are intended (cf. section 2.2.3).

Institutional aspects / Service

The local administration should be in a position to carry out regular sludge removal. This means that it also has to be ensured, that sludge dumping areas and the necessary vehicles are available, the cost of which can be gathered from the studies of individual cases contained in a seperate paper, which can be ordered from GTZ.

Servicing and/or sludge removal work have to be undertaken whenever the scum on the water in the tank has reached a height only about 5 cm (cf. Fig.14). It is also advisable to de-sludge when the surface of the settled sludge layer is about 20 cm below the outlet. It should be possible to obtain this data quickly and without great expenditure. After a more extended running time, empirical data will make it possible to establish the de-sludging intervals. The two following methods of measurement may be easily applied to determine intervals:

a) Determination of the crust thickness

Nail a panel with a diameter of about 15 cm on to the end of a stick and push it through the scum at one point. Push away the broken scum until you reach an undamaged piece and lift it up carefully until the underside of the scum meets the panel. Establish the height of the outlet pipe in the same way; the resulting difference in height will indicate when the tank has to be de-sludged.

b) Determination of the thickness of the sludge layer

Wrap a white cloth round a stick over a length of about 60 cm from one end and introduce this end carefully into the sludge layer. Then draw out the stick slowly after a few minutes. The cloth will be blackened up to the level of the sludge layer.

Should it be intended to connect septic tanks to a public sewerage system, the authorities will also have the duty to take care of the servicing of the drainage system and the subsequent purification (cf. in this connection the administrative possibilities, outlined in Section 2.2.1).

The user has to take care that the system always contains a sufficient quantity of water and that the base plate of the toilet is always kept in a clean condition.

Any new septic tank should always be filled with water before the first use. It will then take some weeks until the biological decomposition process has become stabilized. During this period, there might be certain odour nuisances.

To start the decomposition process and shorten the initial period substantially we recommend to adding some buckets of sludge taken from an installation in operation. Should this not be possible, a handful of slaked lime should be added to the tank every day in order to check the development of any bad odour. Especially in African countries the decomposition process has been initiated by addition of animal carcasses (cats, fish, poultry). But this is futile because these carcasses do not fulfil the intended purpose and clog the effluent channels (20).

Summary and recommendations

A distinction must be made between two types of tanks, i.e.

1. Aqua privies where the tank is positioned directly under the toilet. These represent a simpler form of the septic tanks;
2. Septic tanks which are off-set and connected to the toilet by means of a siphon pipe.

Owing to the fact that septic tanks generally operate in a more hygienic way, we recommend building these rather than aqua privies. They have the following advantages:

- the toilet room can be integrated into the house
- even when the water supply is connected to the toilet, other domestic sullage may be disposed of at the same time
- no odour or fly nuisance
- simple design and service
- requires only minor control by public institutions
- low running expenses

The disadvantages are:

- a low, but absolutely indispensable quantity of water is required (3 to 6 litres per capita per day),
- there must be the possibility to install a second purification stage.

The following standard values have to be observed when designing septic tanks:

1. Maximum population density: 200 people per hectare.
2. Soakaways or drainfields should have a minimum distance of 10 m from the house and 30 m from the next drinking water reservoir (well etc.)
3. The connecting pipe between the toilet and the pit should have a maximum length of 8 m and a minimum diameter of 100 mm.

2.1.5 Biogas Plants

Especially in the two largest developing countries, India and China, biogas plants have been propagated on a large scale and are operated in part with great success.

In Germany, fundamental studies were carried out at the beginning of the 19th century.

In the early fifties J.J. Patel built the prototype of the so-called "Indian biogas plant" of which about 70,000 units are now in operation.

In 1958, Mao-Tse-Tung recommended in the course of the agricultural development of China, to propagate and to promote the biogas technology. The first successful tests, however, were only carried out in 1972 in the province of Sichuan and it is only since 1976 that biogas plants have been introduced all over the country. Since then around seven million units of the so-called "China type" have been installed. But even in other developing countries like Korea (30,000 units, of which today only a small percentage is still under operation due to defects in the technology and propagation), Indonesia, Pakistan, Thailand, the Philippine Islands and Taiwan, biogas plants are becoming more and more important.

Biogas plants are not only units for an economic transformation of waste energy, but also constitute an infrastructure system in which the following functions may be integrated into a natural and complete nutrient cycle (27):

- disposing of waste
- recycling
- raising the standard of hygiene
- supplying energy
- supplying fertilizers
- providing humus

Basic conception

Under anaerobic conditions, that means under the exclusion of air, organic waste products are decomposed by bacteria to the smallest possible form of gaseous molecules, namely methane (CH_4), carbon dioxide (CO_2) and traces of other gases. This gas mixture, consisting of about 60 per cent marsh gas and 40 per cent carbon dioxide, is called biogas.

If decomposition is carried out in a closed tank, the biogas formed may be collected and re-used as combustible energy.

The biological sludge remaining is an excellent fertilizer which is largely free of pathogenic germs if the installation has been designed properly.

A comparison between conventional and biogas processes for obtaining fuel and fertilizer is shown in Fig. 18.

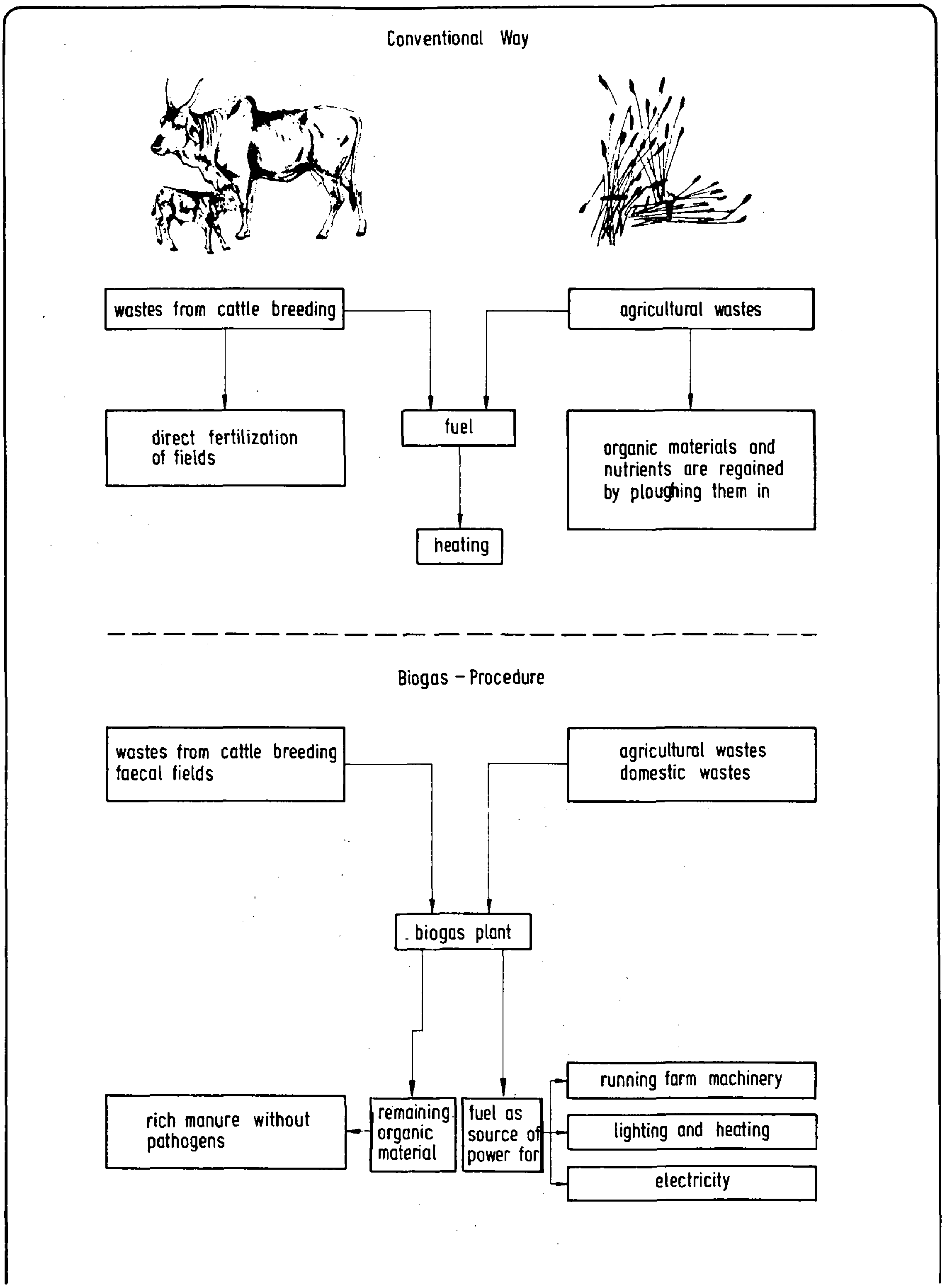


Fig. 18

FUEL AND MANURE GENERATION FROM ANIMAL AND AGRICULTURAL WASTES – CONVENTIONAL WAY AND BIOGAS PROCEDURE

INFU
– 21 –

In this section of the planning manual only a brief description is given of biogas technology, as a separate manual on biogas units may be ordered, "Biogas Plants Building Instructions" developed by the GTZ group GATE (German Appropriate Technology Exchange) in cooperation with BORDA (Bremen Overseas Research and Development Association).

The two best known types of installations are the so-called "Indian biogas plant" with a movable gas cap and the "Chinese biogas plant" with an integrated fixed gas storage tank-

- The Indian biogas plant (cf. Figures 19 and 20)

  The plant consists of a recipient intake with a mixing device, a masoned pit - the digesting compartment -, a gas recipient - the so-called gas cap- and an overflow and/or outlet.

  The organic waste materials (for examples, please refer to Figure 21) are mixed with water to make them pumpable and fluid and then fed into the unit. The fibrous substances can form a floating sludge layer in the pit and may clog the unit. For this reason it is advisable to cut them to lengths of 1 to 3 cm.

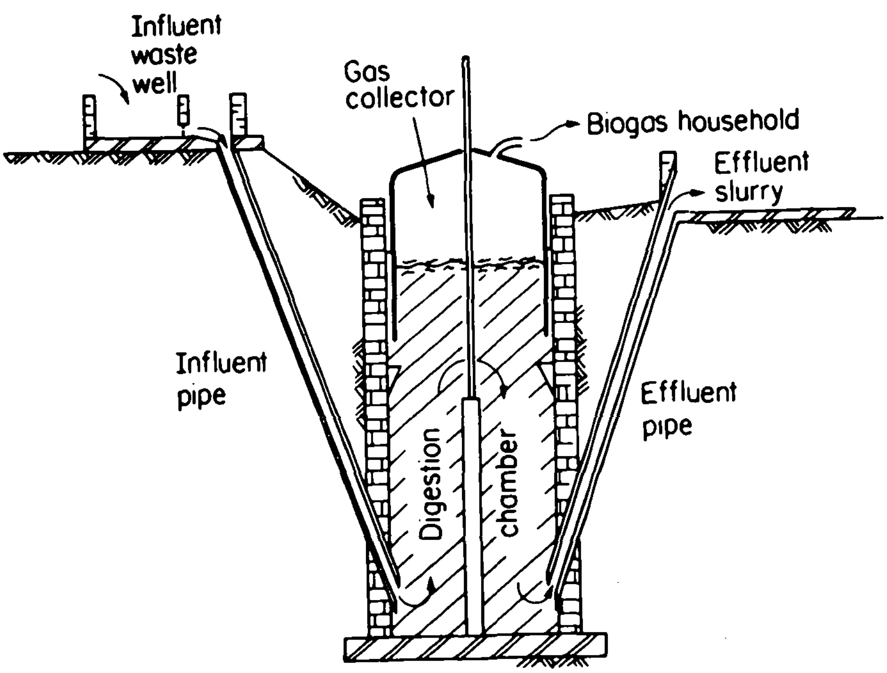


Fig. 19 Indian Biogas Plant

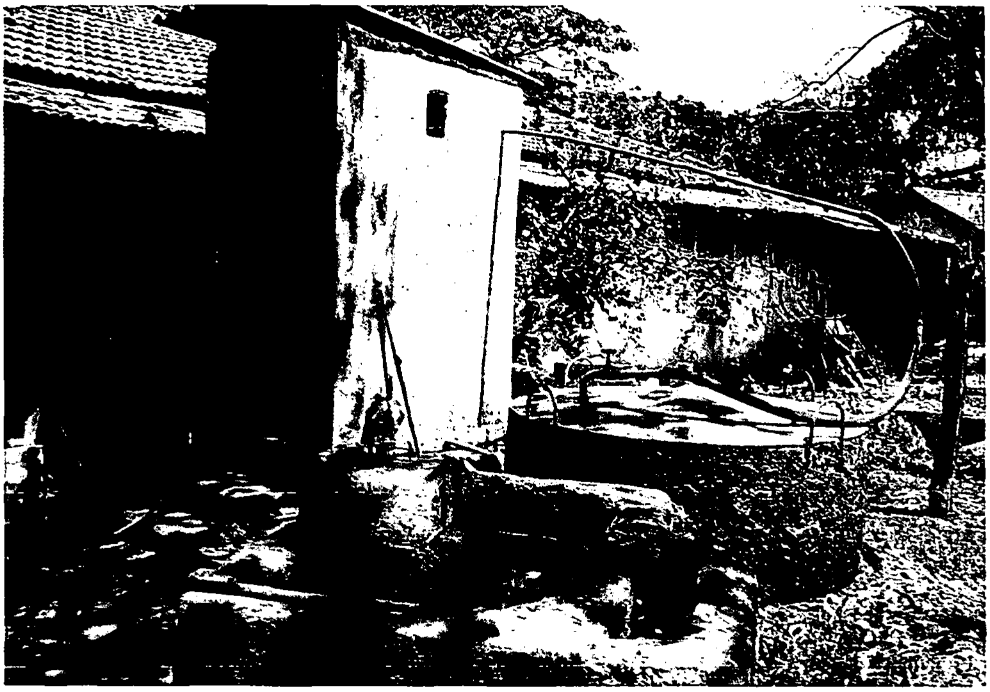


Fig. 20 - Superstructure of an Indian biogas plant. In the front the mixing and intake chamber behind the toilet and the metal hood

The digested sludge which is supposed to remain in the digestion chamber for 40 to 50 days flows out through an outlet pipe and then runs into a basin or pit located a little lower than the level of the inlet basin. The sludge is nearly completely free of pathogenic germs and is an excellent fertilizer which can be spread over fields in a wet or dry condition(cf.Fig. 22).

KIND AND PROVENANCE OF THE WASTES	EXAMPLES
Harvest wastes	Sugar-cane wastes, weeds, grain wastes, straw, spoiled fodder
Wastes resulting from breeding livestock	Cattle wastes (urine, dung), poultry wastes, slaughter wastes, fish wastes
Excreta and domestic wastes	Fecal substances, urine, domestic refuses
Products and refuses from agriculture and the small-scale industry	Oil residues, wastes from fruit and vegetable processing, tea wastes, cotton-mill dust of the textile industry, sludges from the sugar industry, squeezed sugar-canes, rice-bran
Forest refuses	Twigs, tree barks
Refuses form hydroponics	Aquatic plants

Fig. 21 ORGANIC RAW MATERIALS FOR THE BIOGAS PRODUCTION INFU (21)

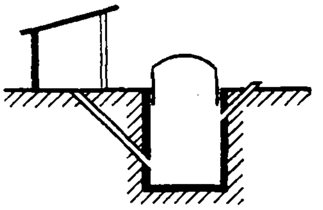


Fig. 22 Emptying of digested and dried sludge of a biogas plant

The Chinese biogas plant (cf. figure No. 23)

In the Chinese biogas plant the digestion chamber and the gas dome are built in one unit, which has various advantages and disadvantages.

In most of the developing countries, steel is a very expensive material and has to be imported; furthermore, the Indian bell-shaped design requires quite a high level of craftmanship, whereas the handling of natural building materials (bricks, concrete) is largely known. An unfavourable consequence of using the latter materials is the possibility of leakages in the bricked-up dome through which the biogas may escape uncontrolled. In addition, the gas pressure is always subject to constant variations (cf. Fig. 24).

The Chinese biogas plant can be operated by charges or in an continuous way. For a discontinuous operation, these installations may only be used if long fibrous materials have to be treated or if the water content of the organic substances is rather low. This has the advantage, that the Chinese biogas plant may even be used if the added raw materials are not fluid or pumpable.

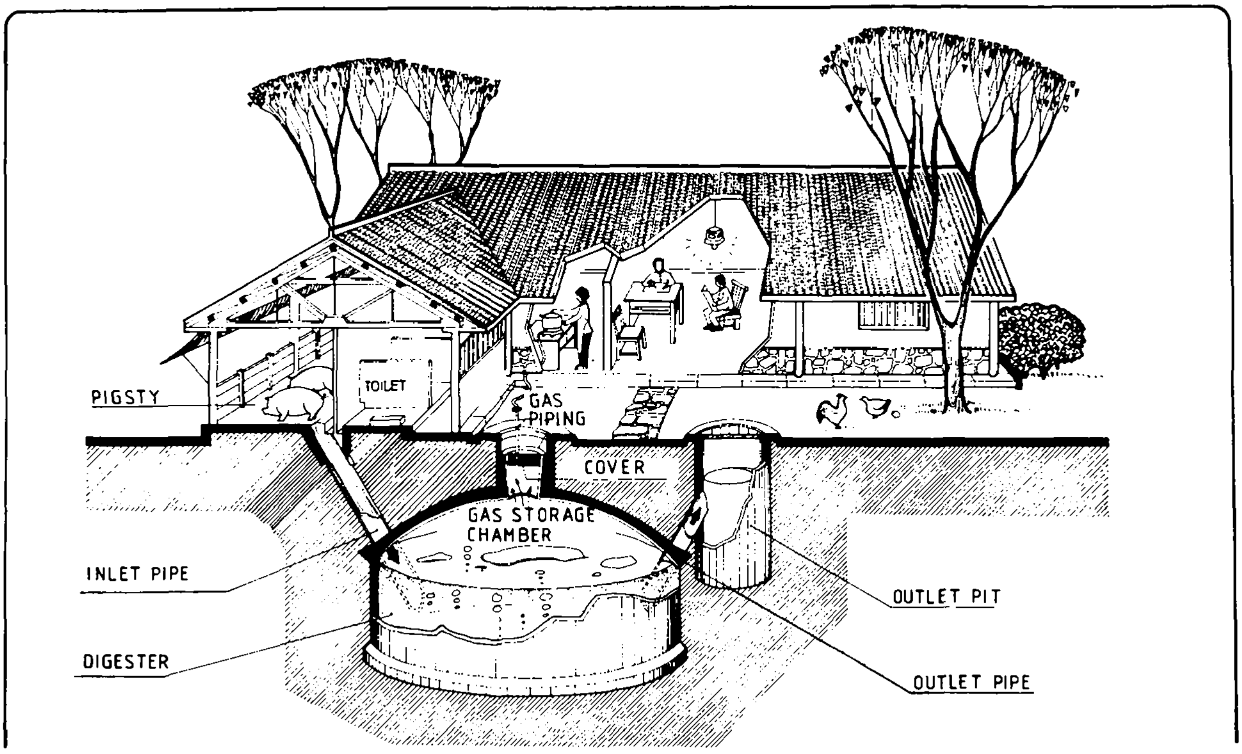


Fig.23 PLACEMENT OF A TYPICAL CHINESE BIOGAS UNIT INFU (35)

Fig. 24 Construction of a Chinese Biogas Plant

Fig. 25 Bucket from China, used as toilet as well as container

The whole construction is situated below the surface of the earth. This has of course the advantage that the digestion temperature is in general constant, but on the other hand heating up by solar radiation - as it is the case with the Indian conception - is not possible. Hence. the Chinese type is generally operating at low temperatures, which reduces the gas output.

The excreta from human beings and animals is transported either by tank trailers or by buckets (cf. Figure 25) which are at the same time used as toilets. A really remarkable characteristic of these plants in China is the scrupulous cleanliness not only of the rooms where the buckets are kept, but also of the buckets themselves.

Design of the plant and costs

The biogas plants are designed according to the quantity of gas required for cooking, lighting and other purposes. An initial synopsis is given in Table 26.

General costs for biogas plants are not stated because of wide variations in costs for materials and construction costs (22), (35).

USE	KIND OF CONSUMPTION/ AQUIVALENT	GAS REQUIREMENT (m3/hour)	REFERENCES
cooking	2 burners	0.33	33
	4 "	0.47	33
	6 "	0.65	33
	2-4 burners	0.2-0.45	34
	per capita/day	0.35-0.45	34
lighting	lamps with 100 W	0.13	22
	single mantle lamps	0.07-0.08	34
engines	converted to gas engines per kwh	0.61-0.68	34
refrigeration	for 100 litres	0.1	33
petrol	1 litre	1.5	34
diesel	"	1.5-2.0	34
boiling water	"	0.11	33

Fig.26 GAS CONSUMPTION for DIFFERENT UTILISATIONS INFU

Table 27 shows examples of the costs of Indian biogas plants of differing capacities, as stated by KHADI & VILLAGE INDUSTRIES.

Size of the plant in m^3	Costs in US $ Basis: February 1975	Necessary number of cows
2	292	2 - 3
3	377	3 - 4
4	420	4 - 6
6	522	6 - 10
8	625	12 - 15
10	763	16 - 20
15	1,063	25 - 30
20	1,438	35 - 40
25	1,600	40 - 45
35	2,300	45 - 55
45	2,593	60 - 70
60	3,250	85 - 100
85	4,850	100 - 140
140	7,250	400 - 450

Fig. 27 - Capacities and costs of Indian biogas plants

Products and re-utilization

a) Biogas

Biogas can be used for a variety of purposes which has already been shown in Fig. 26. In India and China special biogas burners made of metal or fire-clay have been developed (cf. Figs. 28 and 29). The gas produced can therefore replaced all conventional heating materials such as wood, charcoal, dry cow dung and fuel oil and so contribute to developing a healthy environment (without deforestation, drying-up of soil, erosion, smoke development in kitchens, diseases of the larynx and the eyes).

Similar burners also find an application in the small-scale industries, as in the case of two small soap and match production plants of the KHADI & VILLAGE Industries (cf. figure No. 30).

Another important domain is the utilization of biogas for lighting purposes. Here also very simple lamp designs are used, which under normal conditions have an efficiency comparable to a 60-Watt bulb.

Fig. 28 Biogas burner (Chinese type)

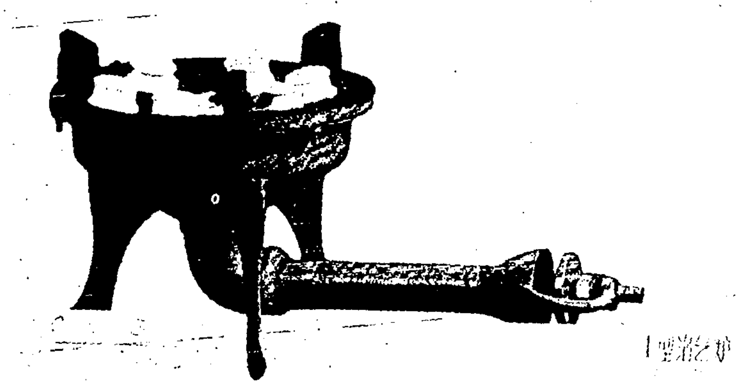


Fig. 29 Biogas burner (Chinese type)

Fig. 30 Biogas burner for industrial use (Indian type)

In addition, there is a long list of other utilization possibilities for biogas, for instance for the cooling or the operation of engines and generators which are used in various developing countries for diverse applications.

In China, there are even some buses operating with biogas as fuel.

Fig. 31 - Bus in China operating with biogas as a fuel

b) Bio-sludge

The bio-sludge which flows out of biogas plants is expected, after a sufficient fermentation period, to be nearly free of any pathogenic germs and may then be used as a fertilizer. This is done either directly after a desiccation in dry beds or after composting together with other agricultural wastes (34).

The nitrogen content of bio-dung is much higher than that of compost and it is, moreover, available in a form which is absorbed more easily by plants. With the utilization of bio-dung the agricultural yield can be increased by 10 to 30 per cent (36).

Planning aspects

Biogas plants can be installed wherever human and animal excreta or other organic substances are available. Depending on the type of installation and the mode of operation it might be necessary to add a minimum quantity of water in order to make the raw material pumpable and fluid.

The fermentation of organic substances in biogas plants is facilitated by high temperatures (about $30/35^{\circ}C$). The charge rate of raw materials and the output of biogas increases with higher temperatures. So these plants are preordained for use in developing countries where the mean outside temperature over the year remains nearly constant and relatively high. This type of installation should preferably be located near the toilet and the stables, pig sties etc. if these exist (maximum distance 25 m). Usually only a short gas pipe is then necessary between the plant and the living quarters where the gas is used. The units should always be located at a minimum necessary distance from the next drinking water well.

In nearly all developing countries, single-unit plants are given preference over communal installations, even single units for each houshold. Even in China and India a lot of problems are encountering in the distribution of gas when such installations are used by several families. As opposed to small units, large-scale installations are practicable for all public buildings and facilities (congress centres, public toilets and hospitals), farms and industrial plants with organic waste materials, and are today widespread. The gas produced is generally used in large-scale catering establishments, for the production of electricity or for the supply of process energy.

Servicing and operation

The most important problem with the Indian biogas plant is the susceptibility of the gas holder to corrosion. For this reason it is necessary to re-paint the dome at intervals of one or two years. It is also advisable to turn the gas holder day by day in order to assure the destruction of the floating scum which has a negative influence on the production of biogas.

The biggest problem with the Chinese biogas plant is gas leakage through the dome. It is relatively easy to check if there are any major leakages. The installation is filled in the usual way and then no new raw material is added nor should any gas be extracted for a period of three days. If the installation is tight, the sludge level will slowly increase in the inlet and outlet, as result of the increasing gas pressure in the dome. If the sludge level falls, the installation has to be emtied, cleaned and made airtight. During this operation, all kinds of gases which could be noxious for human beings, especially carbon dioxide, have to be extracted from the plant. In China they test the gas content by lowering a chicken hanging on a cord through the dome opening into the tank. If the chicken is still alive when it is drawn out after a few minutes, there is no danger of poisoning.

Biogas plants should be started up by introducing sludge from a productive plant in order to inoculate the fresh organic raw material with the micro-organisms necessary for the reduction process.

Health aspects

The positive health effects resulting from the operation of biogas plants have already been pointed out. Problems arise particularly if the design capacity of the plant has not been calculated properly or if it is not operated in the right way. The destruction of pathogenic germs during the decomposition process depends on the detention period within the plant and the ambient temperature. If the supply quantity is too high, the detention time is reduced, whereas lower temperatures result in slower decomposition. For this reason we do not recommend top-dressing vegetables with bio-dung.

Biogas, which for instance is a substitute for charcoal, dried cow dung or firewood used for cooking in the kitchen, also contributes directly to a healthier environment.

Institutional aspects

The biogas plants described above are relatively expensive installations which presupposes that the public authorities have to give a helping hand in financing the costs if the users are not in a position to do so. In India, for example, a country where 70,000 plants are already in operation, the Government grants subsidies up to 50 per cent. At the same time, the KHADI & VILLAGE INDUSTRY COOPERATION (KVIC) has set up a training program aimed at making the population familiar with the construction and servicing of biogas plants. The successful introduction of biogas plants is decisively dependent on financial and committed promotion by the public institutions.

Model plants in a good operating condition will greatly help to motivate the population. The easiest way to install these plants so that they are largely independent of any socio-cultural influences is to build them in agricultural establishments (pig, chicken and cattle breeding) where large quantities of bio mass accumulate as a by-product of the industry. The connection of toilets and the hygienic treatment of excreta may then be considered as a positive secondary effect.

Socio - cultural aspects

In China, all human and animal excreta have always been considered as basic inputs for the farming industry. The situation in India is characterized by certain religous-cultural reservations. Whilst it has from ancient times been customary to collect and dry cow dung for use as firing material, religion forbids mixing it with human excreta.

Summary and recommendations

During the decomposition of organic substances by acid and methane producing organisms, methane and carbon dioxide are produced. The accumulated sludge is almost free of pathogenic germs after a period of 40 to 50 days and can be brought onto fields as fertilizer. Two basic types of biogas plants are wide spread and operate well:

- The Indian biogas plant, in which the gas produced is collected in a movable metal bell works continuously.

- The China biogas plant, in which the gas is accumulated in a bricked-up stationary dome can be operated either continuously or periodically in batches.

The advantages of the biogas technology are:

1. The biogas represents a source of energy that may be used for cooking and lighting purposes, for the operation of machines, etc.

2. The bio-dung produced consists of an odourless and nitrogen-enriched fertilizer which is largely free of any pathogenic germs.

The disadvantages are:

1. Relatively high capital expenditures which are payd off after varying operation periods depending on alternative costs for fuel and fertilizers.

2. The bell of the Indian biogas plant has to be repainted to protect it against corrosion at intervals of approximately two years whereas the dome of the China type has to be checked at regular intervals for gas leakages and has to be made gas-proof, if necessary.

The following recommendations should be observed for the construction of biogas plants:

1. The average temperature range over the year should be relatively uniform and if possible exceed 25°C.

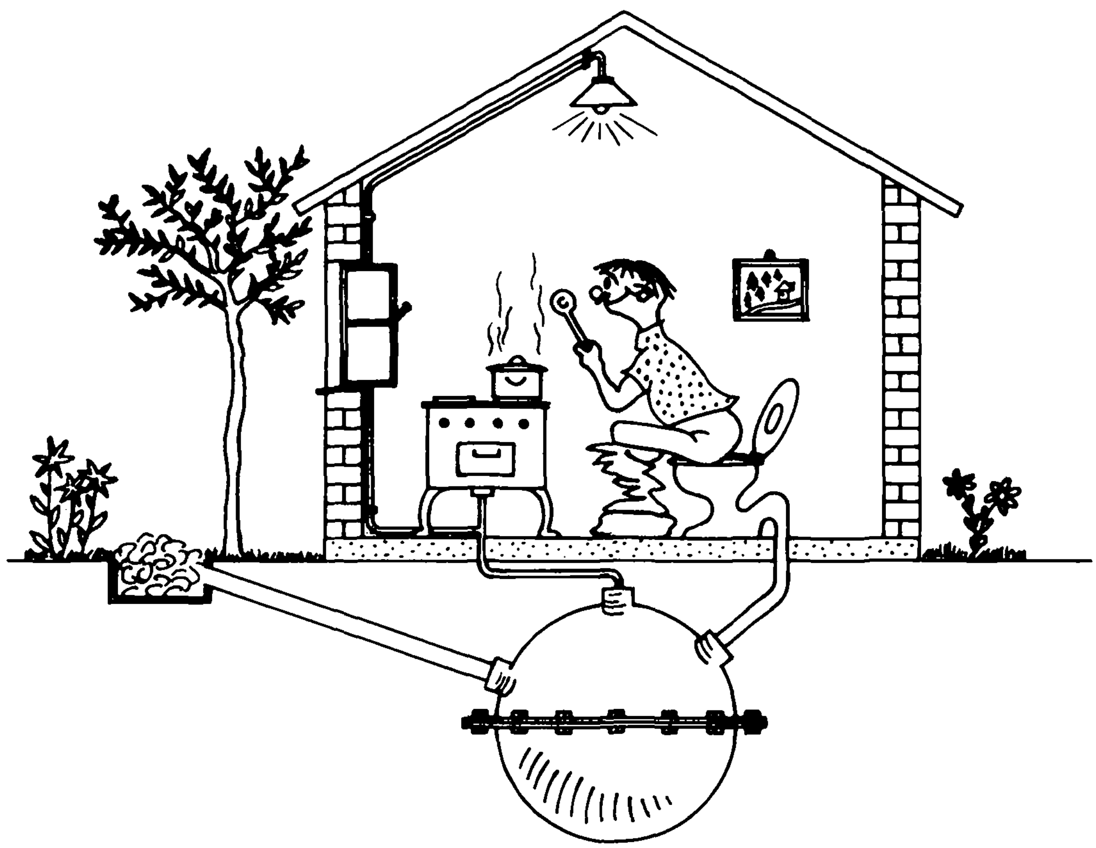
2. If a biogas plant is to be operated in a continuous way, the raw material has to have a fluid and pumpable consistency. To achieve this, it may be necessary to add water. 10 litres per capita per day is roughly the quantity required.

3. Gas pipes are in many cases the source of trouble in a biogas plant (leakages, etc.). For this reason the point of consumption, let us say the kitchen, should not be more than a distance of 25 m from the plant.

4. For the operation of a biogas plant, sufficient quantities of organic substances are required. This means that for the production of 2 m^3

of gas per day, the dung of 2 to 4 cows or of 2 to 3 pigs is necessary.

5. For safety purposes the distance to the next drinking-water well should be at least 20 m in order to exclude contamination of the drinking-water in case of a leakage.



2.1.6 Communal Sanitation Facilities

The installation of a a communal sanitation facility could be considered, from the technological point of view, as equivalent to one of the systems described above. The toilets are blocks installed in central areas. As a rule, they are connected to septic tanks designed according to the number of toilets (cf. Section 2.1.4) and equipped with running water.

According to the nature of utilization, there are two types of communal sanitation facilities:

1. Blocks where the toilets are used only by certain families or - as is practised with great success in Ibadan, Nigeria - by a group of several families belonging to a single social group, for example of totally 100 to 10,000 members.

2. Common installations which are frequented by all inhabitants of one community, according to their needs.

- Number of toilets per block

  As a general rule it can be assumed that every toilet in a block has to be designed for 25 inhabitants. In some cases such blocks were designed for 75 users per toilet. During the so-called "peak-times", that means in the morning and evening, considerable problems might then be encountered. As a general principle, seperate toilets for men and women should be provided for.

- Type of toilets

  As communal sanitation facilities should always be installed at central points, it seems sensible to combine the construction of these facilities with the installation of washrooms and showers. This makes it practicable to provide these toilets with septic tanks or vaults (cf. Section 2.14). It is necessary to have lighting, as otherwise the toilet will not be used during the night hours. The water consumption in the toile is between 15 and 20 litres per capita per day.

- Treatment of waste water

  Such relatively large toilet installations generally have to be connected to a sewerage system (cf. Section 2.2.3). Providing septic tanks permits the use of smaller pipes and has also the advantage that sullage flows without clogging on slopes of small inclination (1m/s) and makes pumps unnecessary. The purification of the accumulated waste water is then carried out according to one of the procedures described in Section 2.2. Fig.32 shows a communal sanitation facility with sewer connection.

- Extension of the facilities

  As a direkt water connection is generally available, it is practicable to extend the sanitary block to include showers and washrooms which would make these facilities so-called "comfort stations".
  The station has to be designed in such a way that each shower

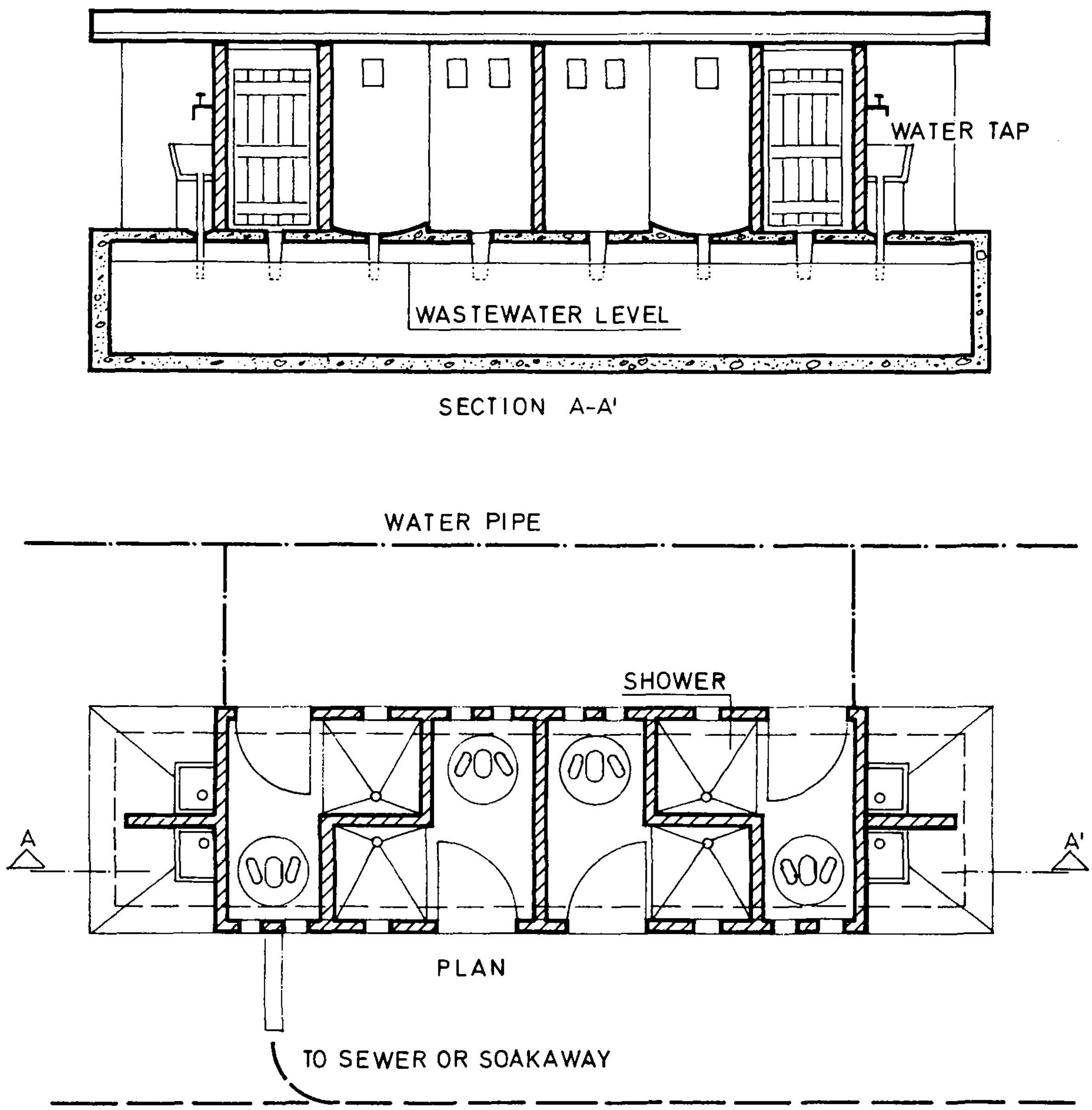


Fig.32

AQUA PRIVY COMFORT STATION (PUBLIC TOILETS WITH SHOWERS/WATER TAPS)

INFU
(14)

and/or washing place could be used by 50 inhabitants. It should also be taken into consideration that a continuously increasing water consumption will have an effect on the dimensioning of the discharge system.

Planning aspects

A block built according to the description given above is designed for about 150 persons. For regions with a higher population density (1,000 inhabitants per hectare) the installation can be extended accordingly. For areas with a far lower density it has to be borne in mind that the installation will only be able to serve an area of up to one hectare as otherwise the distances will be too far and the people living the fringes of these service areas may not frequent the toilets.

Health aspects

As a general principle the conditions laid down for the various types of toilets also apply for communal toilets. The big problem with all municipal toilet installations is their servicing, a problem which will be considered later on in detail. The opposite of the target of creating a more hygienic environment could also, under unfavourable conditions, be the result, as then the installation might become a source of disease.

Institutional aspects

In this connection it is necessary to point out the advantages and disadvantages of public installations as opposed to household toilets.

Kind of facility	Advantages	Disadvantages
Family toilets	In general the servicing is assured	Higher costs in comparision to communal sanitation facilities, because one toilet has to be provided for each family.
Public installations	Lower costs per capita	In general, the servicing is not assured, because of the lack of responsibility. With this kind of installation, the loss of privacy is obvious.

Private toilets are generally provided for by house-owners and are serviced better, simply because they are their own toilets. Such a sense of responsibility cannot be expected in the case of public toilets and it is more than probable that they will get dirty and not be used any more. The logical consequence is, then,only to install public facilities under the condition that the authorities insure a regular cleaning service.

Should the decision be made to install communal sanitation facilities it is advisable to integrate shower facilities in order to increase the incentive to make use of the toilets.

Summary and recommendations

The installation of communal sanitation facilities is appropriate in very densely populated residential areas. They are normally equipped with vaults or septic tanks and connected to a sewerage system. It is a good idea to provide them with washing facilities and showers.

The following recommendations should be observed:

1. Communal sanitation facilities have to be provided for at central places and the area serviced should cover about 1 hectare.

2. Sufficient water for toilets and showers should be available (approximately 30 to 40 litres per day per capita).

3. In the case of very large-scale facilities, separate toilets for women and men should be installed.

4. Each toilet should be designed for an average of 25 users each.

5. Additional showers should be installed for about 50 users.

6. The servicing and maintenance of the facility must be carried out by a permanent full-time employee.

2.1.7 Bucket Latrines / Vault Toilets

The disposal of excreta by removal with tank lorries, wheelbarrows or buckets is a common practice in Asia, Africa and the West Pacific Coast (7).

- The socalled bucket latrines (cf. Fig. 33) are very simple plants with very low construction costs. No excavation work is involved and the costs are in practice limited to the expenditure for the superstructure. Space requirements are small and this is the main reason why such plants are frequently built in slum areas.

- At all places where it is possible to erect houses with solid and resistant materials it is practicable to integrate small pits able to hold large quantities of excreta in or immediately adjacent to the house. The longer disposal period leads to an economic system.

Despite the relatively low financial expenditure, the first of the abovementioned installations presents substantial disadvantages which make it advisable not to continue propagating these latrines and to replace this type by other installations.
type by other installations.

1. Theoretically it is necessary to wash out the buckets used for the transportation of the excreta after thy have been used and emptied; in general, however, this is not carried out. (15)

2. The soiled buckets attract flies, which are potential carriers of diseases.

3. In many Asiatic countries (in India, for example) it is a normal procedure to carry the filled-up containers on the head to the next collecting area. Not seldom it happens that the so-called scavenger will come into undesirable contact with the excreta so increasing the danger of infection (37).

The only case in which we recommend installing bucket latrines is when - for example for financial reasons - the construction of another type of plant is not possible in densely populated areas, e.g. slums, because it is hardly possible to reach every site with a vehicle.

In all less densely populated areas or regions where sufficient approaches are provided for, the excreta could be carried away by tank lorries.

Technological description

The design of toilets with collection pits (in the Anglo-Saxon bibliography also referred to as "vault toilets") resembles in general that of the water flush toilets (cf. Fig. 8).

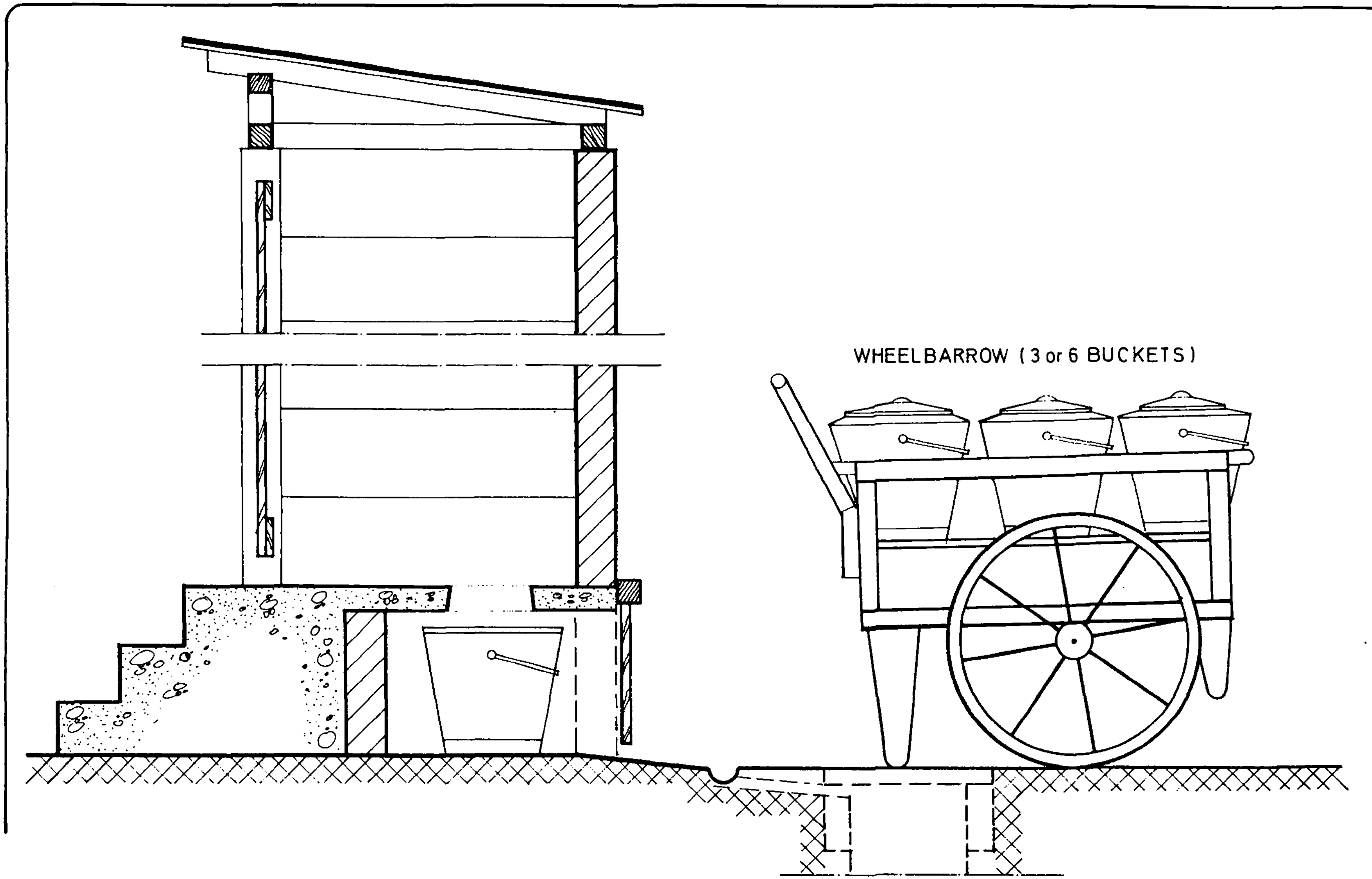
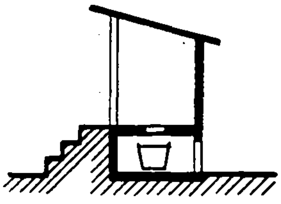


Fig. 33 | BUCKET LATRINES | INFU



The only difference is that the pit has to be emptied at regular intervals of 2 to 6 weeks by tank lorries (cf. Fig. 34) (7).

- The pit

  The volume of the pit should be calculated with the follogwing formula:

  $V = N \cdot q \cdot D/k$

  N = number of users

  q = Excreta and quantity of water added about 7.5 litres per capita day

  D = number of days between two emptying procedures or discharges

  k = factor, stating the maximal content volume before discharge

  k = 1 : full ; k = 0 : empty

As a general rule, the factor k can be put down at 0.5 of the design capacity. Only with really well organized discharge intervals will it be possible to assume factor of 0.85. A six person household with a discharge interval of 14 days and a factor of k = 0.5 needs a pit with a minimum volume of 1.26 m^3.

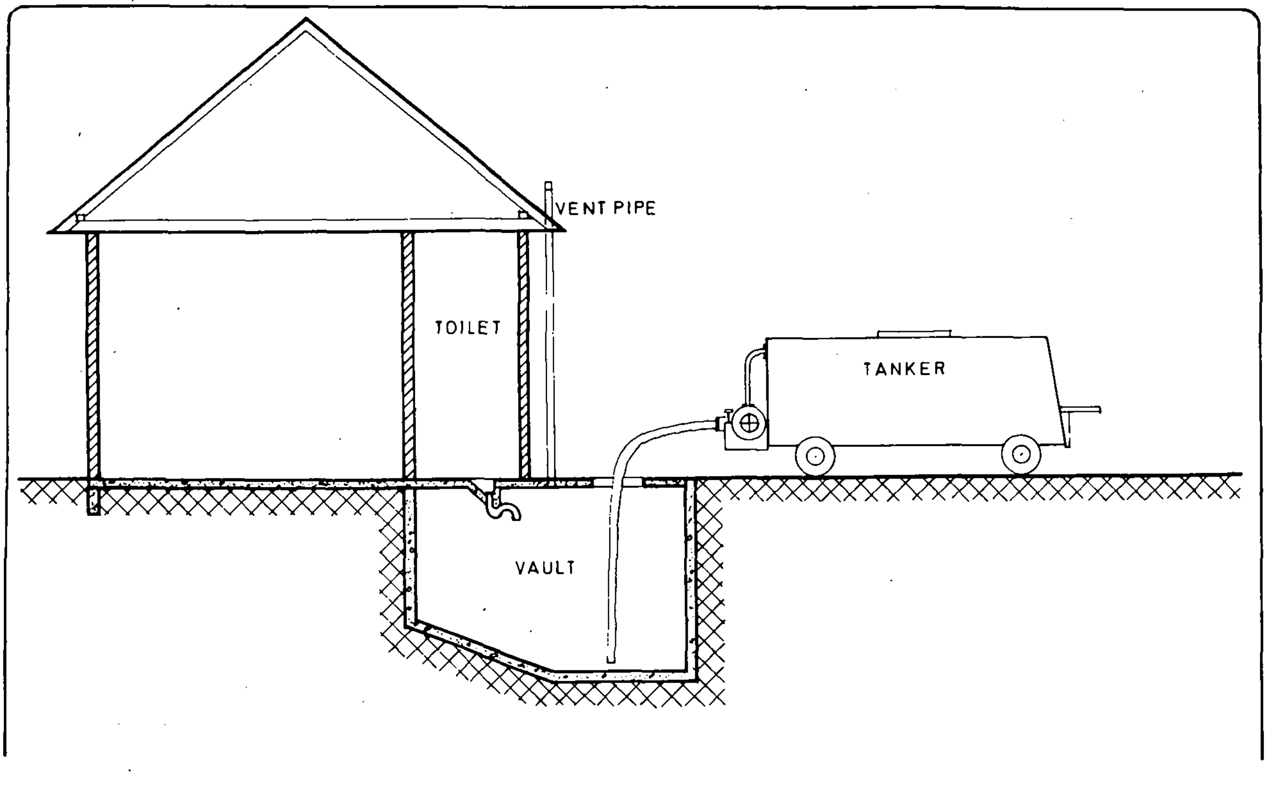


Fig.34 VAULT-TOILET INFU (-)

Planning aspects

In order to keep the collection costs as low as possible, the tank lorries should be as large as possible.

In very densely built-up areas it is often necessary, especially for lack of space, to use smaller vehicles pulled by hand or by animals.

Health aspects

- Collection

  As mentioned above, there are two basic types of toilets with collection basins.

  In one type excreta and urine are intermediately stored in buckets and in the other type storage is in a relatively small pit, the so-called vault.

  The storage units with the smallest capacity are buckets, which therefore very easily flow over and pollute the environment. As a consequence there will generally be more odour than from vault toilets, which can be ventilated by a pipe and for this and other reasons are preferred by the user.

  The presence of flies depends to some extent on the discharge rhythm. The hatching out period of flies is approximately 8 days, and bucket latrines are in general emptied at shorter intervals, whereas vault toilets are emptied at intervals of 3 to 6 weeks, so increasing the risk of flies. One remedy is to install a pour flush siphon (cf. Fig. 34). This will, however mean that a minimum quantity of water of about 3 to 6 litres per capita per day for flushing purposes will be required, a fact which has to be taken into account when dimensioning the pit.

  The health risks during the collection of the excreta by tank lorries are of minor importance.

- Transportation

  As mentioned in Section 2.2.1, the biggest problem are encountered during transportation. In this regard, discharge by buckets is the worst system one can consider. Employees coming into direct contact with excreta risk getting infected by pathogenic germs (Ascariasis and Trikuriosis).

  At the NEERI Institute in Nagpur, India, a handcart (cf. Fig. 35) has been developed to faciliate the work of the so-called scavengers and make it more hygienic.

  Form health point of view, preference should be given to smaller tank lorries which are filled with excreta by means of hand pumps and which are more efficient than hand carts. The disadvantage of creating less jobs in comparison to the conventional bucket system is outweighed by the hygienic advantages of the vehicles.

Figure 35 - Handcart with buckets for the removal of excreta

Not only is the transportation of large quantities of refuse facilitated but more distant treatment plants or drying installations can be reached.

- *Purification and/or further treatment of excreta*

  The most suitable purification procedures will be explained in the following chapters. These are principally stabilization ponds with or without the possibility of recycling, and sludge drying beds. In developing countries it is common practice to utilize a ditch system where the moisture content of the waste water is reduced by infiltration (cf. Section 2.2.3).

  In areas where this procedure is used there is always an increased health risk if proper servicing and supervision cannot be assured. In Bangkok, for instance, there is a dumping site which is approached by tank lorries nearly every hour. The situation there can be described as disastrous because within this walled-in area a number of families have settled in wooden houses and their children use the site as a playground. This dangerous situation could be solved by the installation of fish ponds, as has been proposed by EDWARDS (cf. Section 2.2.2)

A plant with infiltration ditches or drying beds can only be recommended, if

- a proper management can be assured
- the dumping site is far away from any human settlements
- the risk of polluting the ground water can largely be excluded
- the trenches are only filled up to half of their depth - this is not the case either in Bangkok -

From the point of view of appropriate technology it would not appear advisible to construct such plants because long approach ways to a wellplaced dumping site in conformity with the above requirements leads to high operating costs. In relation to the costs of construction they are, however, - beside pit latrines - the most economic plants and are in most cases the only alternative in densely populated residential areas.

In many cases it happens that the accumulated toilet wastes are simply dumped into nearby rivers or lakes (cf. sep. paper). The consequences are serious health risks because these surface waters are generally re-used as drinking-water, bath-water and for washing purposes.

Institutional aspects

The local municipal authority is generally responsible for the training and instruction of all the personnel involved with the collection, transportation and further treatment of excreta. This staff also has to be paid by the municipal administration. Depending on the income structure of the population concerned, cost sharing should be demanded for each emptying in order to reduce the public expenditure . As is shown above by some examples (cf. sep. paper), such a contribution has to be uniform for all users as otherwise bottlenecks in the servicing of poorer inhabitanspaying lower rates are likely.

Sites for the treatment plants have to be provided for by the municipal authorities, the necessary areas are given in the corresponding sections 2.2.

Socio - cultural aspects

As mentioned in the introduction of this chapter we recommend not to continue collecting and transporting excreta in buckets, but to change over to more hygienic methods. Tkis simple and economic way to dispose of excreta is widespread inseveral countries (for example in Taiwan, Korea, Bangladesh etc.) and has also a very old tradition (38). Three examples - Pakistan, India and China - have been chosen here to illustrate that strong social frameworks if new methods for the disposal of excreta are introduced without respecting historical and cultural intesrests. The consequences can be unemployment and more misery, especially among the low-income earners, if they are not considered in planning in new excreta discharge methods.

PAKISTAN

In Karachi - as in many towns in Pakistan - about 5,000 road-cleaners, excreta - carriers, etc. live together as a consolididated and well organized social group. The majority of these people are Christian Punjabis and Hindus isolated from other groups and considered as the lowest class of society. Because of this, however, the group has achieved a certain monopoly, putting them in a relatively strong economic position.

There are different occupational groups:

- the street cleaners
- the coolies
- the mobile coolies
- the sewerage workers, the so-called "kundimen"
- the latrine cleaners .

The workers of the last three categories are the ones with the lowest salary,because they carry out a so-called wet job and have, therefore, a bad reputation. The duty of the mobile coolies is the disposal and/or the transportation of waste water and urine, whereas the job of the "kundimen" is to service the conventional sewerage systems.

All these groups of workers are under the supervision of the so-called muhaddams who keep attendance sheets and procure well-paid private jobs for other certain gifts. The collection of "night soil" in buckets is very common and every worker has his own street which he keeps clean. Sometimes the work is badly executed, and the rich house owners then try to engage their own staff.

INDIA

In India the collection of "night soil" and the cleaning of latrines is the job of the Banghis, the lowest group within the caste of the untouchables. In contrast to the conditions in Pakistan, they are not only regarded as the lowest members of the society, but are also the poorest people among the population in India. In addition, the Banghis will never succeed in creating a monopoly because there are too many people able to occupy their job.

Nearly all the Banghis are employed by the municipal authorities. Their payment is very bad, the daily working hours too long, the work too hard and they do not even receive the absolutely necessary work clothes.

All attempts change this situation have so far achieved nothing. If the trend to provide sewerage systems in all cities continues, it is foreseeable that the situation of the Banghis will become far worse. It has become apparent that they have hardly any possibility of changing their field of activities. The young workers are partly retained to become street-cleaners the older are retired with a very low pension. Owing to the fact that they are offered accomodation in communal halls or houses only for the time they actually work, they are forced to leave and automatically end in slums.

CHINA

In former times, the social conditions of the cleaning personnel in China were in every respect comparable to those prevailing nowadays in India. After the civil revolution in 1949, many endeavours were made to change the sanitary conditions in China. In conformity with the new ideology, the work is done not only by a certain group of the population, but by the whole population. Today there are approximately 6,000 professional cleaning labourers in Peking, 40 per cent of which are women. In the so-called road committees there are, furthermore, certain endeavours being undertaken to participate people in part-time employment and last but not least the whole population is called upon by the "Patriotic Health Movement" to struggle against the four major plagues, these are rats, lice, flies and mosquitoes (39), which has had a positive influence on the nature of the disposal of excreta.

As a result of the different ideologies and conditions in the above-mentioned countries, different social consequences must be expected if a more modern and usually labour-saving technology is introduced. After reorientation, employment problems are inevitable. In Calcutta, for example, a program has been running for many years to construct aqua privies. For such large-scale Projects it seems desirable to retrain the cleaning personnel, which otherwise becomes unemployed. It goes without saying that this involves increased financial expenditure which can, however, be allowed for at least in connection with development aid projects.

Summary and recommendations

There are two basic types of latrines with collection reservoirs

- latrines in which excreta is accumulated and removed in buckets

- latrines in which excreta is collected in vaults which are emptied into tank vehicles at intervals of 2 to 6 weeks either by hand or by pumps.

From the hygienic point of view the second type of plant should be given preference if the site allows their construction.

The advantages of these latrines are:

- construction costs are low
- the vault of the second type can be located next to the house if integration of the toilet is desired
- pollution of the ground-water is not to be expected
- at central collecting places, re-use of the wastes after treatment is possible.

The disadvantages are:

- high operating expenses because of generally long transportation distances to the collection depots

- Owing to the short emptying intervals, of contact with excreta and therefore the danger of infections for the cleaning personnel by pathogenic germs is always very probable.

- The advantages of central collection depots can be neutralized by an unsuitable choice of location (too close to residental areas, bad subsoil conditions)

- Without proper organisation by the municipal authorities usually useless to have such plants in operation.

The following recommendations should be followed:

1. First of all, all other possible excreta disposal methods should be considered. Should they be appropriate from the financial and administrative point of view, the alternative plants may be chosen.

2. The personnel necessary for the collection, transport and treatment of the waste should be employed and paid by the municipal authorities.

3. The municipality has to supply the necessary collection depots for disposal. These places must
   - be located far enough away from built-up areas;
   - have the right subsoil conditions in order to avoid pollution of the ground-water.

4. It should be checked whether a re-use of the wastes, e.g. in central biogas plants or in pond systems, is possible (cf. in this connection also the corresponding sections 2.1.5 and 2.2.2).

5. If roads of approach are available, preference should be given to the transport of the excreta in tank lorries instead of in buckets.

2.2 Sewage treatment in communal sanitation facilities

Sewage treatment in communal sanitation facilities requires that excreta and wastes are collected and transported to a treatment plant.

As explained in Section 2.1.7, one possibility of doing this is by transportation in containers or vacuum tankers; another possibility is to discharge sullage into a sewerage system, but only if a sufficient water supply is guaranteed for the population concerned (50 litres per capita). There are many reasons that make this solution uncertain, especially in rural areas, because

a) only in a very few cases can a sufficient and completed water supply be achieved;

b) the building and population density in rural settlements is usually so low that a sewerage system would have to be over-dimensioned, resulting in very high costs and take a lot of time.

c) it will very rarely be possible to design and to build such a system without the assistance of experts which will again entail higher costs and take a lot of time.

In humid climatic zones where sufficient water is usually available, sewerage systems could definitely be regarded as a suitable technological solution and are, therefore, discussed in following.

It is very common - and under certain conditions even acceptable - to discharge the accumulated untreated waste/water and excreta into lakes, rivers or the ocean. But where the natural capacity of the water to purify itself is overtaxed or where directly or indirectly problems for the population have to expected as a result of pollution, treatment plants have to be installed.

Another point favouring the installation of treatment plants is the possibility of re-using the waste water (e.g. for the production of fertilizers, food, etc.)

The choice of the right dimensioning criteria and the knowledge of the fundamental data listed below are the immideate preconditions for achieving efficient discharge and treatment of waste waters.

1. Classification of the waste water

   - domestic
   - agricultural
   - industrial

2. Characterization of the waste water

   - Volume (maximum, minimum, average)
   - BOD (biological oxygen demand in five days)
   - Solid substances
   - Concentration of nutritive substances (nitrate, phosphate)
   - pH-value (maximum, minimum, average)
   - toxic substances

3. Hydrology and meteorologie

- Rainfall (average, seasonal)
- Temperature of the water and air (maximum, minimum, average)
- Ground water level
- Wind (average force and direction)
- Sun activity (solar days per year)

4. Topography

- Topographic maps and chart
- Ground conditions
- Location of the residential premises, industrial installations, agriculture

2.2.1 Wastewater Transportation Systems

The single units so far described and the disposal procedures for "night soil" presume that all other wastewater, deriving e.g. from bathrooms, kitchens and washing facilities, either does not exist - because of a non-available domestic water supply - or is treated in another way (cf. Section 2.1.4).

If wastewater is available in large quantities (50 to 100 litres per capita per day) it can flow through pipes from the point of production to the treatment plant. In general we have two procedures for wastewater transportation,i.e.

1. in open channels
2. in pipes

Technological description

Sewerage systems should be arranged in such a way that wastewater flows through public owned land and the utilization of pumps is as far as possible avoided. The system is then independent of additional energy, will cause less expense and will require less maintenance.

a) Open Channels

In a large number of developing countries, open channels have to cope, not only with the disposal of wastewater, but with the disposal of rainwater as well. This means more serious problems for the dimensioning of the ditches. Until now the capacity has always been based on the maximum requirements. The consequences are large, concreted and hydraulically exactly designed channels criss-crossing the villages. During the rainy season all the accumulated surface water flows through these ditches which then fulfill their purpose. During dry spells they are nearly empty and are misused as dumping grounds or are used by children as playgrounds. The rainy season then brings a sudden rise in the water level and all the rubbish accumulated over several months is flushed away and very often dams up the flowing water. The intended purpose, to prevent flooding in residential areas, is thus realized at the expense of other areas which are then sometimes hit more severely.

Considering the negative experiences more concentration should be put on alternative solutions, e.g. storm-water retention tanks in combination with infiltration basins. The planning aspects of these will be dealt with in Section 2.2.2. From the technical point of view they resemble the design of stabilization lagoons or oxidation ponds described in the same section, but have a permeable foundation or bottom. This can be achieved with a bottom layer of crushed stone of a thickness of about 50 cm. This will considerably increase the costs of construction of the plants, but has the great advantage that local material can be used and the work can be executed by the local population. This suggestion, however, must always be treated with a certain scepticism when the ponds are situated in the immediate neighbourhood of residential areas, which is nearly always the case, because then hygienic problems are encountered. During the dry season when the ponds remain empty they are an ideal playground for children or entice people to dump their rubbish.

On the face of it these arguments seem to be justified, but on the other hand the rainwater ducts also remain empty during the dry season and likewise attract playing children. But it is much easier to surround such ponds with a fence or the like than it is to guard channels. Under these circumstances the probability of infection is much higher in combinated rain and waste water channels. If, therefore, sewers do not satisfy the requirements of appropriate technology, the foregoing aspects lead to the following requirements:

- Open wastewater channels should be so small that children cannot play in them.
- They should first of all serve the purpose of a sewer duct.
- They should be designed in such a way that only three to six times the runoff of the dry season could be absorbed by them.
- In order, as far as possible, to avoid an overflow of the ditches during the rainy season, retaining basins for the surface water or other possibilities for a separate rainwater dispersion have to be provided for.

Depending on the locally available raw materials, stone and concrete slabs or bricks baked on site should be utilized as materials for the construction of the sewer ducts, whereby with bricks attention should be paid to insure that they are of good quality. The ducts should be designed in a trapezoidal form and should even be covered with slabs, either completely or partly, as far as the dimensions will allow this (cf. Fig. 36)

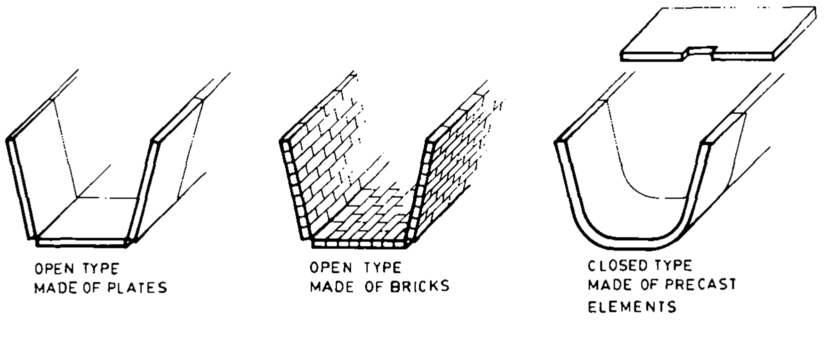


Fig.36 EXAMPLES OF DRAINAGE DITCHES INFU

The following equation can be taken to calculate the ducts:

$$Q = A \cdot v = A \cdot k \cdot R^{2/3} \cdot S^{1/2}$$

Q = rate of flow
A = cross-section of the duct (in m^2)
v = velocity of flow (m/s)
k = coefficient of roughness (depending on the nature of the slab surface, about 70)
R = hydraulic radius ($m = \frac{A}{U}$; U = wet circumference)
S = slope

b) Sewers

As mentioned in Section a), the simplest and most economic solution is covering trapezoidal ducts. More expensive and even more problematical are sewerage systems made of circular pipes because when they are clogged, they are not accessible without extensive civil works. in which case expenditure for servicing is disproportionately large. Especially from the hygienic point of view, an alternative is given by relatively small and uncomplicated duct systems. As the pipes have a small diameter, they can be produced in the developing countries and also contribute to a number of positive secondary effects, such as a reduction of costs and the provision of jobs.
For the right dimensioning of closed and also open ducts (see above), the following data should be on hand:

- the quantity of water running off,

- the slope, whereby it has to be taken into account that a minimum velocity of v = 1.0 m/s for normal waste water must be assured (cf. Fig. 37).

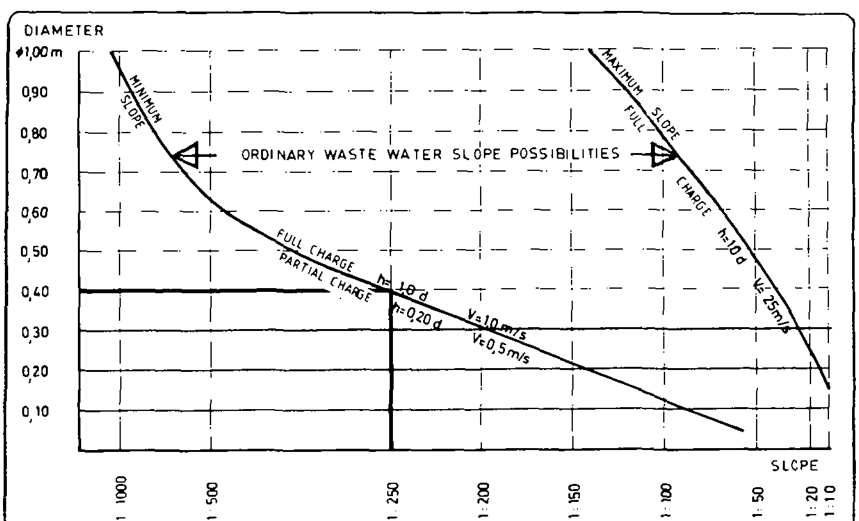


Fig. 37 PIPE DIAMETERS IN RELATION TO SLOPE INFU (44)

An alternative procedure which reduces the high capital expenditure has been adopted in Zambia. Because most of the regions provided with sewers are very flat, extensive measures would be necessary to the achieve minimum velocity of 1 m/s. It has been possible to reduce this problem by placing an aqua privy or septic tank before nearly every connection (cf Section 2.1.4). These reduce the content of solids in the waste water to a minimum. The velocity required for self-cleaning of the sewers is very much lower, which has the advantage that smaller inclimation and therefore less excavation work and fewer pumping stations are necessary.

As shown in Fig. 37 for example, a minimum slope of 0.004 or 1 : 250 is necessary for a cicular 400 mm sewer pipe.

From Fig. 38 we can ascertain, with the necessary data available, the possible rate of flow Q in litres per second, in the example 130 litres per second.

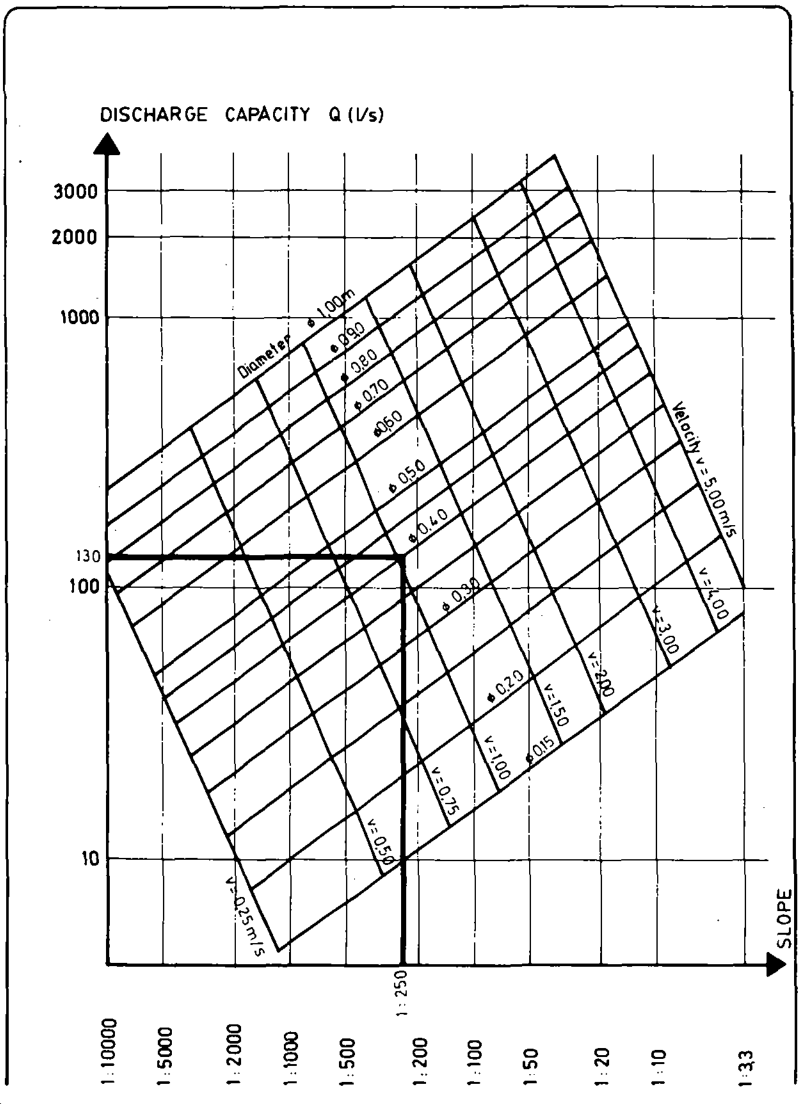


Fig.38 DISCHARGE CAPACATY WITH THE PRANDTL-COLEBROOK FORMULA IN RELATION TO PIPE DIAMETER AND SLOPE

INFU (44)

Planning aspects

Sewerage systems are usually projected in communities where either the treatment of the sewage or the discharge into surface water is planned. In general it can be said that in all the plans realized up to now large-scale sewerage systems for extensive areas have been installed which originated by transfering the technologies of industrialized countries to the conditions prevailing in developing countries. Beside the considerations dealt with in the preceding section, which have a purely technological character, the decentralizing of sewage systems, that is to say more small sewage disposal plants and therefore more small sewage systems, seems to be more appropriate. The following comments refer mainly to the larger municipalities taken into account in this manual, with a population of around 20,000 people.

In the following, the two systems - centralized and decentralized - are compared.

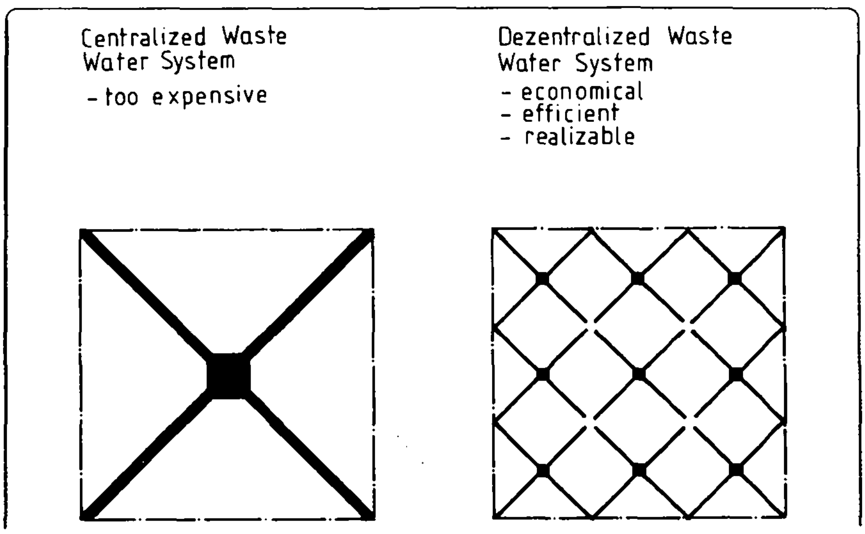


Fig. 39 PATTERN of CENTRALIZED and DECENTRALIZED WASTE WATER SYSTEMS INFU

Centralized sewage systems	Decentralized sewage systems
- Can generally only be planned by foreign experts	- Can be planned under certain circumstances even by home experts.
- Can not reliably be designed for the whole town because of unreliable estimates of population growth.	- Can also be designed for small demarcated urban districts.
- Can not be extended as desired to unforeseen expansion areas because of limited construction phases, dependent on the location of the main ducts and the sewage disposal plants.	- Can be extended at will by simply adding new independent systems. Can be planned for the various districts of a town in any sequence desired.
- Are not so adaptable to existing urban structures	- Are very adaptable to specific requirements, owing to the application of different technologies (domestic waste water, industrial waste water)
- Require a large-sized sewage treatment plant.	

Centralized sewerage systems	Decentralized sewerage systems
Construction	
- Have to be built mainly by foreign companies with imported materials	- Can be built mainly by local civil engineering companies with local building materials
- Require expensive and large-scale technologies (pumping stations, retarding basins, etc.)	- Can be built without expensive pumping stations and equalizing tanks if the right location of the sewage disposal plant is chosen
- Cause high construction costs because of the large intercepting and trunk sewers	- Do not require any expensive and large-scale intercepting and trunk sewers
Operation	
- Require only a small number of well qualified staff	- Provide more jobs because more personnel is required
- Have very long-term amortization or periods because of the high investment costs per houshold	- Have short writing-off periods
- Maintenance trouble can affect large areas of the whole town	- Maintenance trouble only affects the limited area of the system

This comparision of the advantages and disadvantages of centralized and decentralized sewage disposal systems applies especially to the larger municipalities - with around 20,000 inhabitants - which are also included in the scope of this manual.

Decisive factors for the choice of decentralized plants are operational safety and costs. On account of the special situation in developing countries, a system can be considered if the import of expensive spare parts can in general be avoided and the plants are simple enough to be operated and maintained by trained local personnel.

Health aspects

Sewage discharge in open ducts involves a high risk to health (e.g. caused by mosquitoes e.g. Anopheles). In regions where there is no difference between dry and wet seasons and where there is continuous rainfall the breeding possibilities are limited by the running water. The presence of sewage does not increase or reduce the risks. The situation is very different in the case of seasonal rainfall . It should be added that refuse causes clogging of the sewers.

Two alternatives have to be taken into consideration:

1. The municipal authorities have either to be able to arrange regular cleaning of the open ducts, or

2. the ducts have to be covered as mentioned above and serviced at regular-but longer- intervals.

The second alternative will of course cause higher investment expenditure, but has, on the other hand, the advantage of lower operation costs and has to be regarded as the better system from the hygienic point of view (cf. Section 3.3).

Sewage disposal in closed sewers is expensive, but reduces the risks to health immensely.

Institutional aspects

It is an undeniable fact that closed ducts (e.g. pipes) will, as already mentioned, satisfy certain essential hygienic requirements in a far more satisfactory way. On the other hand, they can only be regarded as "appropriate" within certain limits on the basis of the conditions mentioned as pipes with large diameters (over 800 mm) can in general not be produced in developing countries.

Apart from this they can only in a very few cases be built of locally available materials and last but not least a sewerage system requires routine maintenance by qualified staff. In relatively small municipalities with 2,000 to 20,000 inhabitans these limitations mostlyovertax the financial and organisational capacity to the local authorities and especially in this case it should be considered wether the collection system with simple tank vehicles, proposed in Section 2.1.7, would not be economically and organizationally more feasible.

In contrast to closed pipes, servicing open ducts is simpler, as they are always accessible from above. Finding clogging sections and the subsequent cleaning is easier and can be carried out by staff without any special training.

The maintance of all sewerage networks has to be supervised, financed and organized by a public administration.

Summary and recommendations

If sewage is to be treated in a communal plant (cf. Section 2.2), there are two basic transportation alternatives, i.e.:

1. by containers (buckets, tank vehicles)

2. by means of a sewerage system.

Detailed information on the first alternative has been given in Section 2.1.7.

For the discharge of wastewater into a sewerage system, a minimum water consumption and/or a minimum sewage flow of 50 to 100 litres per inhabitant and day are necessary.

There are two technological possibilities for the discharge:

1. in open sewers
2. in closed sewers .

Open sewers are simple to build and have favourable costs. For this reason, they could be part of a self-help program. In comparison to closed sewerage systems, however, they involve certain threats to health.

Pipe systems should only be employed if the sewage volume remains within the discharge capacity of an 80 cm pipe diameter because in this case the pipes can be produced locally in most developing countries. When these systems are properly operated, the health risks are minimized. In many countries of the Third World, however, difficulties due to maintenance cause significant problems or a complete breakdown of the system. For this reason we recommend to installing smaller discharge systems which are simpler and easier to maintain.

Sewers covered with concrete slabs reduce not only the main disadvantage of open sewers, the health risks, but also a disadvantage of the piped systems, that is the relatively difficult maintenance.

During periods of rainfall, large quantities of water may fall in a very short time which can cause an overflow in the system and prevent proper discharge. Because sewerage systems designed for maximum requirements are not considered appropriate for the reasons described above, we can only propose rain detention basins combined with infiltration areas. In this way most of the rainwater can be collected and discharged separately from the waste water.

2.2.2 Waste Stabilization Ponds

All the procedures intended for a disposal and/or clarification of excreta and wastewater should aim at the following two goals:

1. The destruction of pathogenic germs
2. The oxidation and/or the reduction of organic substances.

Conventional clarification systems, i.e. plants with two purification stages (mechanical - biological) and sludge treatment, are employed in various developing countries, but have three decisive disadvantages:

1. Due to the generally short detention periods in the systems, the killing off of pathogenic germs is usually incomplete. A third purification stage (chlorination, microfiltration, etc.) would remedy this but involves financial expenditure which is in general too high for developing countries and especially for their rural areas.
2. Very high investment and operation costs.
3. A high training standard of the operation staff and difficulties in procuring spare parts.

In the following various treatment plants for excreta and waste water are presented which can easily be built and serviced. They are ponds or pond systems without artificial aeration and circulation.

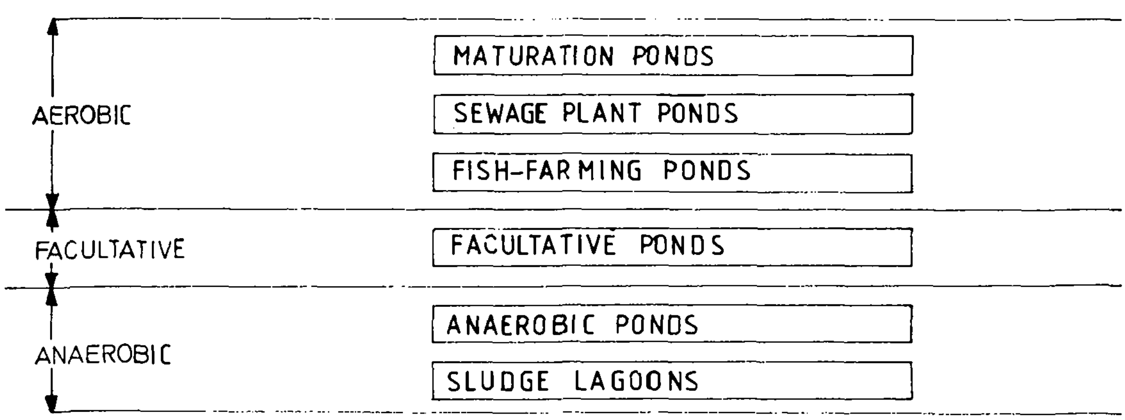


Fig.40 PONDS WITHOUT MECHANICAL OXYGENERATION

INFU (41)

The utilization of ponds for the treatment of wastewater has a long history. In San Antonio, Texas, there is, for instance, a wastewater pond which has been in use since 1901. Since then, a series of scientific papers dealing with dimensioning, load, etc. have been presented and the number of countries where such plants were built increased correspondingly. GLOYNA (42) mentioned in his book, published in 1971, experience gained in 39 countries. TALBOYS (43) and CANTER (44) have extended this list to 52 countries of which not less than thirty are situated in tropical regions.

The basic principle of all wastewater ponds is the same:

> The reduction of pollutants is accomplished mainlv by bacteria and algae and proceeds very slowly in ponds without aeration and circulation.

For this reason, long retention periods and large basins are required. In many high-developed countries this fact has lead to stabilization lagoons no longer being built, especially where land is valuable. Another important factor is the prevailing climate, i.e. the temperature, because this determines the rate of bio-chemical reduction of the pollutants.

In most developing countries, and especially in the rural districts of these countries, there are usually not only large areas of inexpensive land but also relatively high mean annual temperatures. Both can have a positive influence on the decision to choose the waste stabilization pond described in the following.

Technological description

Biological waste water clarification processes differ in hydrolysis and oxidizing reactions during the reduction and the stabilization of organic pollutants. Depending on the content of free and dissolved oxygen we have to distinguish between aerobic conditions (where reactions take place with oxygen), anaerobic conditions (where reactions take place without oxygen) and facultative (aerobic and anaerobic) conditions in the wastewater ponds.

- Anaerobic ponds

  These ponds are in general used for pre-clarification and are usually the first clarification stage of pond systems. From the purely technological point of view they are suited for all areas where heavily-loaded wastewaters have to be treated. The solid substances build a sediment at the bottom of the ponds and there they are biologically decomposed. The biochemical reactions and microorganisms involved are shown in Figure 41.

  To achieve effective reduction of the harmful substances in anaerobic ponds, the right equilibrium between the methane and acid-producing bacteria is essential (cf. Figure 42) which will only be the case if the following two conditions are fulfilled:

  1. The water temperature is more than 15 ^{o}C.
  2. The pH-value is more than 6.

PROCESS	MICROORGANISMS RESPONSIBLE FOR THE DECOMPOSITION	TYPICAL REACTION
Formation of organic acids	A c i d f o r m e r s Various heterotrophic bacteria (Clostridium etc.)	$2\ (CH_2O)_x \rightarrow xCH_3COOH$
Methane fermentation	M e t h a n e f o r m e r s Methanogenic organisms (Methanobacterium, Methanobacillus, Methanococcus etc.)	$CH_3COOH \rightarrow CO_2 + CH_4$
Reduction of sulphur	Photosynthetic bacteria (Thiopedia, Chermomatium)	Org. $S \rightarrow HS^- + H^+$ Acid H_2S Base $2H_2S + CO_2 + h\nu \rightarrow$ $(CH_2 + S_2 + H_2O)$
Conversion of nitrogen		Org. N → Ammonia

Fig. 41 BIOLOGICAL and CHEMICAL PROCESSES in ANAEROBIC PONDS INFU

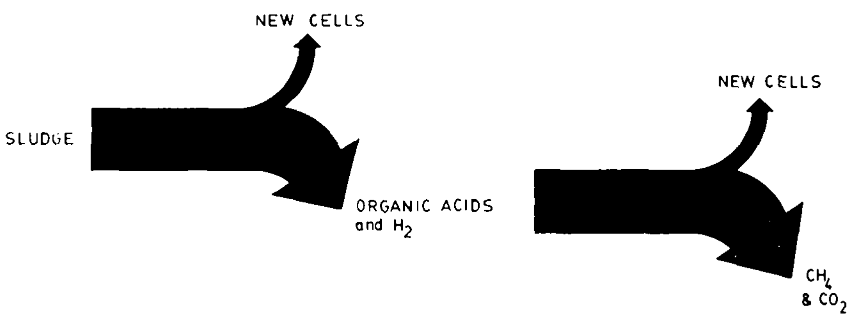


Fig. 42 THE ACID FORMING AND METHANOGENIC PHASES OF ANAEROBIC DIGESTION INFU (16)

Apart from the retention time a major design variable with ponds is the BOD of the inflowing domestic waste water. As shown in Fig. 43, a reduction of 70 % might be achieved within 5 days at temperatures of more than 20 °C.

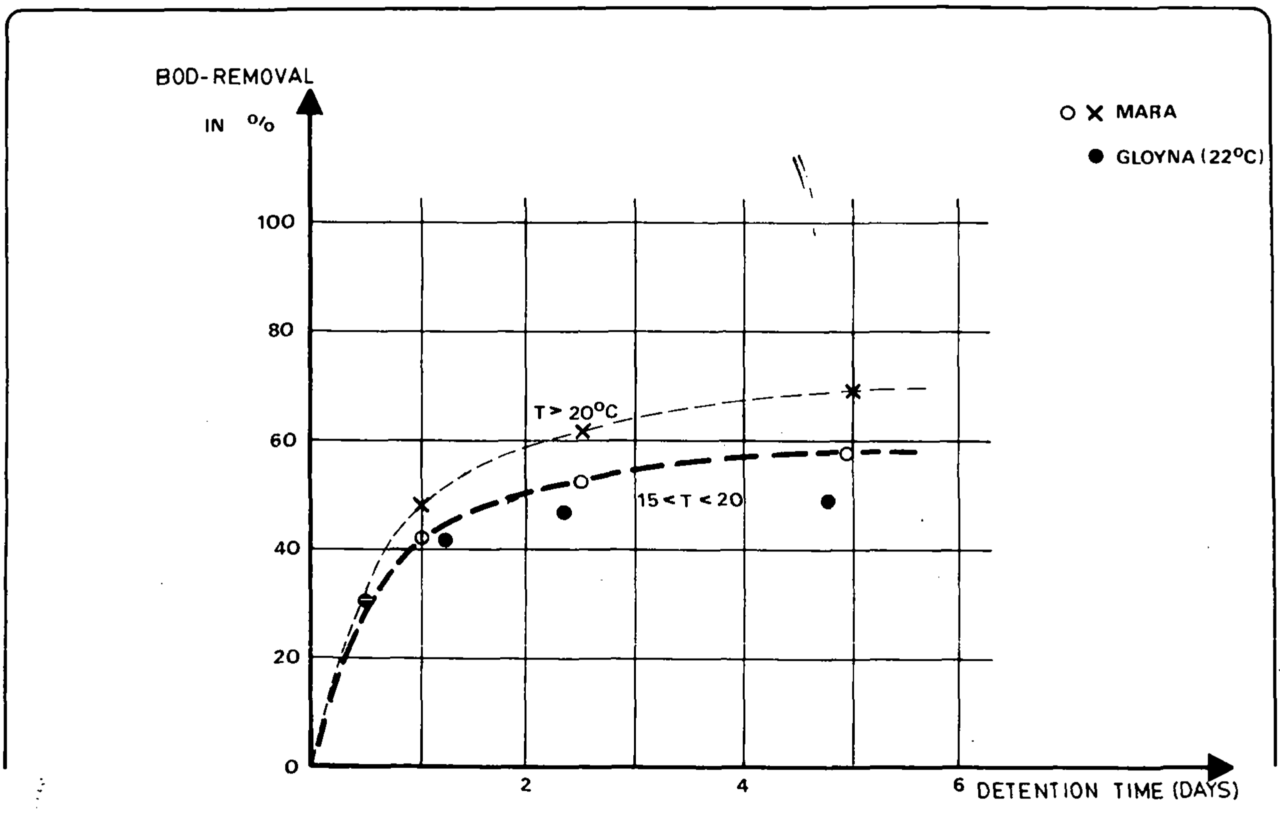


Fig. 43 BOD-REMOVAL IN RELATION TO TEMPERATURE AND DETENTION TIME INFU (42,45)

This rate of reduction is, of course, largely dependent on the BOD-load, as shown in Fig. 44

The hatched part indicates the extent of dispersion of the values obtained from different plants.

All the ponds with substantially longer retention times operate under facultative conditions (cf. also the following section), whereas the anaerobic ponds with shorter retention times present the following disadvantages (15):

- The risk of odour nuisances increases
- The de-sludging intervals are shorter
- The bacteriological quality of the outflow is worse
- The reduction is lower.

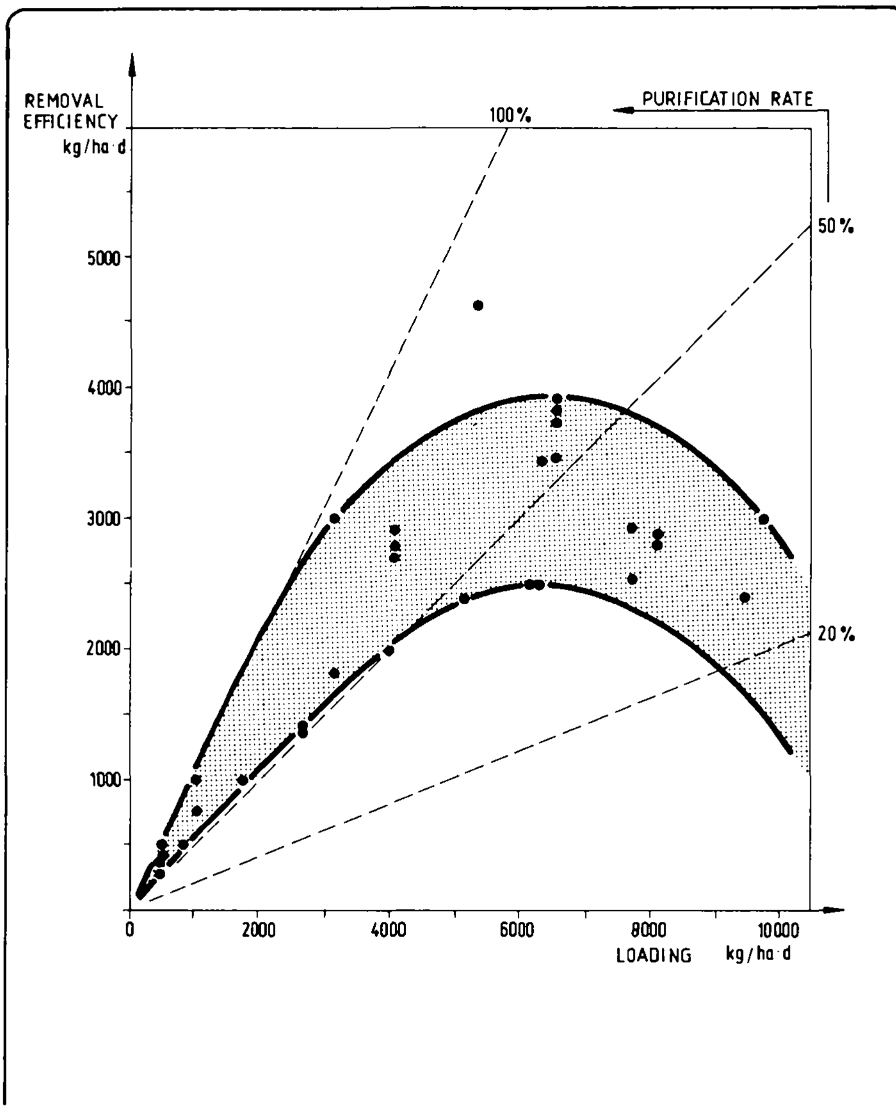


Fig. 44 OPTIMAL BOD LOAD IN ANAEROBIC PONDS IN TROPICAL CLIMATES (25-35°C) INFU (46)

Odour nuisance

The odeur nuisance is mainly caused by bacterial reduction of sulphate to sulphite. Should it be intended to connect agricultural estates and/or small industries to the plant, it has to be expected that the waste water will have a high sulphate content and a high BOD load of more than 400 g/m^3d. Sulphite is mainly developed within a pH-range of less than 8 (minimum 6 for anaerobic ponds, cf. above). If the pH value can be adjusted to around 8, almost only HS^- - ions are present, which are odourless. The simplest way of achieving this is to recirculate the effluent from the facultative or muturation ponds to the anaerobic pond in the ratio 1 to 6 (1 volume of effluent to 6 volumes of raw sewage) (16).

Sludge removal

The amount of sludge accumulating within one year is about 0.03 to 0.04 m^3/ha which must be removed when the basin is about half full of sludge. So we arrive at the following formula:

$$1/2 \cdot V_p \cdot V_S \cdot P = n \qquad \text{- Equation 1 -}$$

V_p = Capacity of the pond (in m^3)

V_S = Volume of sludge (in m^3 per hectare per year) = 0.04

P = Inhabitants connected

n = Sludge removal intervals (year)

Dimensioning of anaerobic ponds

The most important variable is the BOD. In the case of fresh wastewater, the BOD value has to be determined at the end of the sewer system and, if such a system is going to be installed, the values of several households have to be measured in order to obtain average values. The BOD at the pond inlet can be calculated by the following equation:

$$\text{BOD/l (inlet)} = \frac{\text{BOD/capita and day}}{\text{Quantity of wastewater per capita per day}}$$

- Equation 2 -

As an example: BOD/capita, day = 0.05 kg

Quantity of wastewater per capita per day = 100 l

$$\text{BOD/l} = \frac{0.05 \text{ kg}}{100 \text{ l}} = 500 \text{ mg/l}$$

If 70 % of the BOD is reduced within five days (cf. Fig. 50), the outlet still contains 150 mg/l BOD.

For anaerobic basins a depth of 2 to 4 metres is generally recommended (42) (16). The necessary surface can then be calculated by the following equation:

$$A = \frac{Q \cdot t}{D}$$

A = Surface (m^2)

Q = Quantity of wastewater (m^3/d)

t = Retention time (d)

D = Depth

For example: t = 5 days (cf. Fig. 50)

Q = 1,000 m^3/d (is corresponding to 10,000 inhabitants with 100 l each)

D = 3 m

The surface needed is then: $A = \frac{1{,}000 \cdot 5}{3} = 1{,}667\ m^2$

Dimensions of the pond: 21 m x 80 m x 3 m

Capacity: 5,040 m^3

- Facultative ponds

  Facultative ponds are characterized by three zones. In the upper regions, i.e. near the surface of the water, aerobic conditions prevail, whereas reduction at the bottom of the pond occurs under anaerobic conditions. Between these two layers there is a mixture of both reactions, which is called the facultative region.

Aerobic zone

The aerobic conditions at the surface of the pond are due mainly to the photosynthetic activity of the algae growing everywhere where sufficient nutrients and light are available. Like all plants, algae produce oxygen which is absorbed by the aerobic bacteria living in the wastewater and serves to oxydize organic substances. Waste substances resulting from these processes are CO_2, nitrogen and phosphate compounds which serve the algae as nutrition and as raw material for photosynthesis. The symbiosis between algae and bacteria is shown in Figure 45.

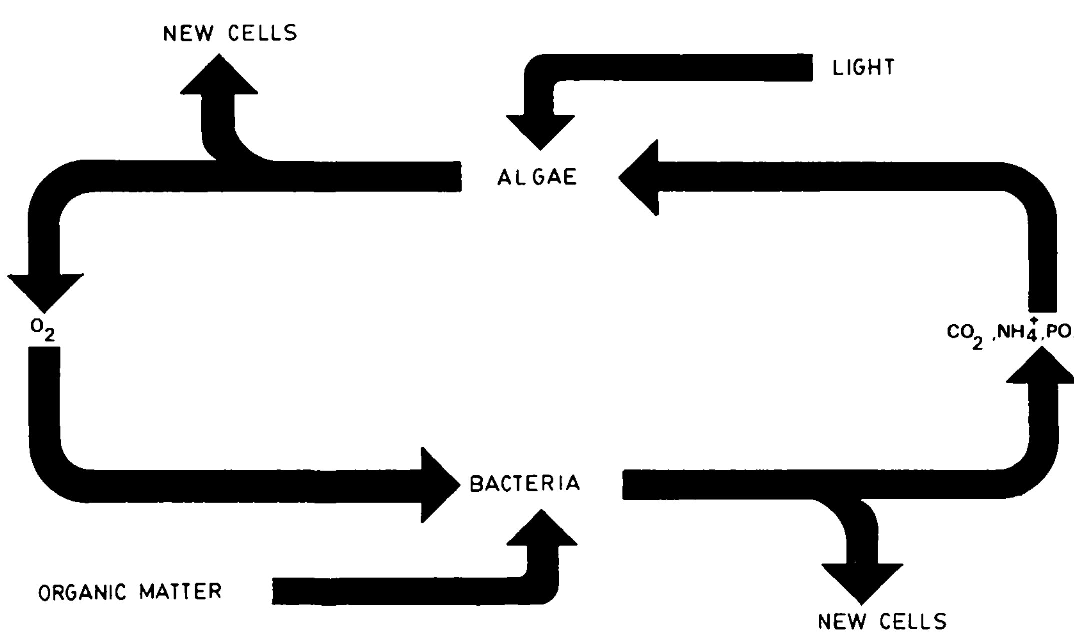


Fig. 45 SYMBIOSIS OF ALGAE AND BACTERIA IN STABILIZATION PONDS INFU (16)

All photosynthetic processes depend on the light intensity. In waste ponds this means that the algae population decreases with the depth in the pond. The proportion of oxygen diminishes correspondingly. From a certain depth on, the water contains very little oxygen - the facultative zone of the pond - and still deeper - in the anaerobic zone - it contains no more oxygen at all.

Wind and heat are also determinants which control the function of facultative ponds. Especially in tropical zones, the upper water layer will heat up rapidly. Without the circulation of the water caused by the activity of the wind, a discontinuity in temperature at a depth of only 50 cm occurs. Some of the algae sink down from the warm water region (more than 35 °C), forming a light barrier. This phenomenon will immediately cut down the rate of photosynthesis and therefore also the production of oxygen and finally restrict the stabilization of the wastewater by bacteria. The pond will therefore "tip over" and become an anaerobic one. The following preconditions are essential for the choice of such waste stabilization ponds:

- The pond has to be placed in an area where a sufficient wind current is available. A high building density, fences or forests will prejudice their function.
- In order to achieve maximum utilization of wind activity, a contact area between the water and the wind of 100 m is necessary (16), which means that the ponds should have a minimum length of 100 m.

Another criterion is the water temperature which will determine the volume and/or the necessary surface of the pond. Knowing the socalled load factor LF, obtained by the multiplication of the existing waste volume (V) by the respective BOD value, the pond surface and the volume can be obtained by means of the diagram in Fig. 46.

This diagram should only be used for a preliminary and rough determination of the necessarv space. A more accurate calculation procedure will be discussed later on.

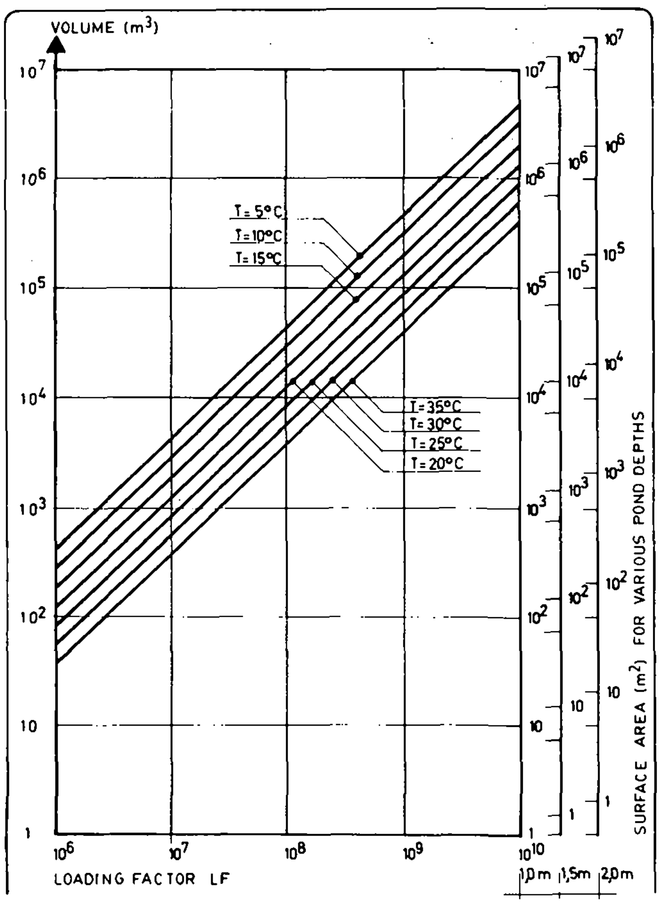


Fig. 46 GRAPH FOR CALCULATING THE REQUIRED VOLUME AND SURFACE AREA OF A FACULTATIVE POND

INFU (42)

Anaerobic zone

During the retention period of the wastewater in facultative ponds, all solid substances form a sediment on the bottom where anaerobic reduction at temperatures of above 15°C takes place, developing methane gas. The higher the temperature, the faster this fermentation proceeds. The rising gas bubbles carry sludge particles into higher layers where they are reduced by the aerobic process.

Fig. 47 shows a schematic summary of BOD reduction in facultative regions.

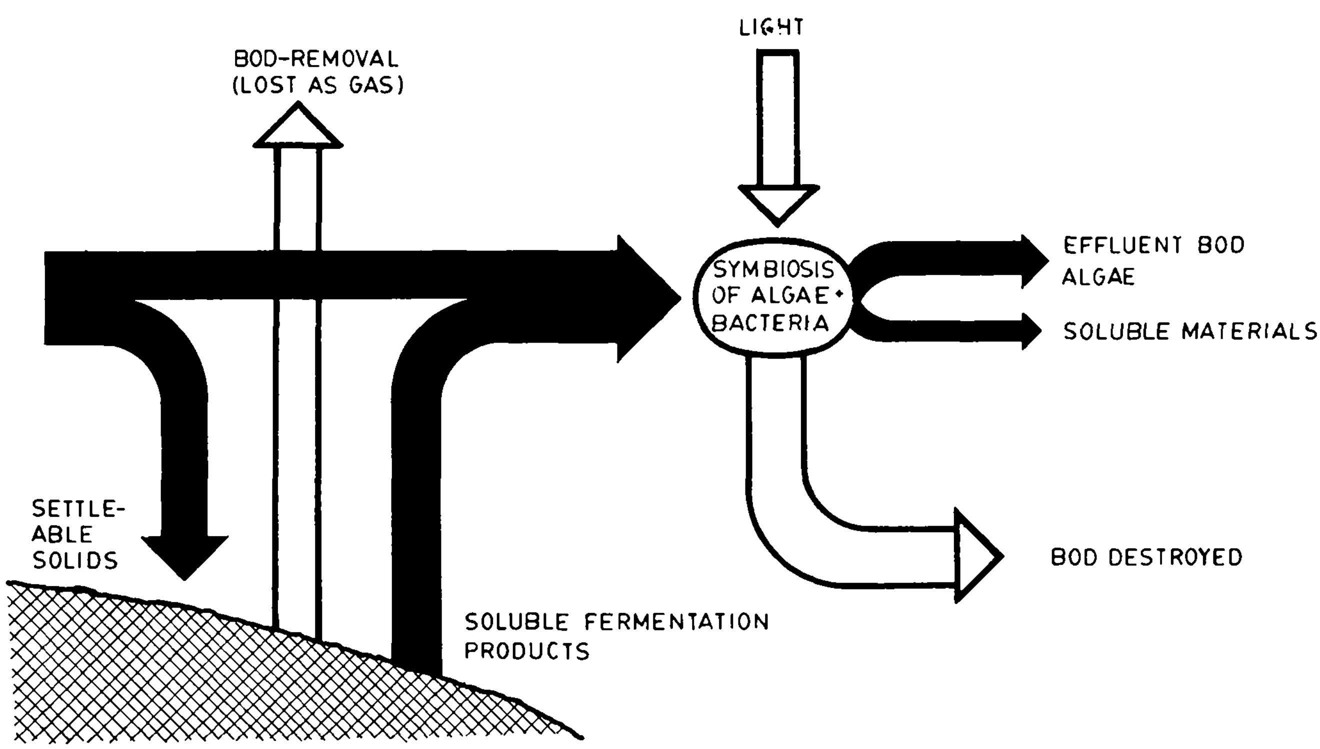


Fig.47 BOD-REMOVAL IN FACULTATIVE PONDS INFU (47)

The reduction and metabolic reactions and the microorganisms participating in this process are summarized in Fig. 48.

REACTION	MICROORGANISMS INVOLVED	TYPICAL REACTION
Biological oxidation (Aerobic section)	Aerobic bacteria, Fungi	$(CH_2O)_x + xO_2 \rightarrow xCO_2 + xH_2O$
Photosynthetic oxidation (Aerobic section)	Algae	$CO_2 + 2H_2O + h \cdot \nu \rightarrow Ch_2O + O_2 + H_2O$
Nitrogen conversion		Org. N $\rightarrow$ Ammonia Nitrate $\rightarrow$ Denitrification
Sulphur Conversion		Org. S $\rightarrow$ Sulfates
Phosphate conversion		Org. P $\rightarrow H_3PO_4 \rightarrow$ Calcium phosphate
Facultative section:		
Nitrogen conversion		Org. N $\rightarrow$ Ammonia $\rightarrow$ Algae combined N $\rightarrow$ Anorganic N
+ Processes in the aerobic and anaerobic section		
Organic acid forming (Anaerobic section)	Various heterotrophic bacteria (Clostridium etc.)	$2\ (Ch_2O)_x \rightarrow xCh_3COOH$
Methanic fermentation (Anaerobic section)	Methane bacteria	$Ch_3COOH \rightarrow CO_2 + CH_4$
Sulphur reduc (Anaerobic section)	Photosynthetic bacteria (Thiopedia, Chromatium)	Org. S $\rightarrow HS^- + H^+$ $\underset{\text{Base}}{\overset{\text{Acid}}{\rightleftharpoons}} H_sS$ $2H_sS + CO_2 + h \cdot \nu \rightarrow CH_2O + S_2 + H_2O$
Nitrogen conversion		Org. N $\rightarrow$ Ammonia

Fig. 48 BIOLOGICAL-CHEMICAL PROCESSES IN FACULTATIVE PONDS

INFU

Basic determination of the dimensions of facultative ponds

In numerous publications issued by a large variety of authors, a whole series of possible procedures for the calculation of ponds has been presented. The most clearly arranged one seems to be the procedure proposed by D. MARA (45) which is given below with the respective equations of the results:

1. Calculation of the pond surface:

$$A = \frac{Q\ (L_i - L_e)}{18 \cdot D\ (1.05^{T-20})} \qquad \text{- Equation 4 -}$$

A = Surface (in m^2)

Q = Quantity of wastewater (m^3/day)

L_i = BOD in the inlet (mg/l)

L_e = BOD in the outlet (mg/l; value is fixed at 60 mg/l)

D = Depth of the pond (in m)

T = Temperature of the coolest month of the year (in ^oC)

2. The retention time:

$$t = \frac{V_p}{Q} = \frac{A \cdot D}{Q} \qquad \text{- Equation 5 -}$$

V_p = Capacity of the pond (in m^3)

In these equations, the values of Q, L_i, L_e, and T are known or can be calculated (cf. anaerobic ponds). The depth which is chosen or fixed is in each case dependent on the prevailing climatic conditions of the environment. Approximate values can be taken from the table in Fig. 49.

RECOMMENDED DEPTH (m)	ENVIRONMENTAL CONDITIONS AND TYPE OF WASTE
1,0	Uniform warm temperature; presettled waste-water
1,0 - 1,5	Uniform warm temperature; untreated waste-water
1,5 - 2,0	Moderate seasonal temperature fluctuations; raw waste-water containing settleable solids
2,0 - 3,0	Wide seasonaltemperature variations; large amounts of settleable grit or settleable solids

Fig. 49 DEPTH OF FACULTATIVE PONDS IN RELATION TO ENVIRONMENTAL CONDITIONS AND KIND OF SEWAGE

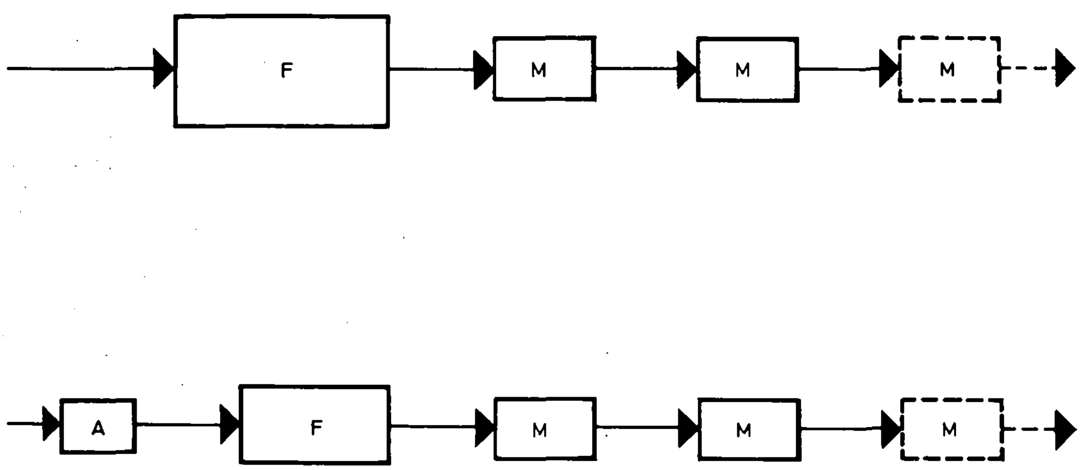
INFU (42)

- Maturation ponds

  The pond for final treatment are connected to the ponds functioning facultatively as an additional stage which cleanses the water of all pathogenic germs. The specific weight of the parasites is only insignificantly higher than that of water . But with a sufficiently long retention period of 5 to 10 days they will sink to the bottom and die off there. Suitably dimensioned ponds reach a reduction of coli bacteria of about 99.99 per cent and a reduction of the BOD value from about 60 mg/l (cf. facultative ponds) to less than 25 mg/l. The ponds work under completely aerobic conditions and in general have a depth of 0.5 to 1.0 m. With these data at hand, the necessary surface dimensions of ponds for final treatment can be calculated on the basis of Equation 3.

General remarks

The function of all anaerobic and facultative ponds is to reduce the BOD values, whereas the ponds for final treatment are intended to remove all pathogenic germs. This distribution of functions means that one should not design only facultative ponds but connect them to at least one or more ponds for final treatment. In the case of heavily loaded wastewater (BOD values of more than 400 mg/l) or in case of limited space, the additional construction of an anaerobic basin seems advisible (cf. Fig 50).



A = ANAEROBIC PONDS
F = FACULTATIVE PONDS
M = MATURATION PONDS

Fig. 50 ALTERNATIVE PONDS LAYOUTS FOR WASTEWATER TREATMENT INFU (16)

Dimensioning of maturation ponds

Research studies have shown that with a BOD load of less than 75 mg/l and a reduction to less than 25 mg/l, a retention time of seven days in two ponds for final treatment, arranged in series, would be required (cf. Figure 51 and No. 52). With a depth D of 1 to 1.5 m, the surface of the pond can be calculated by using the following equation:

$$A = \frac{Q \cdot t}{D}$$

Q = Quantity of wastewater

t = Retention time

Figure 51 - Waste stabilization ponds in Bangkok, Thailand

In case of high BOD loads or future extention of the plant, Fig. 52 can be taken as an example:

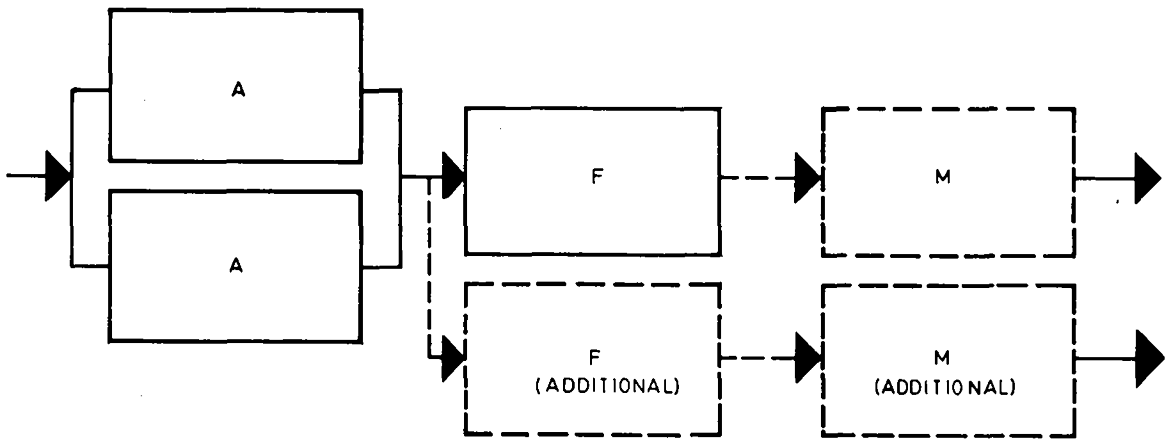


Fig. 52 POND LAYOUT IF A HIGHER DEGREE OF TREATMENT IS DESIRED INFU (16)

As already mentioned in Section 2.1.4, such pond systems are also suitable for the connection of septic tanks and aqua privies by a sewer system in order to treat their effluent.

Finally, these pond systems also render good services in the treatment and/or disposal of night soil (cf. Section 2.1.7). It is, however, absolutely necessary to provide at the point where the excreta is dumped into the anaerobic and/or facultative pond, a concreted ramp in order to guarantee that all human excreta really goes into the pond. SHAW (49) has given a description of such a plant in Pretoria, South Africa.

Planning aspects

In the planning of waste stabilization ponds and oxidation ditches co-operation between designers and engineers is of decisive importance. Because of the fact that these installations are generally designed by municipal authorities, these local administrations are also obliged to grant the necessary ground for them. The dimensions of the area required are calculated by the engineer with data he has at hand or which he has to ascertain. The characteristic values for these treatment plants are briefly dealt with once again below:

1. Quantity of wastewater (Q) in litres per day

   In the case of an existing sewer system the value of Q can be determined simply by measuring the outflow. Approximate values can be obtained by measurements made at each household, the values obtained then have to be multiplied by the number of the inhabitants connected to the system.

2. BOD

   A BOD-value of 50 g per capita per day (domestic wastes) may be expected in most rural regions of the developing countries.

3. Temperature

   For the dimensioning or design of facultative ponds (cf. the above statements) it is absolutely essential to know the temperature of the coldest month (cf. Fig. 46).

4. Ground water

   The maximum level of the ground water must always be below the level of the bottom of the pond.

5. Safety factor

   For all regions where clouding over has to be expected frequently, a safety factor of a 25 per cent larger water surface has to be chosen. The same safety factor should be chosen in the case of low wind activity.

6. Rainy seasons

   In all regions with very heavy seasonal rains, additional ponds might be necessary.

7. Collection of wastewater

   The design prerequisites are shown in Section 2.2.2.

Health aspects

The waste stabilization ponds built according to the requirements described above have an outflow which is largely free of pathogenic germs.

If the existing ponds are overloaded as a result of an increasing population, the overloading can be avoided by connecting new ponds parallel or in series to the existing ponds.

One problem may be represented by the odour nuisance of anaerobic pre-clarification ponds. Different measures have been indicated to solve this problem. When the stabilization ponds are well maintained, one rarely has any problems with mosquitoes. A really efficient protection is assured.

- the embankment vegetation is cut at regular intervals,
- the bank is protected by a consolidated layer at the level of the water line. Especially in the case of very large ponds, this measure is advisable because of the risk of erosion by waves (cf. Fig. 53).

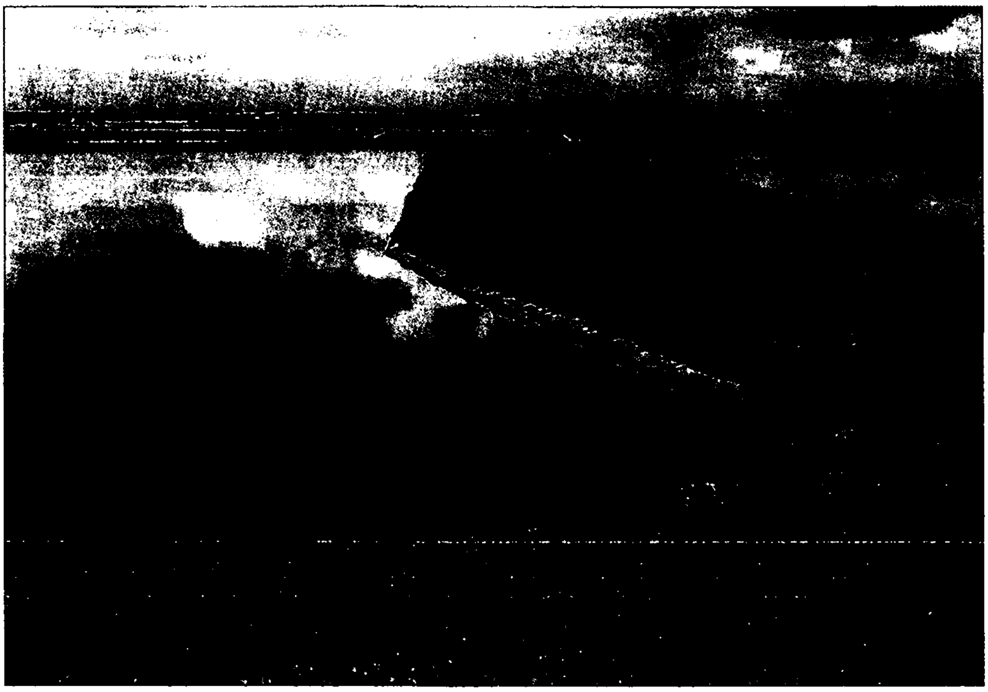


Figure 53 - Embankment consolidation of waste stabilization ponds (Nairobi, Kenia)

In general there is only incomplete disposal of pathogenic germs in aerated waste stabilization ponds and ditches. This disadvantage is overcome by the connection of sedimentation and maturation ponds. If properly designed and operated, the clarified water can be used for irrigation purposes and the sludge produced as fertilizer.

Re-use of organic wastes from waste stabilization ponds

Most of the developing countries are suffering under a continuous shortage of fertilizers which is restricting the food production.

Only in China all organic wastes, including human excreta, are almost completely re-used. In 1966, for example, 299 million of tons of night soil or 90 per cent of all the excreta accumulated in China was collected and re-used.
The goal should be to transfer this model to other developing countries (50).

Fish ponds

The fish bred in waste lagoons represent the most economic source of animal protein. The fish breed very fast in tropical water and the resulting costs are reduced to a minimum because no expensive fish food is needed.

In China fish bred in wastewater ponds with human and animal excreta and harvest wastes, etc. (51) constitute about two thirds of the world yield of fresh-water fish - 2.5 million tons.

In contrast to industrialized countries where 60 to 70 per cent of the food consists of animal proteins, this figure in the asiatic developing countries reaches a percentage of about 14. Fish cultures in wastewater ponds would be one way of increasing this value. One of the most suitable species of fish has been found to be Tilapia nilotica for example (52).

Tilapia is a fast-growing species of fish and the population in wastewater fish ponds can increase correspondingly in a relatively short time. The result is often a large number of very small fish. This problem is mainly due to poor or insufficient maintenance, as it has been proved by tests made in Africa. The ponds have to be emptied every 6 to 9 month after each catching period and then re-stocked. This method also enables a check or examination of the fry stock. We recommend stocking 2 to 4 tilapia per square metre of pond surface, which will enable them to reach a weight of 250 to 500 grammes after a period of 6 to 9 month.

A total output of 5,000 to 10,000 kg of fish per hectare and year can be expected provided the ponds are serviced properly and contain eutrophic water. Tilapia is especially suited because this species of fish is able to eat various kinds of food, e.g. algae, zooplankton, worms, organic residues, etc. (53).

The success of fish ponds depends to a large extent on the organic load (kg BOD or COD per hektare and day). A prerequisite is of course that the quantity of dissolved oxygen is higher than 0.5 mg/l because otherwise the fish would die. Some tests which, however, have not yet been concluded have shown that a minimum COD load of 50 kg per hectare per day will not impair the reliable functioning of such a plant (53).

There are other carp cultures, but these present far greater difficulties and should only be undertaken in regions where carp breeding has a tradition.

Dimensioning of fish ponds

The dimensioning of fish ponds is governed by three basic criteria:

1. The average temperature over the year and/or the climatic conditions
2. The loading of the fish pond with organic pollutants
3. The species of fishes bred.

Studies have shown that tropical temperatures have a positiv influence on the reduction rate and therefore promote the growth of the fish. Criteria 2 and 3 are highly interdependent (53).

In addition to the above factors, air-breathing fish such as catfish can withstand poor water quality and thus live in a pond which receives the waste from a relatively large number of livestock/unit area. Pangasius catfish are commonly raised in such ponds in Thailand, but in China, India and Israel carps, which derive their oxygen from the water, are more commonly stocked, and need a larger water surface to recycle a given quantity of wastes.

For the dimensioning of fish ponds the total quantity of wastes is of decisive importance. This quantity may be about 50 per cent of the total sludge accumulation of one municipality. The remaining percentage is disposed of by other means (for example by discharge into surface waters, deposition in pits, etc.).

If we have a sludge quantity of 30 g BOD per capita per day in a municipality of 10,000 inhabitants, we may have a total waste quantity of 150 kg of BOD per municipality per day. The BOD loading of the ponds per hectare per day should not exceed approximately 50 kg, as has been shown by recent studies. For the example at hand, this would correspond to a pond surface of 3 hectars Fig. 54 shows how to demension single ponds.

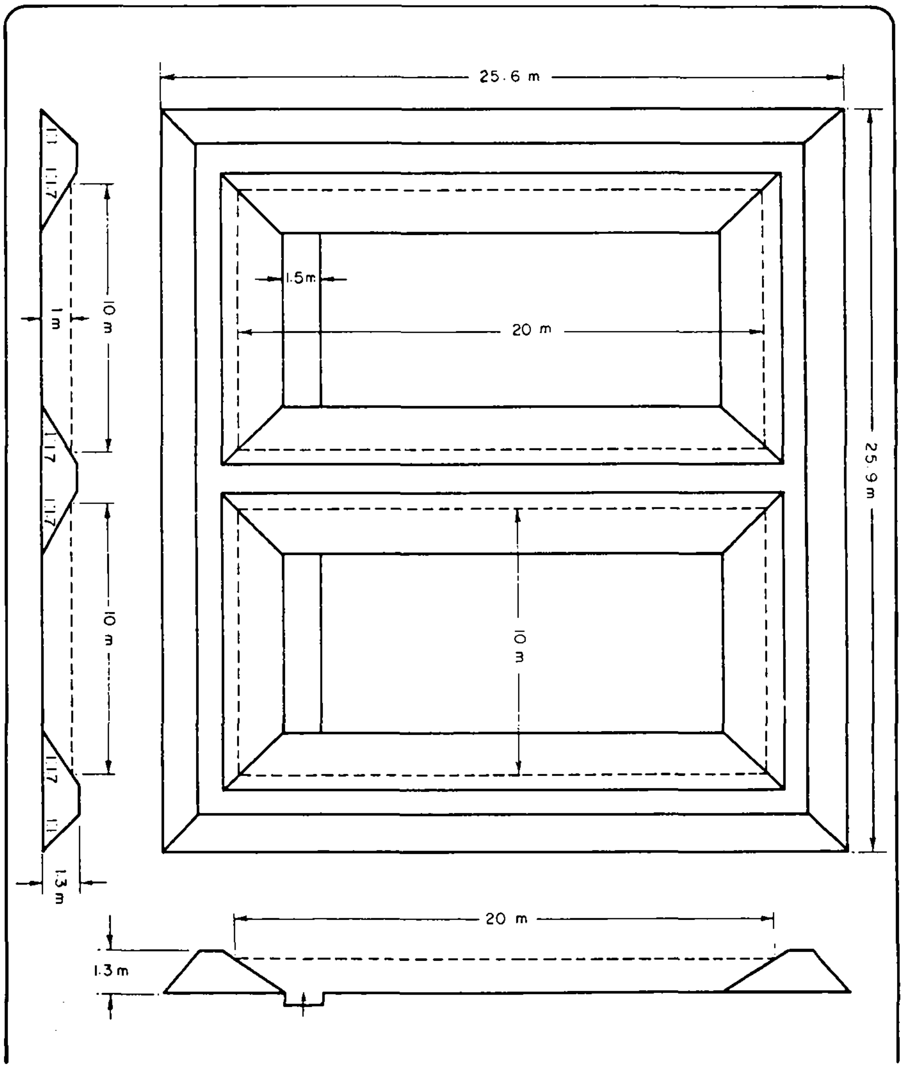


Fig. 54 DESIGN OF FISH PONDS INFU (70)

The breeding of fish in ponds with animal wastes

The idea to use the nutritious substances of animal wastes to breed fishes was born in China. Owing to the fact that animal excreta still contains 72 to 79 per cent of the nitrogen, 61 to 87 per cent of the phosphorous compounds and 82 to 92 per cent of the potassium contained originally in the animal fodder, recycling offers a profitabel method. The risk of contaminating the fish with resistant pathogenic bacteria in the fresh sludge has always been pointed out. Different studies have, however, not presented any negative results (54),(55),(56).

In China it is quite normal to mix up animal excreta with agricultural wastes and sludge and leave them to ferment for about 10 days in the pit.

An alternative is to combine biogas plants and fish ponds, as digested biogas sludge is largely free of any infectious germs and rich in nutritive substances (cf. Section 2.1.5) (58).

The fish yields obtained by this procedure vary depending on the conditions prevailing in case to case. Some examples are given in the table in Fig. 55.

Country	Yield in kg/ha, year	References
Israel	10,950	(57)
Israel	14,600	(51)
Philippines	8,000	(58)
Indonesia	7,500	(59)
India	8,500*	(60)
Thailand	30,000	(61)

* For a period of 11 months

Figure 55 - Fish yields from ponds. The source of nutrition is animal waste products

Plants currently in operation

Only in China does the breeding of fish in ponds in which animal excreta is discharged represent an integrated sector of agricultural production.

In Taiwan the first attempts were started in 1972 to breed fish in ponds into which the waste of ducks, pigs and chicken were directed. In the meantime, this technology is widespread and is becoming more and more popular (62).

In Thailand there are a number of integrated farms, run mainly by Thais of Chinese descent.

In most other Asian countries e.g., India, Indonesia, Malaysia, and the Philippines integrated farming systems are few or are mainly at an experimental stage (59).

Barnyard manure has to be collected and transported to the ponds. For this reason it is practical to minimize the transport distances in order to keep operation costs low.

Figs. 56, 57 and 58 show some ways of doing this. There are so far no reliable figures on how many animals should be kept per hectar of pond surface. In the available literature on this subject the figures vary greatly, as shown by the following data:

500 to 10,000 ducks,
1,000 to 10,000 chicken,
15 to 200 pigs

per hectare of pond surface (63).

In Thailand there is one plant with 400 pigs per hectare in operation.

These figures vary very much on the one hand because of differing climatic conditions and on other hand because of the very different species fish bred in the ponds.

Figure 56 - Fish ponds into which the manure of pigs is discharged (Thailand)

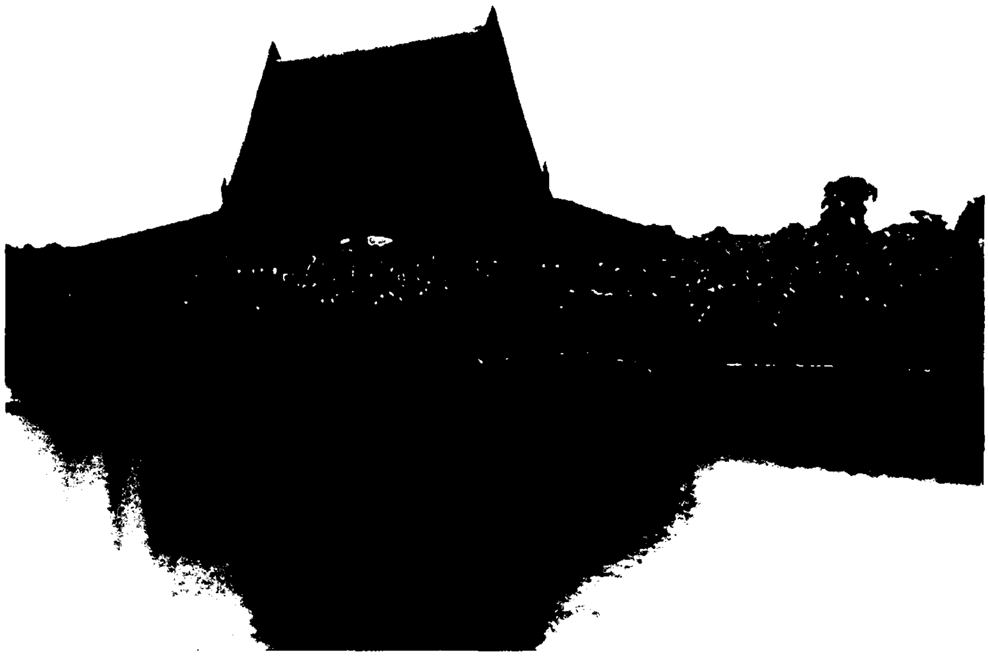


Figure 57 - Fish pond in which the nutrition consists of manure from pigs and chicken (Thailand)

Figure 58 - Poultry farm erected directly over a fish pond. The waste material drops directly into the pond (Thailand)

Breeding of fish in ponds fed with wastes from agriculure and small-scale industries

The processing of many agricultural products requires the use of large quantities of water. The resulting waste water is usually discharged into the nearest body of water, which is then contaminated. In Malaysia, for example, it is estimated that 80 million litres/day of rubber effluents and 3.4 million tons of oil palm effluent/year are produced, and most of this is discharged with little or no treatment.

As all wastewater produced by agriculture and small-scale industry has a high content of nutritious substances, re-use would be logical.

This is why PARKER (65) proposed a modified waste pond system (cf. Section 2.2.2). In an anaerobic pond 70 per cent and more of the BOD load is decomposed, while algae grow in the next pond, providing an excellent fish food with a protein content of about 50 per cent. Other tests, made by NUGENT (66) with the use of brewery wastes, resulted in a fish yield of 2,500 kg per hectare and year. Other positive results from other industries (destilleries, production of rubber, etc.) have also been published.

Some fruit and vegetable wastewaters contain only few usable nutritious substances and should, therefore, be blended with other wastewater, for example with wastewater from the milk processing industry.

Breeding fish in ponds enriched with excreta

Breeding fish on excreta is rejected in most developing countries. Only in China it is customary to use human excreta as a fertilizer or as nutritious substance for fish ponds.

Apart from some small plants installed only for test purposes, there is only one large plant outside China, this being in Calcutta. The domestic wastewater of the town is used as a fertilizer for a fish farm covering about 2,500 hectares. The fish ponds, with an area of 1 to 50 hectares, are fed by channels diverted from the trunk sewer of Calcutta, which opens into the sea. The quantity of inflow from this plant, which was built in 1930 and has since been extended several times, is controlled by the users themselves.

The fish obtained from these ponds are brought to the market every morning in metal containers and play an essential rule in the town's fish supply. The yields range between 10,000 and 28,000 kg per year. Encouraged by these good results, the Government of the District decided to extend the existing system to a total of 10,000 hectares. It also intends to build an additional wastewater treatment plant.

At present, thorough tests are being undertaken at the "Asian Institute of Technology" with the object of optimizing the process described above (53).

In a stabilization pond, the quantity of pollutants is decomposed and all pathogenic germs are killed. At the same time, an accerlerated growth of algae due to photosynthesis takes place. The resulting outflow runs into fish ponds where the algae serve food for Tilapia nilotica. The nutritious substances remaining in the outflowing water are used to irrigate maize fields.

No studies are known in which the contamination of fish with pathogenic bacteria has been proved.

According to a second series of studies carried out by EDWARDS, it is possible to breed about 20,000 kg of fish per hectare an year in earth ponds (cf. Fig. 54 and 59)As the price per kilogram of this so-called trash fish is currently US $ 0.125, the gross return would be US $ 2,500 per hectare and year which far exceeds gross return on rice, the most common crop in the area.

Fig. 59 - Fish ponds in Bangkok. They are surrounded by a meshed fence in order to keep away snakes

Socio - cultural aspects

In China andIndia one is unlikely to encounter any reservations against the consumption of fish indirectly fed on human excreta. In other asian countries, for example in Thailand and Indonesia, The fish is normally re-used as animal fodder. Interviews have shown that there are in general no clear ideas regarding the possibility of becoming infected with deseases. In some cases it was possible to dispel the concerns of the population by transferring the fish to a fresh-water pond prior to its sale.

Health aspects

The available data is insufficient to permit recommendations. In 1949, the re-use of excreta without any previous processing lead to widespreading disease : in the meantime all the wastes are retarded in composting units for a period of ten days before beeing discharged into ponds (52).

Even if the fish ponds carry out the same function as the stabilization ponds, the eliminitation of pathogenic germs will generally not be complete. For this reason it is recommended that a treatment unit for excreta, i.e. a composting unit, a biogas plant, pond systems, etc. be installed upstream of the fish ponds (cf. Fig. 60).

Itis not likely that mosquitoes can breed in a fish ponds because the larvae are eaten up by the fish (depending on the species of fish).

Wastewater lagoons with aquatic plants

Some plants are able to absorb dissolved organic and inorganic material and incorporate these in their own structure. The clarification capacity of these plant cultures which are either connected in a series as the last treatment stage of a sewage plant or operate without any pre-clarification is in most cases of such a good quality that the outflow can for instance be re-used for irrigation purposes.

The plants can also be reaped and used later on, so reducing the costs of the plant. The nitrates, phosphates and organic carbon are essential nutrients for agriculture, and especially the first two are most important components of fertilizers. The production of artificial fertilizers requires a great deal of energy and is often beyond the financial means of farmers in the rural areas of developing countries.

Consequently, aquatic plants fulfill two important functions:

- They absorb organic and inorganic matter contained in wastewater, which is clarified by this process.
- Owing to their high content in nutritious substances, they can themselves be used as fertilizers.

The design of a waste water treatment plant with aquatic plants is very simple: The wastewater is fed into shallow ponds covered with aquatic plants. These plants extract from the effluent the nutritious substances described above. They also extract heavy metals like cadmium, nickel, mercury and even phenolic compounds and carcinogens. The concentration of these substances reaches up to 20,000 times the effluent concentration. The plants are harvested several times a year in regular intervals or at the end of each season. Besides fertilizers, the harvest may be used as a raw material for biogas production (cf. Section 2.1.5) or as an animal fodder (72).

Today, more than 40 plant species are known, which can be used to treat wastewater, many of them have long been used as food (water spinach for example)

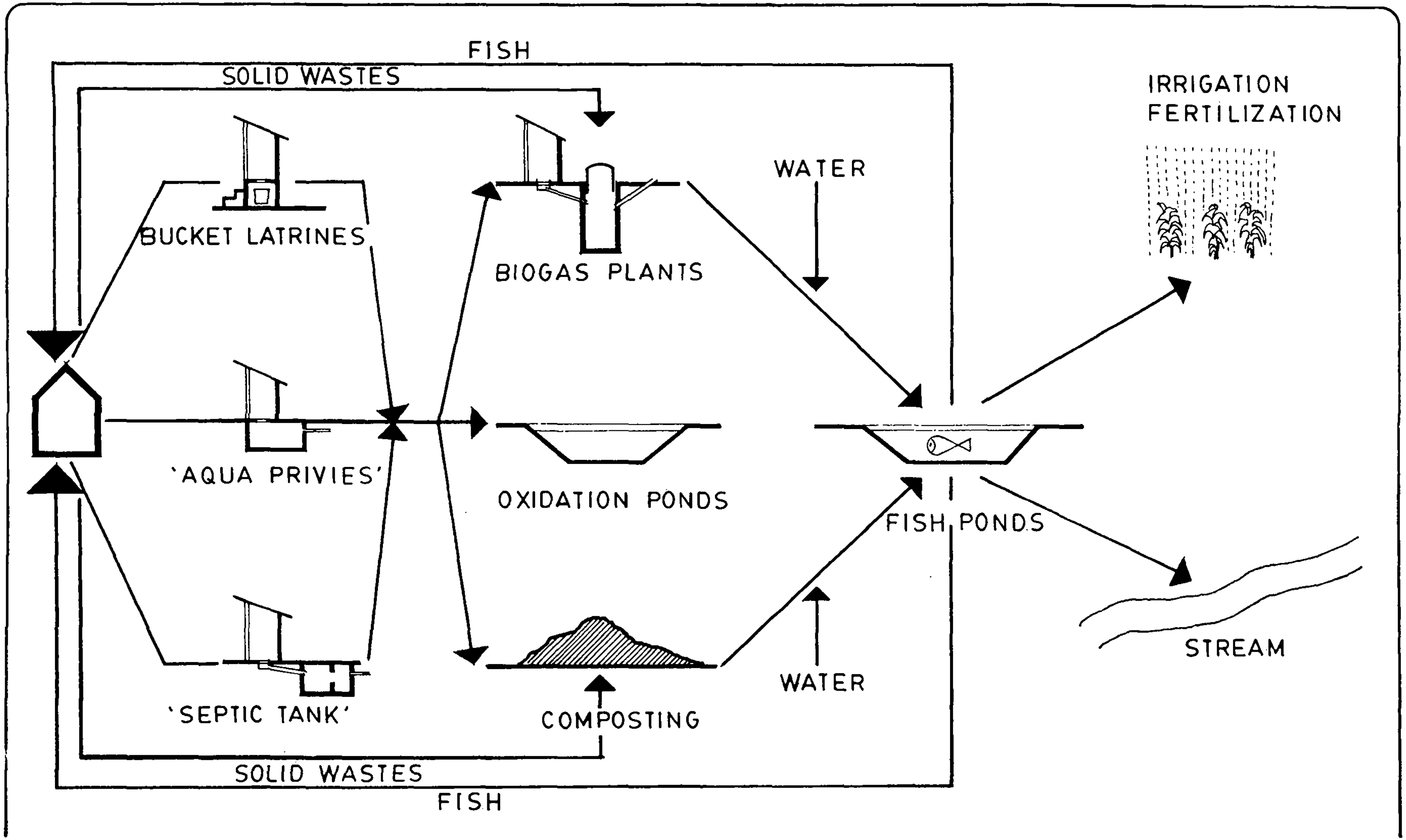


Fig. 60 — POSSIBILITIES OF COMBINING DIFFERENT WAYS OF PRETREATING AND RE-USING SOLID WASTES IN FISH PONDS

INFU
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others are only consumed in small quantities and only if produced in certain areas of developing countries.

The following plants have proved suitable for the treatment of waste waters:

1. Bulrush (Scirpus lacustris)
2. Water hyacinths (Eichhornia crassipes)

The following plants are also well suited, but they are grown mainly as food, fodder or fertilizer:

3. Duck weed (Wolffia spp., etc.)
4. Bluegreen algae (Spirulina spp.)
5. Water spinach (Ipomoea aquatica)
6. Aquatic ferns (Azolla pinnata)

1. Bulrush (Scirpus lacustris)

The exploitation of aquatic plants - as for example bulrush and common reed - for treating domestic and some industrial waste waters, has been examined by SEIDEL. The wastewater is discharged onto a crusned-rock and sand bed on which the reeds grow. The plants grow very fast, reaching heights of 2 to 4 metres. The roots are anchored in the crushed rock. The solid substances of the wastewater are retained by the rock-sand bed, whereas the water seeps through. All the organic and inorganic components are absorbed by the reed or decomposed by the microorganisms forming a biological slime on the rocks. Because of the fact that these reeds have air-vessel, oxygen is transported down to the roots, where it is released and provides an aerobic condition for the microorganisms. If a sludge layer is formed, new roots grow along the stems, which promotes the reduction of pollutants and sludge volume.

This pre-treated water then flows into a second treatment stage.

2. Water hyacinths (Eichhornia crassipes)

The water hyacinth is a very fast growing and reproductive plant. Under subtropical and highly nutritious conditions, this plant is able to double the partial surface covered in 6 to 7 days. This means on the one hand that every day approximately 20 to 40 tons of fresh plants can be harvested per hectare (with more than 95 per cent water content) and on the other hand that nutritious substances can be extracted from the pond water in large quantities within a very short time.

With a sufficient quantity of nutrients and a subtropical climate (ideal water temperature: 26 to 30 ^{0}C), the water hyacinth is able to extract through its roots the following quantities of elements from the wastewater (72):

Nitrogen	22 - 44	kg/ha /day
Phosphorus	8 - 17	"
Calcium	11 - 22	"
Magnesium	2 - 4	"
Potassium	22 - 44	"
Sodium	18 - 34	"

In a stabilization pond in Florida, into which 2.2 million litres of waste water are discharged daily, the water hyacinth reduces the nitrogen components by 80 per cent and the phosphorous compounds by 40 per cent, with a retention time of two days. In addition the plants remove algae and coli bacteria, reduce all dissolved substances and neutralize odeur components.

In South Mississippi the NASA erected a plant which treats the wastewater of a small municipality. On an average, 35 mg of nitrogen and 10 mg phosphor compounds are fed into the pond. With a retention time of 14 days in a pond of 5,000 m^3, these pollutants in the waste water are reduced by 80 per cent by the hyacinths. About 1,000 inhabitants were connected to this system. The respective rates of decomposition of the solid substances and the BOD are shown in figure No. 61, compared to the values obtained before planting the hyacinths.

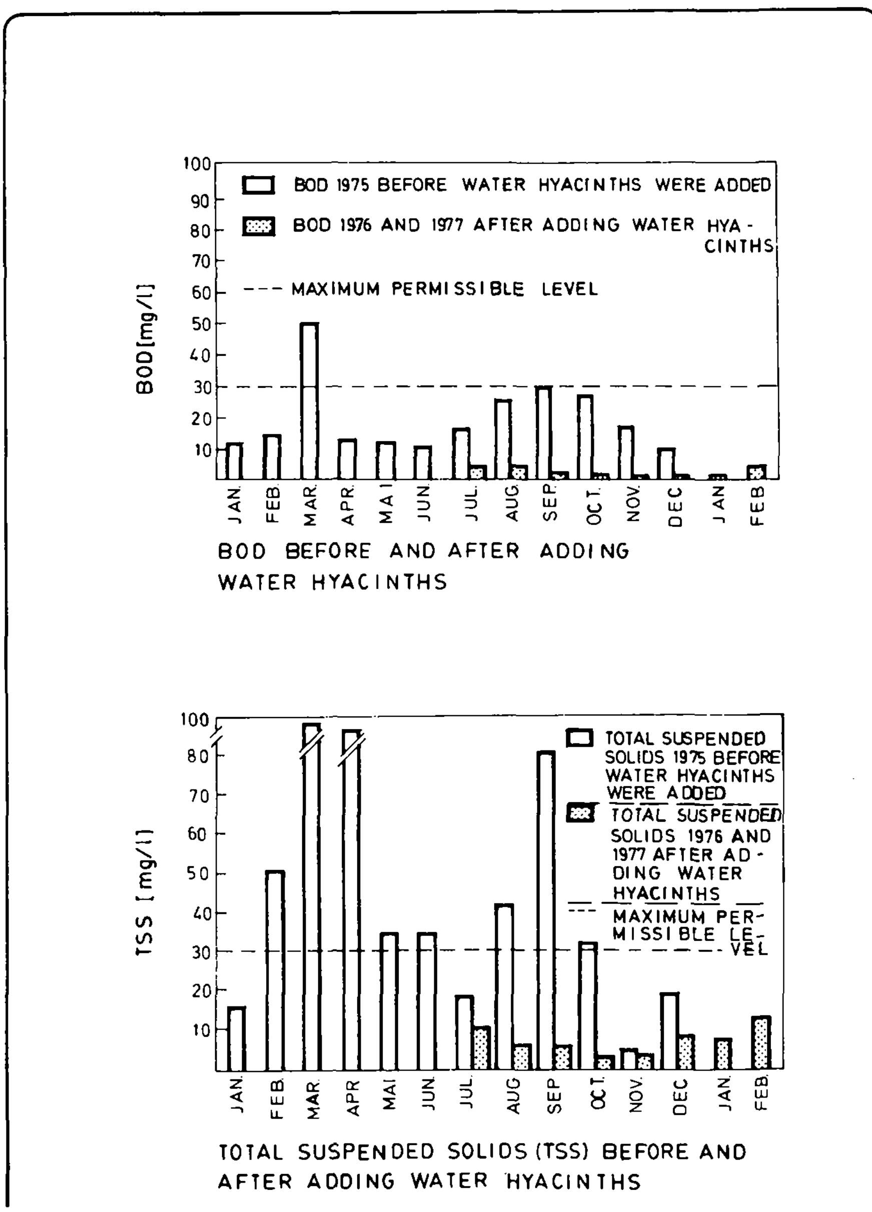

Fig. 61 ABILITY OF WATER HYACINTHS TO REDUCE BOD AND TSS

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- Re-use of the plants

The stabilization ponds only function properly if the plants are regularly reaped. The large quantities of plants harvested are suitable for further use (cf. above).

The goal aimed at by the NASA was to re-use the waste of human beings in a completely closed system. The water hyacinths are rich in proteins, vitamins and trace elements or could be transformed into energy (biogas) and fertilizers.

This waste treatment method originally tested for space laboratories could also be successful in developing countries and produce vital products.

	Protein %	Fat %	Calcium %	Potassium %	Sulphur-	Nitrogen- compounds %	Phosphor- ous
Water-hyacinth	2.34	2.2	1.5	4.0	0.4	3.74	0.85

Very good results have also been obtained with a small water hyacinth pond fed with laboratory wastewater containing heavy metals. The following table shows certain pollutant values (mg/l) contained in the wastewater inlet and outlet:

	Organic carbon	BOD	Dissolved substances	Nitrogen	Phosphates	Silver
Inlet	75	33	380	2.36	0.48	0.99
Outlet	13	3.6	212	0.43	0.08	0.001
Reduction %	83	89	44	82	83	99.9

a) Animal fodder

In Asian countries it is customary to use reaped hyacinths as fodder for pigs, cows, water buffaloes, etc. A pig, for instance, consumes daily 1.5 to 2 kg of fresh plants. In this case a further recycling stage is possible because the water hyacinths are also able to treat the pig wastes in the same ponds. The treatment capacities are illustrated on the following page (72).

In India we learnt that cows fed with approximately 7 kg of water hyacinths per day yielded 10 to 15 per cent more milk. But this milk had an increased water content and could only be transformed into butter with difficulty.

In the Sudan, India and Bangladesh, water hyacinths are used as fodder mainly during the dry periods (77), (78), (79).

In Malaysia, Singapore, Thailand, China and Hong Kong the plant is mainly used as pig fodder.

b) Fertilizers

Owing to the large amount of nutritious substances they contain, the plants are very suitable for improving the soil. The most simple procedure is to plough the plants in after the harvest and to leave them to putrefy. This is, of course, quite difficult because the plants are very voluminous.

A more simple method, known already in ancient times, is to compost the plants with earth, ashes, animal wastes and excreta.

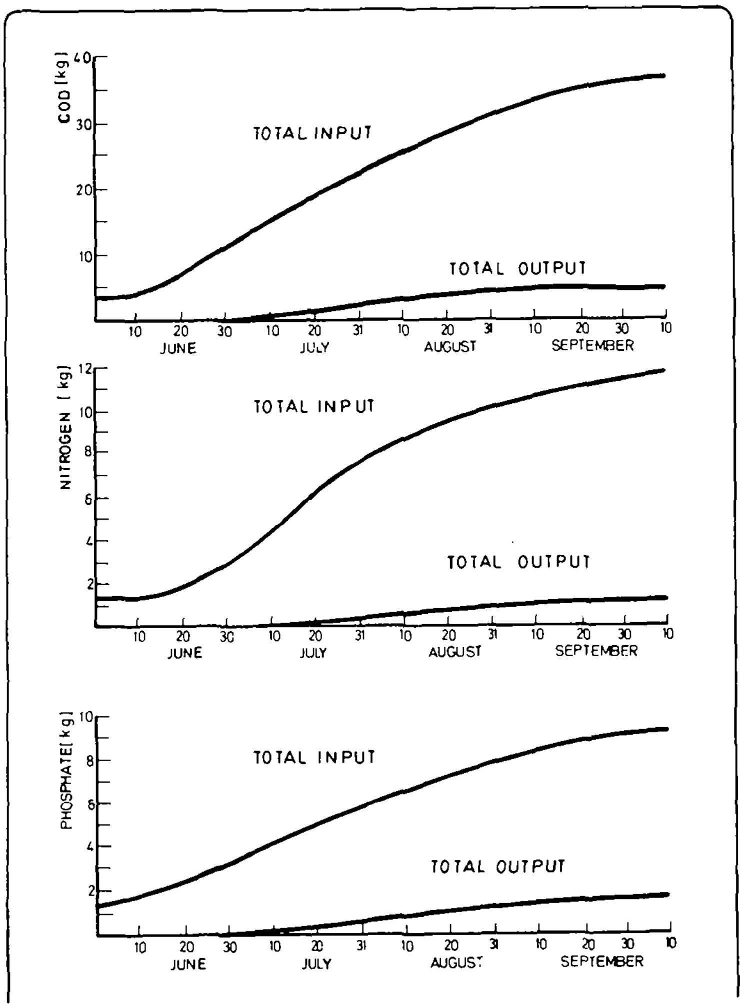

Fig. 62 PURIFICATION OF WASTEWATER FROM A PIGSTY BY WATER HYACINTHS INFU (75)

In Thailand successful tests have been carried out by composting water hyacinths with night soil. The hyacinths are cut into pieces 5 cm in length in order to faciliate the bacteriological transformation. As the C/N ratio of a hyacinth/ night soil mixture does not have the necessary values between 20 and 40, leaves, for instance, may be added. The mixture proportions are given in the table in Fig. 63.

C/N-ratio	20	30	40
Night soil %	14.4	10.9	7.3
Water hyacinth %	57.4	25.4	10.9
Leaves %	28.2	63.7	81.8
Water hyacinth : night soil	80 : 20	70 : 30	60 : 40

Figure 63 - Mixture proportions for composting night soil and water hyacinth

c) Biogas

The water hyacinths are a good organic raw material for biogas plants, and tests made by the NASA have shown that with the harvest of one hectare more than 70,000 m^3 of biogas can be obtained, which means 370 litres per kg dry weight. A prerequisite is of course that the plants are cut up before feeding them into the plant (cf. Section 2.1.5).

Health risks are not to be expected in this procedure. The coli bacteria will be reduced by 70 to 90 per cent within a composting period of 10 weeks. Neither do ascaris eggs represent a risk as they are also killed off during this long period with composting temperatures ranging between 40 and 60 °C (81).

Combination of different possibilities of re-use

Owing to the positive experiences made by the NASA with water hyacinths, a prototype model has been developed in which the plants are completely converted into animal fodder, fertilizer and biogas (cf. figure No. 64).

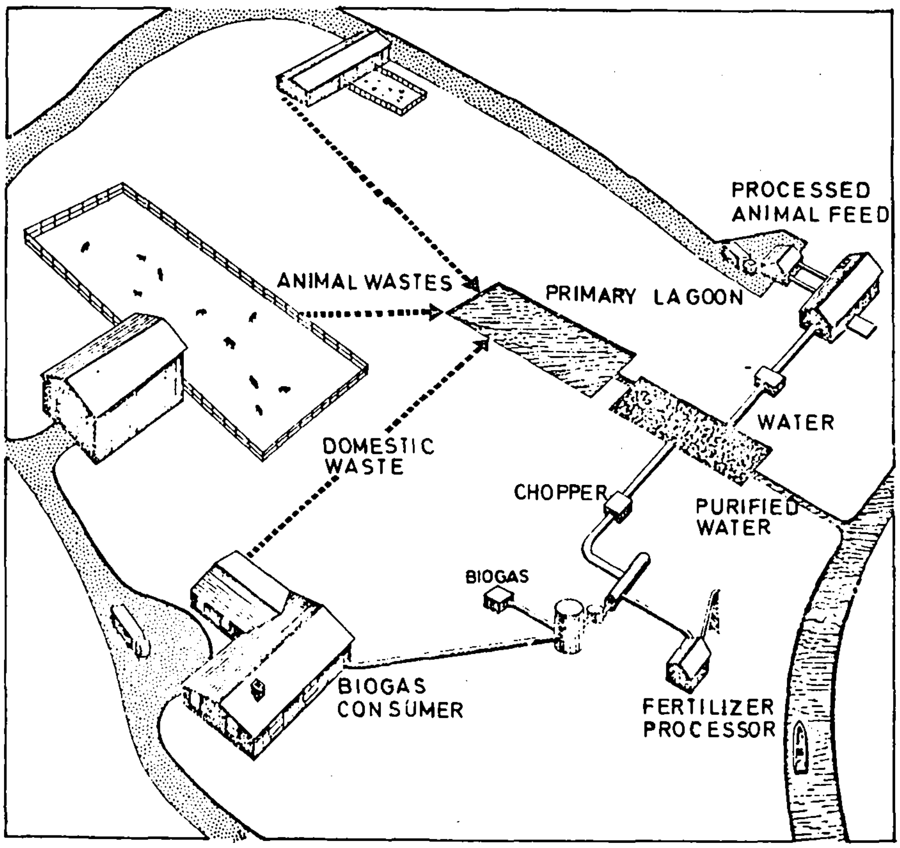

Fig. 64 MODEL FARM WHERE ORGANIC WASTES ARE CONVERTED INTO BIOGAS, FERTILIZER AND ANIMAL FEED

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3. Duck weed (Wolffia spp., Wolffiella spp., Lemna spp.)

Duck weed is a plant which floats freely on the water surface and is able to absorb for instance nitrates and phosphates not only through its roots, but also through its leaves. Within only three days, in tropical regions, they double the surface covered by them.

Harvesting is very simple and is normally effected by means of grids or nets. This means that with a sufficient quantity of nutrients, and under favourable conditions, up to 40 tons (dry weight) per hectare are reaped every year. The harvested raw product contains about 40 per cent protein.

- Further use

a) Food

For many generations the harvested duck weed has been consumed in Burma, Laos, Thailand and in certain regions of India as a vegetable and is known there as "water eggs". It should, of course, be pointed out that these are mainly plants grown in natural waters with relatively low pollution. If plants from waste ponds are consumed, they have, first of all, to undergo a hygienic examination.

b) *Animal fodder*

The utilization of duck weed as fodder also has a long tradition. It is consumed either directly by fish, duck, geese and other animals or is fed to cows and pigs after the harvest. These weeds are also suitable further use, in the same way as the water hyacinth. The highly nutritious waste materials from pigs or cows discharged into ponds serve as fertilizer to develop a high quality and protein enriched duck weed which is well suited as animal fodder. Fig. 65 shows the chemical components.

	Fat %	Calcium %	Potassium %	Nitrogen- Sulphur- compounds %		Ashes %	Energy cont. cal/kg
Duck weed	4 - 6 (72)* 3.4 (74)*	1	1.5 - 3 (72)* 2.0 (74)*	6 - 7 (72)* 6.32 (74)*	1.4 - 3 (72)* 0.85 (74)*	8 - 14	1958

* References

Figure 65 - Chemical components of duck weed

4. Algae

a) Bluegreen algae (Spirulina spp.)

Bluegreen algae are composed of 60 to 70 per cent protein and are rich in vitamins, especially vitamin B_{12}.

The residents at Tschad Lake in Afrika reap the algae by simple filtration through pieces of cloth, they then dry them in the sun, cut the residues into small blocks and consume them as vegetables.

These algae were, by the way, the protein source of the Aztecs and today in Texco-co, near Mexico City, a pilot plant has been built in which about one ton of dried bluegreen algae are harvested per day. The product is sold as a protein and carotene enriched additive for the pig fodder. Tests on the possibility of adding this product to human food are currently being carried out with great success. This kind of algae grows mainly in water or ponds with a high pH value; for this reason, it is especially suited for certain kinds of wastewater.

b) Different kinds of algae (Scenedesmus spp., Micractinium spp., Oocystis spp., Chlorella spp., Euglena spp.)

In Israel (Haifa) SHELEF et al. (77) have carried out tests to treat domestic wastewater in algae ponds and in the course of those tests no differing purification capacities were noted for the various algae species. The plant consists of an oxidation ditch 0.45 m deep (cf. ection 2.2.3) in which wastewater with a BOD content of 220 to 800 kg/ha per day with a retention time of 2 to 7 days was treated, giving a crop of 120 tons of algae per year (dry weight). The outflow contained a BOD value of less than 20 mg/l. The algae were removed from the water, dried and used as animal fodder. As a result of the low production figures, the meal of the algae currently has no marketable value, but it has the same quality as the soybean meal. In 1978 about 25 US $ per kilogram dry weight were paid on the market for soybean meal. It is also comparable to fish meal with a price not lower than 50 US $ per kilogram. However, temperatures of 25 $^{\circ}$C and a large quantity of fertilizers - for example night soil - are required for fast growth. Normal cultivation disposes of about 3,100 kg of night soil per hectare in 2 to 3 days. The growth is very fast and the first crop can be harvested after about 30 days, from then on every 7 to 10 days. The total harvest per year is approximately 90,000 kg/ha.

The algae are very small which means that the harvesting technique can become very expensive. There are algae ponds in developing countries, but they are not widespread because they are difficult to operate as far as re-utilization is concerned.

5. Water spinach (Ipomoea aquatica)

Water spinach is a floating plant rooted in the sludge of the pond. In India, South-East Asia and China it is consumed as a vegetable. The fresh and young leaves may be cooked. Their protein content ranges between 18.8 and 34.3 per cent, calculated on the dry weight (76).

In Thailand these plants are found mainly in eutrophic channels and shallow ponds into which the effluent of septic tanks - among other wastes - is often discharged (cf. Fig. 66).

The use of water spinach is most widespread in Hong Kong where about 3 to 5 million kilograms are harvested per year. This amount represents about 15 per cent of the local vegetable consumption.

Figure 66 - Pond with aquatic plants in Bangkok, Thailand

The night soil load in water spinach ponds is usually about 3,100 kg of night soil per hectare within 2 to 3 days (77).

6. Water fern (Azolla pinnata)

Azolla grows as a free-floating plant in eutrophic and warm waters. In China this plant has been used for a long time as a fertilizer for rice cultivation and as fodder. The plant grows in symbiosis with a type of bluegreen algae. This algae is able to absorb enough atmospheric nitrogen to assure productive plant growth. Owing to the nitrogen absorbed this plant is predestinated to be used as a fertilizer (35).

Planning aspects

To cultivate aquatic plants, large and flat basins operating under aerobic conditions are required. A low water turbulence must be assured which means that in the planning stage of the ponds provision should be made for the utilization of the natural wind aeration of the pond surface (no dense built-up areas or forests around the basins).

The spreading-out plant cover not only reduces the turbulence, but also the photosynthetic process of the algae which also enrich the water with oxygen.

This means that part of the pond surface should always remain free and uncovered which is achieved by regularly reaping the aquatic plants.

Socio - cultural aspects

The utilization of aquatic plants for the purpose of wastewater treatment is still in an experimental phase and so far only has a tradition in Asian countries.

The implementation should, therefore, not encounter great difficulties in those countries, but in other continents it is recommended to provide comprehensive instruction and training courses parallel to the planning and construction phase.

Health aspects

All the objections described in the preceding chapter on stabilization ponds also apply to this procedure. Pestizides, heavy metals or industrial wastes represent a risk for the whole pond cultivation. The consequences are odour nuisances, mosquitoes, ground-water pollution and insufficient reduction capacities. For certain wastewaters it can only be suggested to plan a controlled test stage.

The fertilizing of hydroponics with excreta can result in three fundamental health risks, i.e.:

- The absorption of pathogenic germs by the human beings who reap the plants and come into direct contact with the water. One disease caused in this way is schistosomiasis.
- The reaped plants can be contaminated by pathogenic germs and there is, therefore, a risk that human beings consuming these plants will be affected by a disease. This is particularly imminent if the vegetable is not cooked before consumption.
- Finally, the risk of infection by the liver fluke is a factor of major importance for a large part of the Asian continent. (It is estimated that in this part of the world about 10 million people are affected by the liver fluke.)

In consideration of all these reservations it seems more advisable ans less problematic to use the reaped plants as raw material for composting or biogas in view of excluding health risks.

Institutional aspects

With the exception of China, all such plants existing on the Asian continent are in private ownership and are, therefore, not creating any institutional problems. But in all cases where these plants are used as a foodstuff, regular checking by the public authorities seems to be absolutely necessary.

Summary and recommendations

Of the great number of utilizable aquatic plants, five species have been described, three of these being very suitable for re-utilization:

- The water hyacinth used in some developing countries as animal fodder seems to be very suitable for composting and as raw material for biogas plants.
- The duck weed which offers - as opposed to the water hyacinth - the advantage that is easier to reap and could possibly be a better animal fodder, seems to be the most suitable of all the aquatic plants so far mentioned.
- The water spinach which is reaped in many areas of the Asian continent.

2.2.3 Activated sludge process with extended aeration

(Aerated ponds, oxidation ditches and package plants)

- General information

The supply of oxygen from the air and by photosynthesis through the natural water surface is not sufficient for highly polluted wastewaters and in places where only a limited surface is available. For this reason additional air has to be fed into the system. The activated sludge process which accomplishes this is suited not only for domestic but also for industrial waste water.

The process is carried out by aerobes which are contained in large numbers in the wastewater. They settle in flakes, forming the biological sludge. A good mixture of the wastewater-sludge combination guarantees aerobic conditions in the whole basin. The microscopic organisms, mainly bacteria and protozoa, transform the sludge into a biologically effective compound. By circulating the wastewater within the tank it is assured that the flakes do not sediment at the bottom but remain in free suspension.(Anaerobic conditions would form at the bottom of the tank if the flakes were allowed to sediment.)

In general a distinction is made between mechanical or superficial and pressure aeration. The former, which is achieved, for instance, by means of rotors and surface aerators, requires less maintenance expenditure and less energy and for this reason this type of aeration alone is recommendable for developing countries. By the rotary movement the water surface is broken up, enlarging the boundary surface between air and water. The oxygen supply is controlled by the depth of immersion and the number of revolutions.

For the waste stabilization ponds described above, the necessary pond surface could be substantially reduced by an additional aeration, but this advantage is brought at the cost of energy required. This fact sets a limit to the field of application - especially with respect to the rural districts of developing countries - and calls for the necessity to provide such plants only for certain requirements (for example in the case of limited space, highly loaded wastewaters, etc.).

In this case, the utilization of wind energy represents an alternative solution. Up to now, wind-wheel operated aerators have only be used to a limited extent in the Asian countries, especially in Japan, for the aeration of low loaded lagoons. For large size oxidation ponds, special rotors have to be developed and tested.

- Dimensioning of an aerated lagoon

The intensive stirring up of the wastewater-sludge mixture leads to a uniform distribution of the oxygen content in the lagoon, the concentration of which should alway be about 1 to 2 mg/l.

In contrast to the plants described above no sludge sedimentation takes place in an aerated basin because of the fact that the velocity of flow ranges between 15 and 30 cm/s.

The BOD-loading and the sludge loading ratio are of decisive importance to dimension the design capacity of a lagoon for a certain degree of purification. The volume V_T of the lagoon can then be calculated as follows:

$$V_T = \frac{\text{Influent BOD per day}}{\text{BOD-loading per day and m}^3}$$

or, should the sludge loading ratio be known, by:

$$V_T = \frac{\text{Influent BOD per day}}{\text{Dry weight of the sludge x sludge loading ratio}}$$

As shown in figure No. 70 (cf. section "Oxidation ditches"), the sludge loading ratios differ considerably, this is the reason why in Asian countries and also other developing countries the basins are very often dimensioned smaller by a factor between 2 to 6. The special conditions in the hot climate zones have to be taken into consideration here, as for instance the decreasing solubility of oxygen in water with increasing temperatures (cf. figure No. 67).

Within the scope of this manual it is not possible to deal with further and more complicated dimensioning fundamentals. In nearly all cases it will probably be necessary to call experts for the design of aerated lagoons. Furthermore, the detailed literature (16) and the suggestions of manufactorers of aeration units have to be taken into consideration.

The accumulated sludge is not fed back as it is in the case of oxidation ditches. The sludge concentration in the outlet is relatively low (200 to 500 mg/l) and the BOD-reduction with a retention time of 2 to 6 days is generally above 90 per cent. The low concentration of activated sludge shows that this plant has to be regarded as a pre-clarification stage to which some maturation ponds or settling tanks with a retention period of 5 to 10 days have to be connected in series.

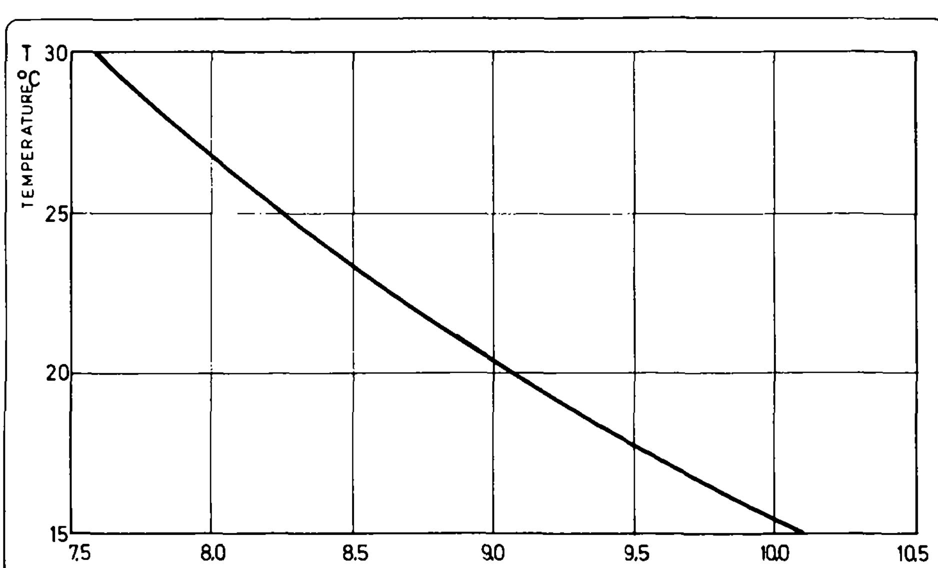


Fig. 67 | SOLUBILITY OF OXYGEN IN WATER AT DIFFERENT TEMPERATURES (BASIS: SEA LEVEL) | INFU (85)

1. The connection of maturation ponds in series

As a result of the low technological expenditure, this solution seems to be rather interesting for developing countries. The selection of the ponds depends on the loading of the raw sewage with pathogenic germs. The first pond behind the aerated lagoon will serve as sedimentation tank with a retention period of 10 days and a depth of 1.5 to 2 metres. The following ponds (maturation ponds) should be dimensioned in such a way that the wastewater can undergo treatment in 1.0 to 1.5 metre deep ponds for a period of 5 days in each.

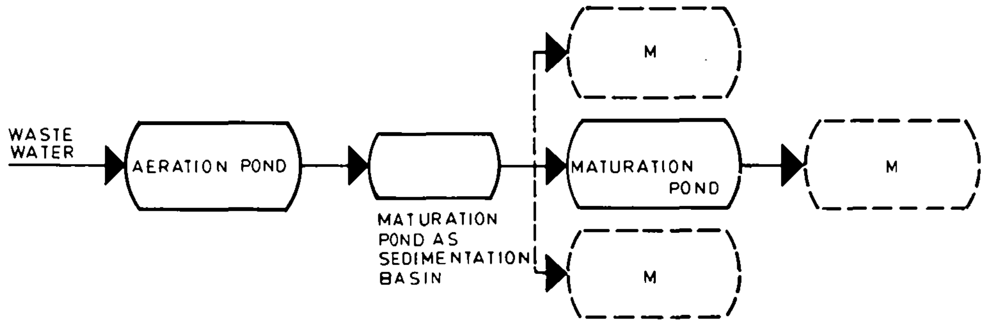


Fig. 68 | SYSTEM OF OXIDATION - AND MATURATION PONDS | INFU

2. Connection of a sedimentation tank and anaerobic stabilization of sludge in series

The activated sludge-water-mixture flows into a sedimentation tank where a minimum retention time of two hours must be assured in order to allow a proper separation of the water and sludge. The clarified water can then be fed back into the surface water and the sludge is pumped onto sludge drying beds where it is dehydrated. During this procedure odour problems may be encountered and this makes it advisable to provide an intermediate anaerobic digestion stage (cf. Fig. 69)

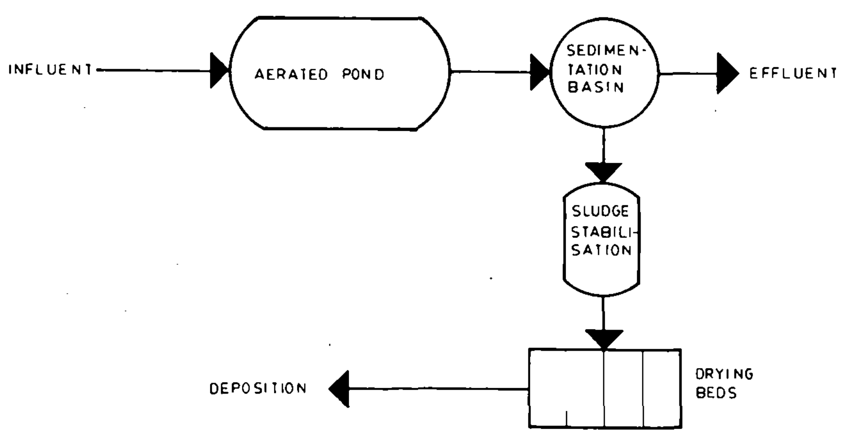


Fig. 69 | AERATED LAGOON WITH SLUDGE STABILIZATION AND DRYING | INFU (16)

The second procedure is especially suited to all those cases where industrial or commercial sites discharge wastewater with high organic loading, where concentration or quantity surges are to be expected or if the further development of the connected municipality is hardly predictable.

The size of the stabilization pond should be calculated on the basis of a specific storage capacity of 40 litres per capita or per population equivalent.

It is undisputed that an anaerobically digested sludge presents two advantages over an aerobically digested sludge:

- The content of solid substances (4 to 8 per cent) is higher
- The hygienic properties are better.

Especially the second point is very important for the conditions prevailing in developing countries. The treatment of the sludge and location of drying beds will be dealt with in more detail in the next section.

- Oxidation ditches (200 to 15,000 inhabitants and/or population equivalents)

The oxidation ditches are wastewater treatment plants similar to the system of the activated sludge plant with a simultaneous sludge stabilization characterized by a low (0.5 to 1.5 m deep) ditch type form. The outflow of the plant enters a sedimentation tank from which more than 95 per cent of the deposited sludge is pumped onto drying beds. Owing to the return, a total retention time of the solid substances of 20 to 30 days is reached. During this period, a eutrophic sludge is formed which has only to be dehydrated before its re-use. The design of the plant should be made according to the statements shown in figure No. 69. The aeration tank is replaced by an oxidation ditch.

The aeration of the effluent is done by one or more rotors. In contrast to the previously mentioned aerated lagoons the concentration of the solid substances is much more higher and is about 3,000 to 5,000 mg/l, as a result of the returned sludge.

In figure No. 70 some characteristic data is given for the construction of oxidation ditches.

The quantity of oxygen which is added depends largely on the type of the rotor and should, therefore, be quoted by the manufacturer. A comparison of this data for plants in Europe and India demonstrate that the dimensioning criteria can vary greatly.

Owing to the higher sludge concentration in the oxidation ditch and the higher rate of reduction, the retention time of the wastewater may be reduced to 0.5 to 1.5 days, as compared to the 2 to 6 days in the aeration tank. The reduction of the BOD is very high so that an oxygen consumption of less than 15 mg/l during the process under normal operation of the plant can be expected. On the other hand, however, the reduction of coli bacteria is only 90 to 95 per cent.

PARAMETER	INDIA	EUROPE
Sludge loading factor (d^{-1})	0.1 - 0.3	0.05
Aeration requirement ($kgO_2/kg\ BOD_5$ applied)	1.5 - 2.0	2.0
Excess sludge production (g/hd d)	5 - 10	25 - 30
Area of sludge (m^2/hd)	0.025	0.35
Overall land requirement (m^2/hd)	0.125	1.2

Fig 70 DESIGN CRITERIA FOR OXIDATION DITCHES IN EUROPE AND INDIA INFU (86)

Arrangement of oxidation ditch plants

The oxidation ditch has an almost trapezoidal cross section and is arranged as an oval ditch system (cf. Fig. 71).

It is advisable to pave or concrete the walls of the ditches and the area around the aeration rotors. In case of very soft soil and with a view to reducing maintenance work it is even advisable to build the whole plant of concrete.

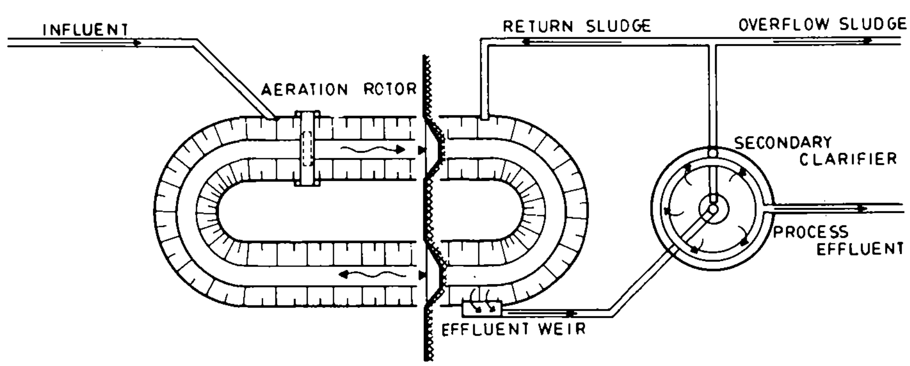
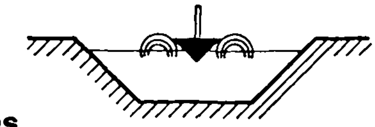


Fig. 71 OXIDATION DITCH INSTALLATION WITH SECONDARY CLARIFIER INFU (87)



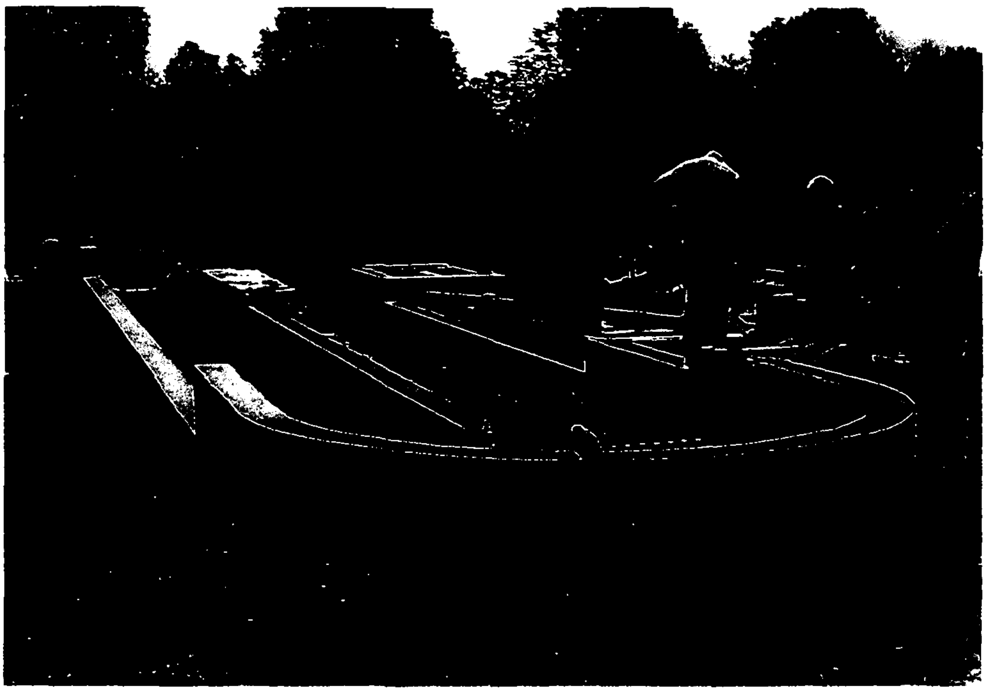


Figure 72 - Oxidation ditch (Plant at the National Environmental Engineering Institute - NEERI - Nagpur/India)

The rotor is fixed to a crosspiece. The waste water should be discharged the water in front of the rotor. The water outflow of the ditch is diagonally opposite to the inlet via a weir.

Final treatment

The water sludge mixture flowing out runs into a settling tank. A relatively simple design of such a tank is shown in Fig. 73.

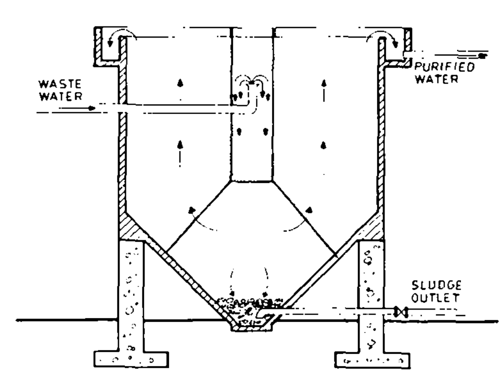


Fig. 73 SEDIMENTATION TANK INFU

Sludge treatment

The excess sludge with a solid content of about 1 per cent should be dehydrated and as far as possible be utilized. Drying beds have proved to be the cheapest and simplest way of doing this. The wet sludge is carried to permeable ground where it is dehydrated by evaporation and infiltration.

The decomposition of pathogens is good and the dry sludge can in general be used as fertilizer on fields after a retention time of 2 to 3 months.

As a basis for the dimensioning of the necessary surface for such drying beds, an area of 2.5 m^2 per capita or population equivalent (86) should be taken. It would, of course, be hygienically more harmless and unobjectionable if the sludge treatment would be made in a sludge digestion tank at a temperature of 40 to 50° C.

Independent of the kind of sludge treatment it is in any case necessary, especially from the hygienic point of view, to treat the sludge for the maximum possible period of time and at the highest practicable temperature (cf. also the section "Health aspects").

Dimensioning an oxidation ditch (16)

Assuming that for a municipality of 10,000 inhabitants an oxidation ditch has to be designed where the wastewater rate averages 80 litres per capita and day and the BOD_5-value averages 40 g per capita per day.

a) The ditch

1. Wastewater flow Q = 80 x 10,000 = 800 m^3 per day
2. Influent BOD : L_i = 40/80 = 0.5 g/l = 500 mg/l
3. Sludge loading factor (cf. table 78): = 0.2 per day
4. Concentration of solids in the oxidation ditch S: can be assumed to be 4 g/l in order to make a rough calculation
5. Volume of the oxidation ditch $V_{ox} = \frac{Li \times G}{S \times} = 500\ m^3$
6. Retention time: $t = \frac{V_{ox}}{Q}$ = 15 hours
7. The required oxygen should be as high as twice the total BOD value

   R_{O_2} = (2 x 40) x 10,000 = 800 kg per day = 34 kg per hour

The right size of the rotor has to be found out from the data given by the manufacturer.

b) Drying beds

8. According to figure 70, 0.025 m^2 per capita have to be quoted for drying beds, which means

$$F_{TB} = 10,000 \times 0.025 = 250\ m^2$$

- Package plants

In view of increasing the clearness of a plant and of reducing the construction costs structures for a mechanical and biological treatment are united to a package plant with a variety of possible combinations. They are characterized by the limited area required and can be delivered as a complete and prefabricated plant. In addition to this, they can be connected in series to any number simplifying a later required extention.

Some of these plants are designed in such a way that they can be removed at a later date and transported to other sites if the connected residential area is going to be served by a central sewerage system. The range of employment of such plants in rural areas of developing countries will in general be limited to some exceptional cases because the portion of goods to be imported and the energy requirements are very high. They will probably be limited to those cases where highly loaded wastewaters have to be treated in a very limited floor space (small-size industries, trade).

The systems mentioned below can only be regarded as examples of a large number of types.

a) Prefabricated treatment plants

The prefabricated treatment plant (for examples those shown in Figures 74 and 75) run according to the bio-aeration process. By injecting air over filtering candles a water cylinder is formed which covers the whole width of the aeration tank. By this the two main prerequisites of the activated sludge process-sufficient oxygen and an entire mixture of wastewater and sludge - are met. A certain quantity of wastewater, proportionate to the quantity at the inlet, is fed from the aerated tank into a secondary settling tank. The sludge flocks settle and the surplus water runs off into the receiving watercourse. Any floating sludge which might have been formed is automatically returned into the aeration tank. These plants are usually prefabricated as steel tanks and delivered as a completely assembled unit.

b) The "Essener Becken"

In a similar principle as the oxidation ditch a circular construction style is, for example, found in the "Essener Becken".

The aeration phase takes place in the central section, while the outer ring forms the space for the secondary treatment. In the case of higher loading rates, it is recommended that a grit chamber precedes the treatment plant.

In the following diagram one plant model is shown for which all the details regarding design, dimensions and costs for different loading rates are given (89). They are dimensioned for the specific quantity of sewage of 150 litres per inhabitant per day at a load of 60 g of BOD_5 per inhabitant per day of the domestic wastewater.

The stated costs which vary only insignificantly within Europe have, according to the manufacturers of these plants, to be multiplied by certain factors if exported to developing countries, for example because of political events.

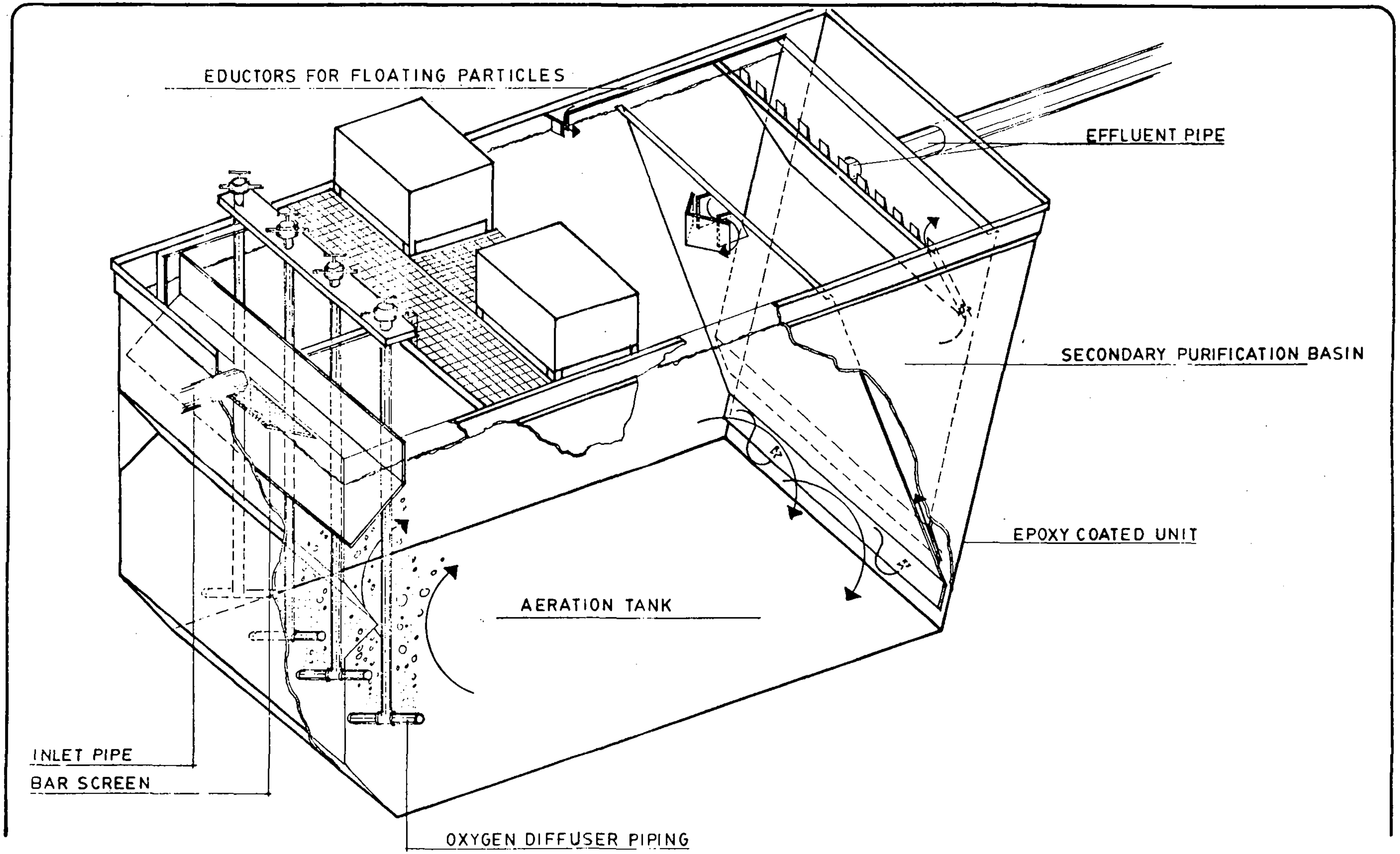
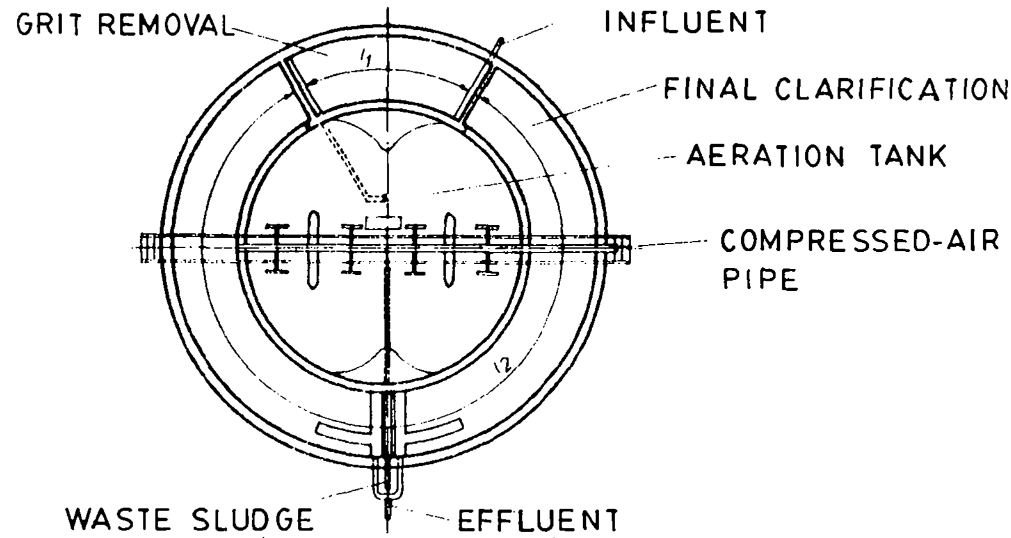
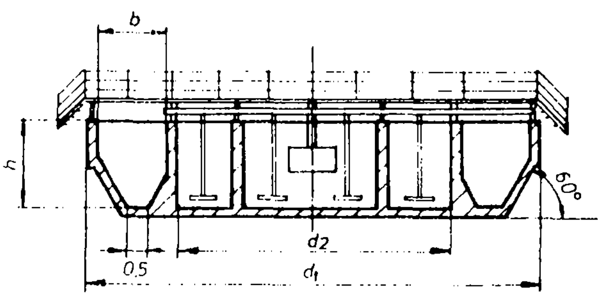


Fig. 74 | FACTORY-BUILT SEWAGE TREATMENT PLANT ("OXIGEST") | INFU (88)





population equivalents			Unit	1500	2500	5000	7500	10000	15000
d_1			m	18.6	22,0	28,8	34,60	39,60	42,00
d_2			m	13,4	15,8	22,6	27,40	31,40	[illegible]
b			m	2,5	2,5	2,5	3,00	3,50	4,00
h			m	4,0	4,5	4,5	4,5	4,5	5,0
waste water quantity Q_{ww}			m^3/d	225	375	750	1350	1800	3150
dry weather flow Q_{dw}			m^3/h	27,2	45,3	90,6	168,8	225	356
infiltration water Q_{iw}			m^3/d	115,5	187,5	375	1350	1800	3150
storm water flow Q_{sw}			m^3/h	50	83	166	281	375	581
pollution load Bd			kg/d	90	150	300	450	600	900
grit removal	I_1		m	6,0	7,0	8,0	8,0	10	10
grit removal	surface		m^2	12	15	20	25	35	40
grit removal	volume		m^3	28	40	55	68	93	123
grit removal	det. time	Q_{sw}	h	0,56	0,48	0,33	0,24	0,25	0,21
grit removal	det. time	Q_{dw}	h	1,03	0,83	0,61	0,4	0,41	0,35
aer. tank	volume		m^3	450	750	1500	2250	3000	3600
final clarification	I_2		m	44,2	52,3	72,7	89,24	90,60	97,00
final clarification	surface		m^2	88	129	176	268	355	435
final clarification	surface loading for Q_{sw}		m/h	0,57	0,64	0,94	1,05	1,06	1,33
costs (1980)			US$/c	330	275	230	200	175	175

Fig. 75 "ESSENER BECKEN"

In order to get a rough idea of the orders of magnitude, the specific cost factors valid for the first months of the year 1980 are given below. They may vary only slightly among the different exporters.

Cost factors for the export of a package plant (89).

Africa	1.80
Arabia	2.00
Asia	1.75
South America	1.85

c) Rotating-disc treatment units (a steel construction for 400 to 10,000 population equivalents)

The rotating-disc treatment processes are aerobic systems developed from the activated sludge and the trickling filter process.

The plants consist in general of a preliminary treatment basin, a biological phase and a secondary treatment basin (cf. figure 76). The treatment of the organically polluted wastewater in the bio-phase is carried out by a double effect: On the one hand it is effected by freely moving microscopic organisms in the wastewater sludge (activated sludge) and on the other hand by stationary microscopic organisms at the surface of the submerged contact aerators. These absorbe the polluted matter in the wastewater, oxidize them or transform them during their procreation into new activated substances. The oxygen required for the metabolism dissolves at the wet surface during the phase of emerging from the wastewater and can in addition to this be fed into the activated wastewater through air bubbles.

As soon as the attached growth at the rotating discs has reached a certain thickness it falls off in small pieces of several square centimetres. The treated water and the excess sludge contained in it run off into a secondary treatment tank where the sludge is separated.

The package plants are also installed in prefabricated steel sheet troughs and can be combined into units as required for loads connected later.

The investment costs of a plant for 5,000 population equivalents are about 140 US $ per population equivalent (1980) (90).

Should an existing sewage pond system (cf. section 2.2.2) prove to be overloaded because connected load is too high, a bio-phase can be combined, as it is shown in figure 76.

Clarification effect

In this case of normal plant loads (up to about 160 mg/litre) - domestic or industrial wastewater - decomposition rates of the BOD of 90 per cent are customary (cf. Fig 77).

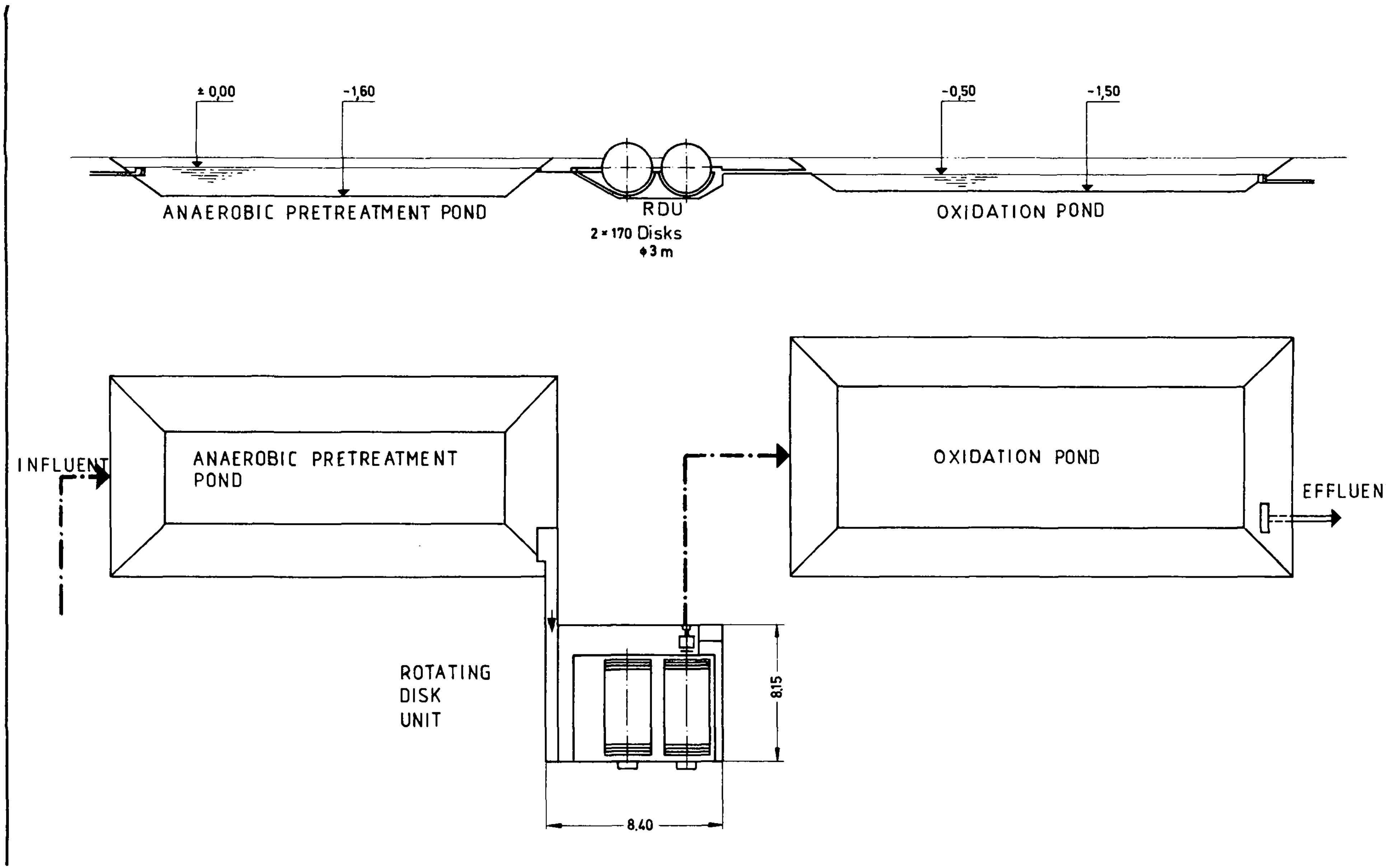


Fig. 76 ROTATING DISC UNIT (RDU) with SEWAGE TREATMENT BASINS INFU (90)

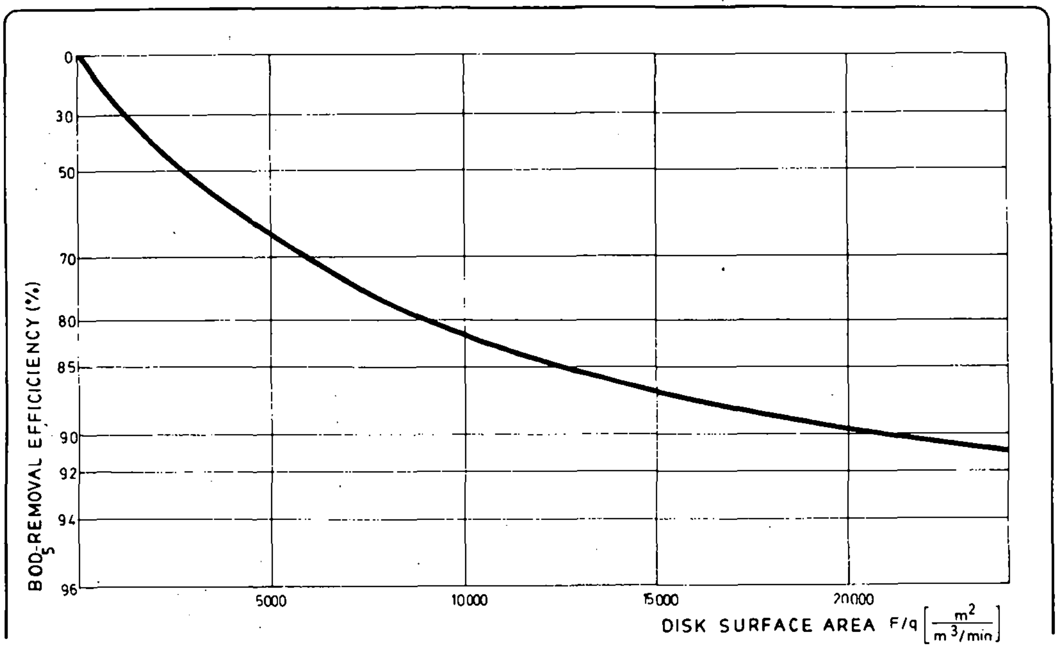


Fig. 77 BOD5-REMOVAL IN A ROTATING-DISK UNIT INFU (90)

Servicing and operation of activated sludge plants

As it has just been pointed out the availability of energy sources necessary for the operation of the machinery of activated sludge plants constitutes the first essential for the application of such plants.

Besides all the difficulties connected to the procurement of the necessary spare parts, this fact leads to a very limited field of application in rural areas of the developing countries. They are mainly limited to small size industrial companies with highly loaded organic wastewater and to all those municipalities which as a result of topographic characteristics (for example mountain regions), are not in a position to provide large areas for waste stabilization ponds, as described in Section 2.2.3.

In both cases, however, it might even then not be recommendable, as a well trained operating staff is essential. The operating costs themselves are very high.

Health aspects

The maximum retention time of the wastewater in an activated sludge tank is 12 hours. During this time not all the pathogens can be killed which on the other hand means that the outflow of the sewage plant can not directly be used for irrigation purposes.

The sludge quality depends on the secondary treatment used in each particular case. In Fig. 78 the influence of the time and temperature on different pathogenic germs is shown.

From this figure it follows that decomposition temperatures of 40° C at a minimum have to be reached to eliminate the Ascaris eggs, as well.

Plants to which sewage stabilization ponds are connected in series are, from the technological point of view, easier to design and build up. In this case the advantages given in section 2.2.3 take effect. In such a system nearly all pathogens are killed because of the extended retention time which has been graphically shown as an example for submerged contact aeration plants (cf. Fig. 76).

Summing up it may be said that more than 90 per cent of the pathogens are removed from the wastewater in biological sewage plants. The germs contained in the raw sludge are removed sufficiently with a storage time of 2 to 3 months (91).

Ascaris eggs are found mainly in the raw sludge, because with a settling time of 2 hours at a minimum about 70 per cent sediment from the raw wastewater into the sludge layer. This means that only about 30 per cent of the total number are discharged into the receiving watercourse and that for a definite elimination of the ascaris eggs from the sludge an anaerobic digestion has to be connected in series.

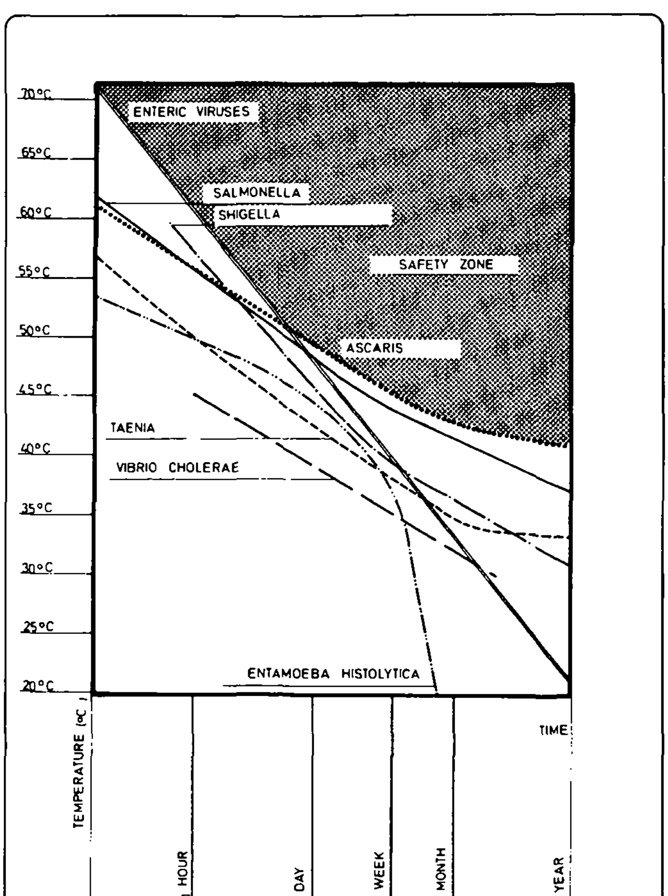


Fig. 78 INFLUENCE OF TIME AND TEMPERATURE ON SELECTED PATHOGENS IN NIGHT SOIL AND SLUDGE INFU - 13 -

2.3 Summary of the technical results

Fig. 80 provides a tabular of the information in the Sections 2.1 and 2.2.

In addition to more hygienic living conditions, the exploitation of new sources of capital for the rural population constitutes a decisive point in favour of the propagation of the plants, while the possible of a combination of different technologies also plays an important role. It is , for example, possible to use the sludge of septic tanks or bucket latrines - if properly handled - as the basic raw material for fish cultures or aquatic plants which could then be re-used as foodstuff or animal fodder.

	PIT LATRINES	COMPOST TOILETS	TOILETS WITH AQUA PRIVIES/SEPTIC TANKS	BIOGAS PLANTS	PUBLIC TOILETS	BUCKET LATRINES	SEWERS	SEWAGE TREATMENT LAGOONS	ACTIVATED SLUDGE PROCESS
PIT LATRINES									
COMPOST TOILETS								X*	
TOILETS WITH AQUA PRIVIES/SEPTIC TANKS					X		X	X	X
BIOGAS PLANTS					X	X		X*	
PUBLIC TOILETS	X	X	X	X		X	X	X	X
BUCKET LATRINES				X				X	X
SEWERS			X		X			X	X
SEWAGE TREATMENT LAGOONS		X	X	X	X	X	X		X
ACTIVATED SLUDGE PROCESS			X		X	X	X	X	

* DIGESTED SLUDGE/COMPOST AS NUTRIENT SOURCE

Fig. 79 POSSIBILITIES OF COMBINING DIFFERENT TYPES OF TREATMENT UNITS

INFU

UNIT	COSTS		TECHNICAL ITEMS						PERSONNEL REQUIREMENTS		INSTITUTIONAL REQUIREMENTS (Supervision)
	CON-STRUC-TION	OPERA-TING	REQUIRED SOIL CONDITIONS	POPULATION DENSITY	SELF-HELP POTENTIAL	WATER REQUIREMENT	COMPLEMENTARY INVESTMENTS REQUIRED	REUSE POTENTIAL	CONSTRUCTION PERSONNEL	OPERATING PERSONNEL	
PIT LATRINE	low	very low	stable permeable soil, ground water table constantly below surface	up to about 150 inh./ha	very high	none	generally none	none	unskilled	none	none
COMPOSTING TOILET	medium	medium	none	up to 300 inh./ha. according to area available for compost deposition	low at continuous composting toilets, high at batch composting toilets	none	sludge treatment and deposition if necessary	high	building trade workers at cont. composting toil., unskilled workers at batch compost. toilets	unskilled, trained on continuous composting	none
TOILETS with AQUA PRIVIES and SEPTIC TANKS	high	medium	permeable soil to lay out filter areas	up to 200 inh./ha according to area available for infiltration of effluent waters	low	at least 3-6 liters/ day and capita	water piped to house and toilet, sludge removal and disposal	none	good building trade workers	few, but trained workers	discharge intervals are to be maintained
BIOGAS PLANTS	high	medium	none	medium to low density	very high	10 liters/ day and capita	generally sludge drying beds, water near unit	very high	building trade workers	unskilled	none
PUBLIC TOILETS	per capita low	medium to high	according to kind of unit (see other sanitation technologies)	up to very high densities	high	according to type of unit (see other sanitation technologies)	according to type of unit (see other sanitation technologies)	generally none	building trade workers	unskilled	high
BUCKET LATRINES	low	high	none	up to very high densities	very high	none; 3-6 liters/day and capita, if a pour flush toilet is used	collecting-and transportation vehicles, sludge deposition areas and drying beds	very high	building trade workers	generally unskilled	high
SEWERAGE	high	high	preferable stable soil no rock	up to very high densities	none	at least 50-100 liters/ day and capita	water piped to house and toilet, central waste water treatment	high	civil engineer	well-trained	high
WASTEWATER TREATMENT POND	per capita very low	low	preferable stable soil no rock	up to very high densities	low	see other sanitation technologies	sewerage or transportation vehicles	very high	civil engineer	few, but trained workers	high
ACTIVATED SLUDGE PROCESS	very high	very high	preferable stable soil no rock	up to very high densities	none	see other sanitation technologies	sewerage	high	civil engineer	very good trained	high

Fig. 80 DESCRIPTIVE COMPARISION OF SANITATION TECHNOLOGIES INFU

3 Project realization

3.1 The aspects of settlement and population structure in the planning sewage plants in developing countries

While planning settlements and infrastructure in developing countries, a major objective should be to arrange the physical environment of the people in such a way that the contact with human excreta is excluded in order to minimize any health risks. In this connection, different possibilities of the transmission of pathogenic organisms (parasites, bacteria) have to be taken into consideration, i.e.:

- direct human contact with excreta;
- consumption of infected foodstuff and drinking water.

Within this transmission cycle, the following factors are of importance and have to be included in the design considerations to achieve a successful interruption of transmission, namely:

- the human behaviour
- the structure of the settlement
- the type of climate
- the type of water supply
- the economic structure

These factors are examined one by one in more detail below.

Parameter: behaviour structure

The right behaviour of human beings dealing with their own excreta has to be regarded as the sole guarantee for the avoidance of any health risks. The complete spectrum of technical aids can at best facilitate this behaviour, but in no case replace it. For this reason the keenest attention should always be turned to the possibilities of controlling "hygienic" behaviour.

Religion / Traditional manners and customs

The religious confessions have at all times tried to incorporate all questions regarding hygiene into their sphere of influence and to regulate them to the best of their follows. In this connection they used the force of commandments and/or prohibitions, the contravention of which would not really cause any physical damages, but only detrimental effects for the soul of the faithful. Such religious regulations are in fact still respected in many cases with most care. The following remarks demonstrate the whole problematic nature of these regulations:

a) The regulations mostly date back to times of completely different living conditions to those encountered today in developing countries. But under the changed conditions the originally sensible regulation can become counter productive.

b) The regulations mainly date back to times when only very little was known about the mechanisms at work in the field of hygienics. On the basis of the knowledge in the meantime we have acquired about diseases and the transmission of diseases, many more regulations should be formulated.

c) The regulations are for the most part neither explained nor substantiated and for this reason the proper sense of them can not be imparted in many cases. Frequently, the sense of a religious commandment is not seen as a means of reducing physical risks but only as a word-for-word order which has to be fulfilled; to ask for the sense is seldom even allowed.

With the vanishing importance of religion, social taboos gain more importance. In their effectiveness, they do not differ very much from religious regulations, so that they too are neither flexible, nor explainable nor even questionable.

Within the scope of this examination, however, it will not be possible to give a comprehensive survey of all the religious commandments, traditional customs and social taboos relating to hygiene. But the importance of this factor can be illustrated by some examples.

Example 1: Passing of excreta

In all Islamic countries, Mecca is considered as a holy city, a fact which also finds its expression in various regulations, such as the one expressed by Ayatollah Khomeiny, saying: "During the relieve of nature the front part of the body, the abdomen and the chest, as well as the back should never be directed to Mecca..." (93)

Example 2: Touch of excreta

The taboo against touching excreta which is normal in all Western countries does not necessarily apply in all developing countries. Cow manure is used in India for firing purposes and for the plastering of the mud huts; the processing and utilization is undertaken with bare hands. On the other hand, the disposal of human excreta is the duty of the lowest caste, regarded also as an "unclean caste" (cf. Section 2.1.7).

In contrast to this, Moslems regard the excreta and urine of human beings as "unclean" (93).

Example 3: Subsequent treatment of excreta

The mixture of human excreta with cow manure necessary for the operation of biogas plants is regarded in certain religions in India as sacrilege. This attitude constitutes a basic obstacle to the propagation of biogas plants in the areas concerned in India.

Example 4: Water purity

For religious reasons the water of the river Ganges is regarded as "clean" water. In the pilgrim centres, for example Baranasi (Benares), millions of people carry out ceremonial ablutions at the banks of the river.

Many Moslems prefer the rivers water as drinking water rather than other sources - for example wells - because the water they will drink later in Paradise will also come from the same river (Koran Sure 47 v. 15).*

Social norms

Besides the above-mentioned social taboos directly related to the way human beings treat their own excreta, there are also social structures and behavioral rules of a universally valid kind which tangentially influence hygienic behaviour.

Responsibility of each individual for the community

Within a family, and even more so within an extended family, each individual feels jointly responsible for the prosperty and well-being of the other family members. Cleanliness on the toilets or in the handling of drinking water and foodstuff can always be expected and is accepted. In the developing countries all the traditionally effective family structures are threatened as a result of the outcoming changes, especially because of the changes resulting from urbanization without the possibility of developing other forms of social organization and responsibility. This fact is causing the following problems:

The use of communal sanitation facilities

The servicing and maintenance of communal sanitation facilitites has not yet been solved in a satisfactory way. It has been found that all state organizations lack motivation and are inefficient, whereas the community of the users will in general not find any form of organization for keeping the toilets clean.

The use and maintenance of communal property must first of all be learned, a process which even in the industrialized countries has not yet been brought to an end (in this connection one only needs to look at the condition of the toilets in railway stations and on motorways).

Sense of responsibility for the environment

For many people (this applies for all countries) the range of their responsibility for the environment ends at the door of their home. All the waste and rubbish is brought carefully onto the street and no more care is taken of what happens with it later on. If an annoyance arises, the call for public order and maintenance rings out, but nobody wants to pay the costs caused by this. It is the order of the day to have streets blocked by rubbish heaps and clogged sewers and overflows, as found for example in Kano/Nigeria.

Social leaders

Each society has its idols, of different origin according to their system of value and structure, namely: the Church, the cinema, politics, the business world, etc. It might be possible to reach changes in the behaviour of the population more quickly if it is possible to incoporate the accepted idols into the chosen strategy.

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* Information given by Dr. Jahn, Pilot Project for Rural Water purification, Khartoum, Sudan, 1980

Parameter: structure of the settlement

In accodance with its objectives, this manual deals with rural areas and towns with a maximum of 20,000 inhabitans.

It is typical for the fast growing cities in developing countries that their settlement structure has to some extent a rural character, at least in the outskirts. The border between rural and urban cannot be clearly defined as even settlements with less than 20,000 inhabitants can have a marked urban character. For this reason it seems to be necessary to explain first of all thecorrelation between settlement structure and the sanitary systems and to derive clear criteria for a definition of the sphere of application of this manual later on.

Location

The location of a settlement determines to a large extent the possibilities for the collection and the treatment of the wastewater:

a) The relief of the location defines the kind and the expenditures of sewerage systems. We have to distinguish between locations on summits, on inclinations, in valleys and on the plain. Dome shaped summits and inclined locations are better suited for sewers than valleys or plain locations.

   Dome shaped locations very often lead to numerous decentralized locations for sewage plants, whereas incline and valley locations will mostly allow centralized locations. Locations in the plain require the construction of very expensive and sensitive pumping stations for the sewers.

   The decision for the one or the other system is very often made more complicated by the fact that a town often covers more than one of the stated types of terrain.

b) The nature of the soil defines the extend of expenditures for sewer systems and the possibilities for infiltration systems. A rocky subsoil excludes any infiltration and causes exclusively high construction costs for sewers. A soft and dry subsoil is the prerequisite for infiltration systems, but opens on the other hand also the installation of relatively economic sewers. A wet soil excludes any infiltration system and increases the construction costs (increased expenditure for packings, foundations and harder working conditions).

c) The proximity to a river suited to serve as a receiving watercourse

   For all the systems in which the wastewater does not remain directly at the point of occurence and is disposed of and/or treated there, fresh water for the transport and the dilution of the wastewater is required, the quality and quantity of which depends on the nature and quantity of the wastewaters to be treated. The nearer the settlement is situated to suitable natural waters, the lower the expenditures for the provision of the receiving watercourse will be. Attention should of course be paid to the fact that because of the substantial seasonal variations of the waters only the minimum quantity of water to be expected should be used as a calculation basis. It is also very important if there is any settlement downstream and at what distance; if so, whether the water is used there for drinking purposes or for the irrigation of fields.

Structure of the settlements

The distribution of built-up areas and facilities over the populated area defines where what quantity and what kind of wastewater is to be expected and has to be treated.

a) Classification of settlement structures

In rural areas, the potential classifications can be summarized as follows:

- Living areas with a more or less high quota of agricultural activities as for example the keeping of animals, production of vegetable
- Small-sized workshops, mostly placed in residential areas
- Stores and shops, mixed with living areas
- Small-scale industrial plants, mainly settled in residential areas; in most of the cases a separation between the functions is not made
- Institutions of the public infrastructure, as for instance schools, administrative authorities
- Markets, partly as facilities with permanent buildings, partly as occasional events on streets or public places.

In most cases a marked mixture of different hand uses, especially with living, can be regarded as typical.

The types of land use mentioned always have typical kinds of waste water with individual demands regarding the kind of waste water treatment and disposal plants necessary.

b) Intensity (density) of land use

The quantity of wastewater obtained on a certain area is mainly dependent on the intensity of the land usage. The higher the population density in a certain area or the more products manufactured there, the greater the quantities of the specific wastewater to be treated. For the design of more simple sewage systems it is very important to define limits for the intensity of land use which admit or exclude the use of certain systems.

This may still be possible for residential areas in the developing countries because the composition and quantities of domestic wastewaters is relatively well known, but in the case of larger quantities of commercial or industrial wastewaters a more accurate analysis can not be bypassed.

c) Access Network in settlements

All sewage systems able to clear away wastewater directly at the point of its occurrence(for example seepage pits) can be realized independently of the road and/or path network. If the pits have to be emptied it is an advantage if the pumping vehicles can approach the pits as close as possible in order to avoid any manual work (scooping, carrying of buckets). This aspect is also important if at the moment pumping vehicles are not in use so as not to exclude them from future use.

All systems where the wastewater is collected in sewers are more or less bound to road and path networks. The reasons for this are a more simple maintenance and a cost-saving construction and repair, not to forget otherwise the possibility that the authorities might at any time without previous notice have to intrude on private ground.

If it is intended to lay sewers under the roads, the roads must run in such a way that the effluent is able to flow from the point of origin to the sewage plant without any additional technical expenditures (pumps).

In the case of planning a new settlement, the point should be taken into consideration from the very beginning, whereas for the redevelopment of existing settlements this aspect will always present a substantial obstacle which could jeopardize the use of sewers at a justifiable technical and financial expenditure.

d) Distribution of land use

The decision to build a certain system to clear away wastewater is also determined by the distribution of the land use within the settlement lay-out. To plan the future land use, the kind and quantity of the wastewaters to be expected, as well as the possibility of the collection and treatment, should always be a point of thorough consideration.

Parameter: **type of water supply**

All settlements that cover their water requirements from a well produce only small quantities of wastewater. The problem of the water transportation and the productivity of the wells set clear limits to consumption and prevent squandering the water. The consumption per capita in these zones lies around 10 to 15 litres of water per day. All wells situated in populated areas are very susceptible to pollution by wastewater, especially if the wastewater source is in the immediate vicinity of the wells. Providing settlements with running water will considerably increase the quantity of wastewater. In this connection, the structure of the supply plays an important role:

- Private connections entice a very high water consumption (150 litres and more per day per capita)
- Collective lines will considerably reduce the water quantity used by each household owing to the amount of work concerned in transportation from the tap to the house. At the same time they lead to a displacement of many activities directly connected preparation of meals, personal hygienic) to the watering places, where large quantities of wastewater are produced.

A comparison of the above mentioned figures shows that the kind of water supply influences the quantities of the domestic wastewater produced to a similar extent as the population density does. It therefore constitutes one of the major design criteria.

Parameter: type of climate

The rural region is characterized by activities connected to farming and stock-breeding. These are, of course, much more dependent on the prevailing climatic conditions at a location than for example industrial production. The products of the rural regions are mainly produced for self subsistence and these products determine the nature and quantity of the domestic wastewater.

The developing countries are situated mainly in the southern hemisphere and partly in the southern part of the northern hemisphere. This means that they are situated in zones with a wide variation of climates (cf. Fig.81)

Continental climates are found with very high seasonal variations in temperature as well as maritime compensated climates, zones of absolute drought and also zones with nine month rains or a monsoon influence. Depending on the altitude, the average mean temperature of these types of climate also vary considerably.

The climate influences:

- the way of life of human beings;
- the vegetation and therefore the food and eating habits;
- the proper design construction and the materials to be used;
- the extent of health risks during the contact of human beings with their own excreta because the temperature and the humidity considerably influence the life expectancies of pathogenic germs;
- the choice of a suitable sewage system; for this the quantity and the fluctuations of the rains to be expected are the most important criteria for a decision:
  - o infiltration pits can only be chosen if there is no danger of flooding which could cause an overflowing of the pits,
  - o in the case of sewer systems, heavy and seasonally varying rains will in many cases necessitate the arrangement of seperate systems for rain and sewage water,
  - o open sewage ducts can only be built if no heavy rains are to be expected which will probably cause an overflowing (cf. Section 2.2).

Parameter: economic structure

In this connection "economic structure" has to be understood as follows:

a) The degree of industrialization

b) The extent of division of labour

c) The proportion and the kind of export orientation

d) The availability of public funds for infrastructure measures.

The importance of these factors is explained in the following.

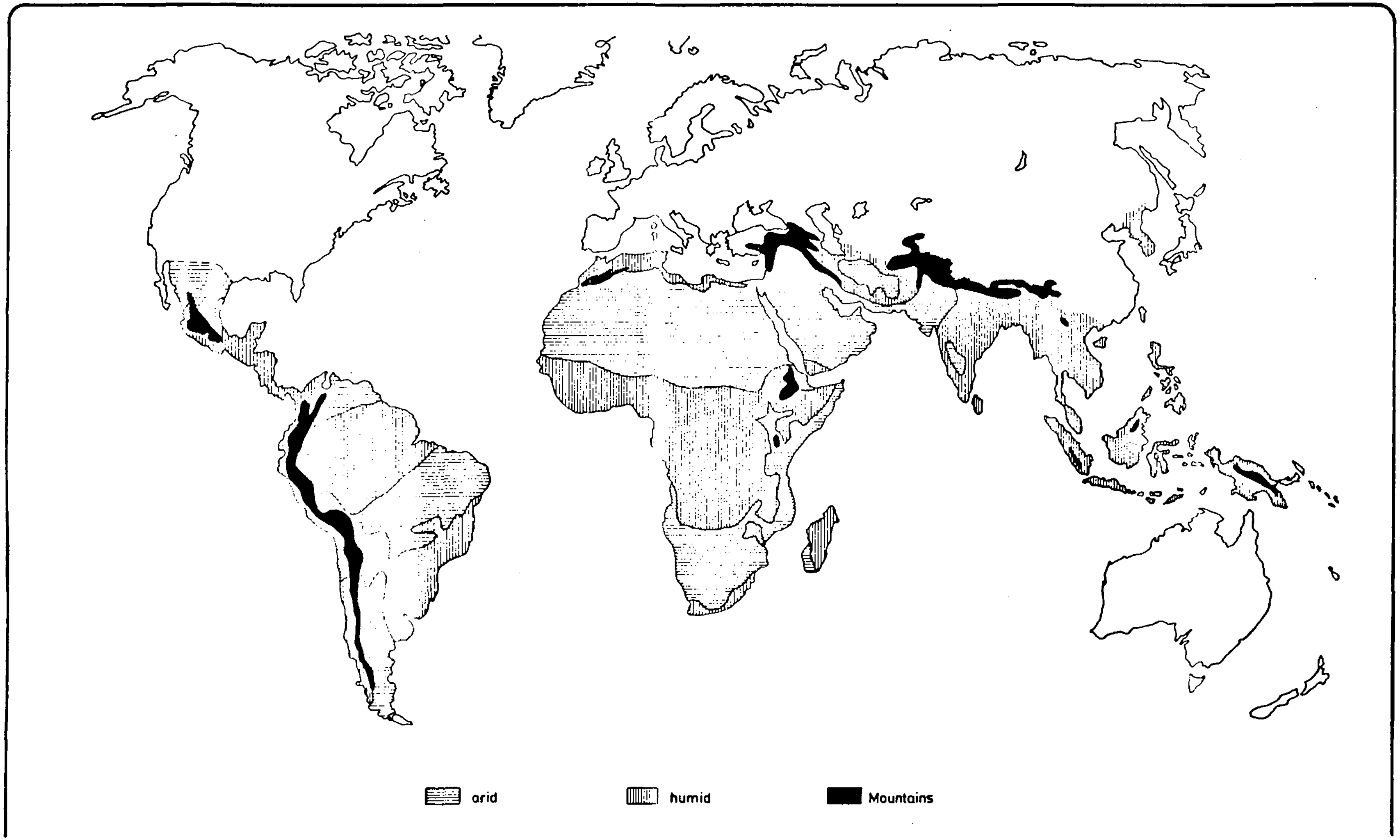


Fig. 81 | CLIMATIC ZONES IN DEVELOPING COUNTRIES | INFU

Degree of industrialization

In the developing countries, the industrialization normally starts in the cities because there the infrastructural, organizational and personnel premises may be regarded as more favourable. The resulting disparities between the cities and the rural areas lead to substantial problems, either by the migration of the rural population to the overcrowded areas or by the penetration of new types of products into the rural areas.

All the attempts made to gradually remove the city land disparities by a purposive development of the rural areas are having a bad start and are partly doomed to failure because of insufficient capital possibilities to establish infrastructure. For this reason the growth of smaller townships in the rural districts is proceeding more slowly than the growth of metropolitan areas, and the problems involved with a fast growth are more seldom as the establishment of slums for example. But this situation will change to the same extent as industrialization spreads to the rural areas. With growing industrialization, more poisonous wastewaters will be produced in larger quantities and health risks will increase. The environmental conciousness which is gradually developing in the industrialized countries cannot be expected yet from the developing countries and utilities for the purification of wastewaters and their removal can in many cases not even be supported financially in the face of the enormous development needs. What is more than disquieting is the fact that technical and chemical processes with a high degree of environmental hazard are sometimes delivered to developing countries because there the companies do not find such rigorous environmental standards. This, for example, applies to the tanner's trade which has established in many cases even in rural townships in or close to residential areas.

With growing industrialization, many ecologically beneficial and traditional products are superseded by biologically non-decomposable plastic substitutes (for example the replacement of sisal bags by plastic bags). These new products require changed behaviour patterns which are in many cases not yet developed and/or accepted, the lack of which could lead to substantial environmental problems (such as the clogging of sewers by durable plastic bags).

The degree of the distribution of duties

The degree of the distribution of duties and, therefore, also a division of the functions, are immediately connected to the degree of industrialization. In the traditional rural settlement, a close interaction of all functions can be found; on a given plot, living, production and trade take place simultaneously. With an increasing distribution of duties, single activities are torn out of this economic unit and concentrated at other locations. As a result a differentiation of wastewaters always has to be expected, even in areas where the traditional structure still seems to operate without any changes.

Degree and type of the exports

A number of materials used for infrastructure utilities cannot yet be produced in the developing countries. For this reason it is necessary to import them, a measure which can only be financed by an export surplus. The goal of this investigation is to reduce the dependence of the developing countries on imports by the application of simple technologies. There is no need to deal with this factor in more detail here.

Availability of public funds for infrastructure measures

The question of the financial possibilities constitutes the crucial issue of all projects concerning infrastructural utilities.

The financing of sewage systems directly by private households will in general only be possible for decentralized installations solely for the use of the householders with low investment requirements as well as beina installed on the plots of the respective householders. All more complicated installations involving higher costs (as for example biogas plants) will generally require the employment of public funds, at least in the form of credits, even if these plants are used only by the household concerned.

All the systems with wastewater collection entail such high costs that they can only be financed by public authorities,which is also appropriate from the point of view of their structural form.

The systems to be chosen will be decisively influenced by the amount of money the Government or any financing institution is prepared or in a position to grant for a project to solve the sewage disposal problem. The general practice, which is normally applied in industrialized countries is to reclaim the costs for the construction and the service directly from the users in form of user's charges, comes up against many difficulties in all developing countries because the private households barely dispose of any surplus money. This means that the costs will finally remain in the hands of the Government. The application of appropriate simpler technologies will in the first place result in lower expenditures and will also increase the elbowroom for Government action.

Property structure

There is no getting away from the fact that personal property always receives more care than rented goods. This also applies for houses and sanitary facilities, especially if more than one tenant family uses a common toilet. In rural areas, however, which are dealt with in this manual, the construction of houses for rent plays only a subordiante role. If houses and/or flats are let the tenants will in any case - subject to the kind of construction and the settlement structure - have similar possibilities of utilization and modes of behaviour as any owner. For this reason there is no need to deal with the aspect of property structure in more detail here.

Aspects of utilization

In the case that new installations for the removal of human excreta have to be accepted by the inhabitants they must realize obvious improvements offered by those installations and those must be more than just the health point of view.

The following improvements seem to be of particular importance:

- Convenience and comfort of utilization, which means: A short and safe distance from the flat to the toilet; the appropriate standard of privacy to fulfill social requirements; avoidance of any odour annoyances; a design adapted to the climatic conditions, which makes the use of the toilets as agreeable as possible; the employment of waterproof and easy-to-clean materials (smooth surfaces).

- Simple maintenance, which means: A design suited to the specific topographic and climatic conditions and requiring little maintenance; special consideration has to be given to risks to the structures as a result of heavy rainfall, with subsequent erosion of the buildings and the subsoil; constructions which work without trouble even under special conditions prevailing in developing countries and do not require special servicing; adequate dimensioning to guarantee a long service life of the installation.

These aspects have been discussed in more detail and with respect to their technical and constructional aspects in section 2. Nevertheless they are mentioned again now in order to emphasize their special importance for the success or failure of measures to improve infrastructure in developing countries.

Planning aspects

As a result of the above-mentioned system correlations and usability requirements of toilets and sewage treatment plants certain points should be mentioned regarding their planning. In this connection we have to distinguish between two fundamentally different project cases:

1. Planning in existing settlements:

   In the case the designer has to come to terms with a lot of set restrictions which will remain completely out of any influence of planners the existing structures are considered to be worth preserving.

2. Planning settlements to be newly erected

   In this case the structural settling can to a certain extent be co-ordinated with the requirements of the infrastructure measures.

In the following some methods of proceeding for these two planning cases have been described. These show the necessary analysis steps and derive typical project measures.

- Redevelopment schemes of existing settlements

The redevelopment planning of existing settlements should include the conservation and development of the qualities of existing structures, as well as the reduction or elimination of their defects.

The following restriction, however, seems to be necessary: There are settlement structures and/or settlement locations within which the establishment of acceptable minimum requirements for healthy living conditions can not be reached. Typical examples are the squatter settlements situated on seasonal floodplains. Their location corresponds with the economic possibilities of the inhabitants who have in general a very low income (no costs for the ground acquisition, proximity to working places, to markets, etc.). The poor quality of the location is vital to the existence of the inhabitants.

But minimum hygienic requirements can only be reached with difficulties and at very high costs. On the other hand it cannot be expected that the inhabitants can themselves raise the necessary means for the improvement of their situation.

Redevelopment requires a thorough inventary report of all the characteristic features of importance for the design and influencing it. To do this one can procedure in two stages:

Under step no. 1, the applicable system for the disposal of the sewage is chosen ("system selection").

Under step no. 2, the necessary adaptions to the specific situation are examined ("system differentiation").

To simplify the method of procedure, only the essential and easily managable factors should be taken into consideration.

In each individual case one should also investigate whether there are any other factors influencing the system selection and/or the system differentiation (cf. Section 1).

a) System selection

The selection of an appropriate system can be decided on by answering the following three questions:

1. Density of population:

   How many inhabitants are living on each hectare of the settlement area ?

   For a very rough determination of the population density, the following procedure could be adopted: Within a given area with a uniform settlement pattern (the demarcation of areas with another settlement pattern is preferably done by means of up-to-date aerial photographs) with clearly definable areas, for example building blocks encircled by roads, have to be established. By questioning all the housholds within a certain area the number of inhabitants can be established.

The population density can be calculated by dividing the number of inhabitants by the size of the areas (in hectare). It is important to distinguish between net density and gross density.

The net density refers only to the area of the residential plots. All unused areas and communal areas (e.g. roads) are not included.

The gross density contains also the areas of development and smaller areas for communal use (for example primary schools, mini markets for a certain town quarter, etc.).

For the design of sewage disposal plants the following threshold values are of importance:-

D1

Density less than 150 inhabitants per hectare:

The population density allows the design of simple latrines.

D2

Density of 150 to 250 inhabitants per hectare:

Under favourable conditions, the design of simple latrines is possible (recommended are toilets with solid pits).

D3

Density with more than 250 inhabitants per hectare:

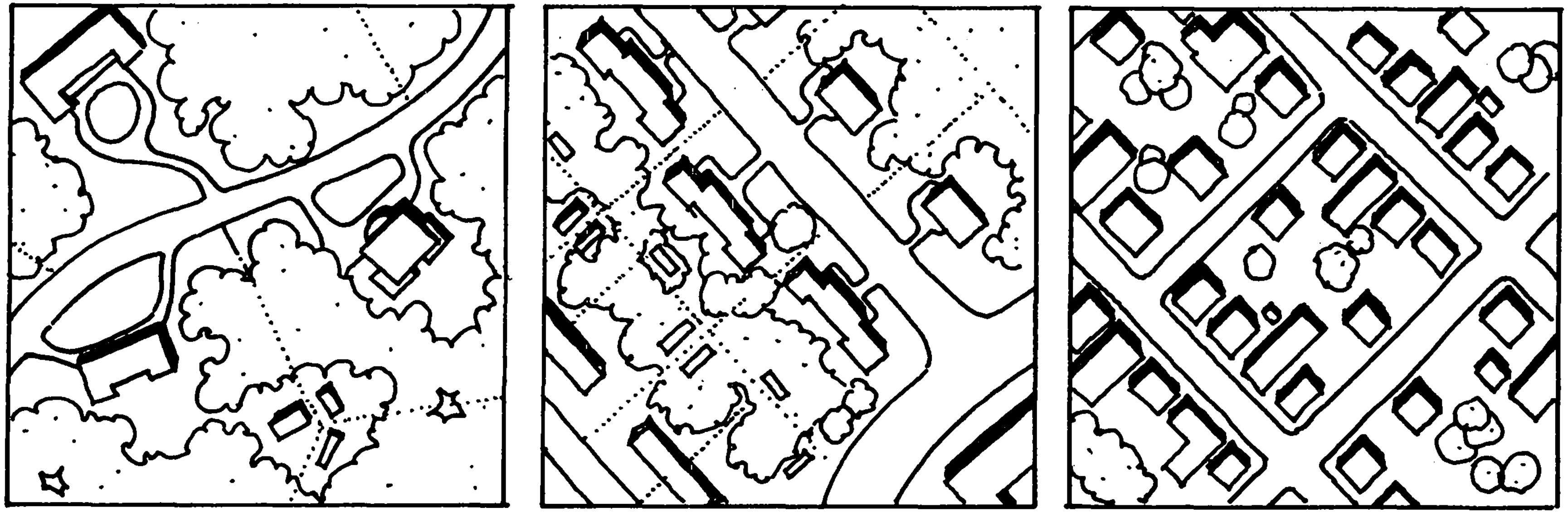
The use of latrines has in general to be excluded.

2. Water supply: How is the drinking water produced and distributed ?

W1

The extraction of drinking water from wells on a residential plot fundamentally restricts the construction of pit latrines unless it can be guaranteed that a contamination of the drinking water with bacteria is excluded.

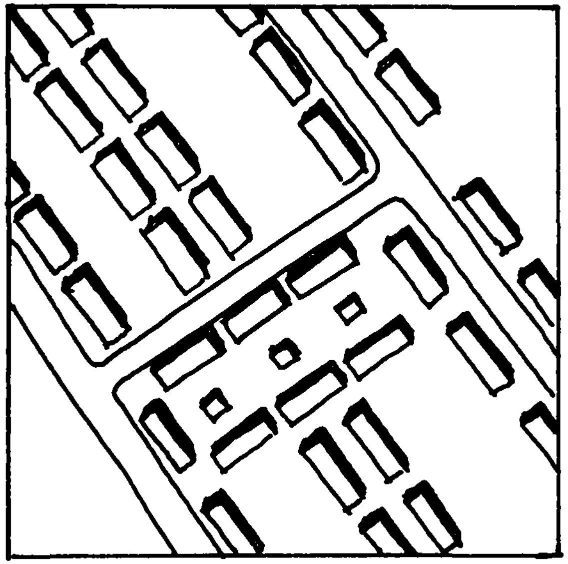
As a matter of principle this can only be obtained by a sufficient far distance between the latrine and the well whereby the necessary distance is determined by the nature of the soil and the direction and velocity of flow of the ground-water stream. Because of the fact that the direction of flow and the velocity of flow are in the majority of the cases not known or determinable only with great difficulty, large safety margins should be included in the calculations. In normal cases, the distance between a well and a latrine should not be less than 30 metres.



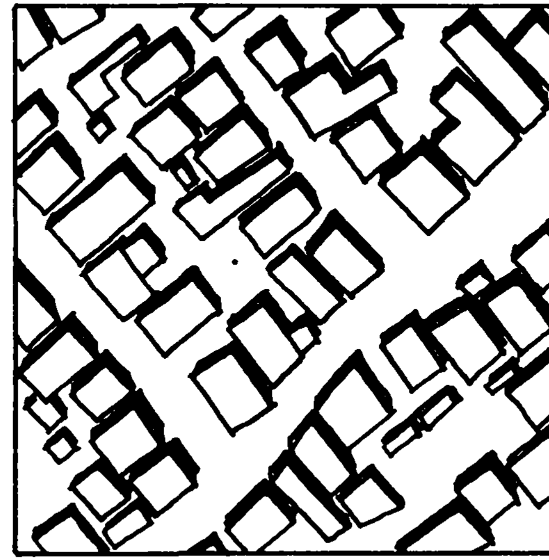
10 inh./ha 50 inh./ha 150 inh./ha

Soakage pits are feasible at a population density up to 150 inhabitants/hectare

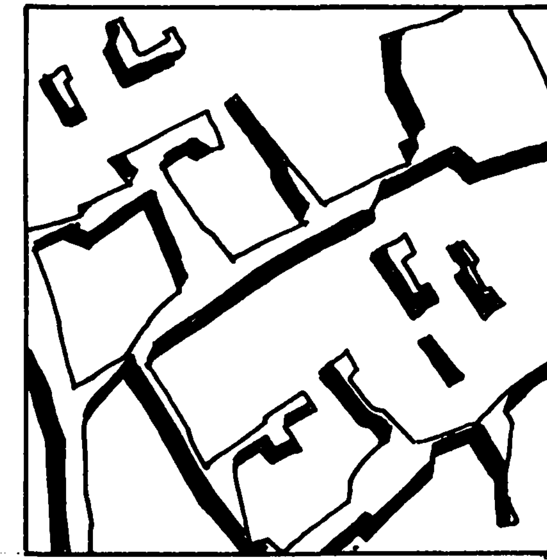
Fig. 82 POPULATION DENSITY and SETTLEMENT STRUCTURE INFU



300 inh./ha



500 inh./ha.



1000 inh./ha

In general, soakage pits are not feasible at a population density of more than 150 inhabitants/hectare

Fig. 83 POPULATION DENSITY AND SETTLEMENT STRUCTURE INFU

W2

> If the source of the drinking water lies outside the range of influence of the pit latrines and if the drinking water is distributed in a pipe system in good working order, no objections can to be made against properly designed latrines from the hygienic point of view.

With the improvement of the water supply, the problem of the domestic wastewater has to be solved (see also chapter 3) which makes the selection of the right disposal system more complicated:

Case no. 1:
Areas with a water supply from wells are always very susceptible to contamination by the seepage of wastewater, so latrines have in most of the cases to be excluded (cf. Section 2.1.2). In most cases this excludes the use of pit latrines.

Case no. 2:
Areas with a centralized water supply and house connections are relatively safe from water contamination, and therefore the construction of pit latrines should be absolutely safe from the hygienic point of view. But, the continuous availability of water results in large quantities of domestic wastewater which will in many cases surpass the capacities of seepage pits and will make additional measures necessary:

* Latrines complemented by an additional collecting system for domestic wastewater (cf. Section 2.1.7).

* Septic tanks for excreta and domestic wastewater with an overflow to a seepage field or connected to a collection system (cf. Section 2.1.4).

* Toilets with water flushing (W.C.), connected to a network of sewers with a sewage plant.

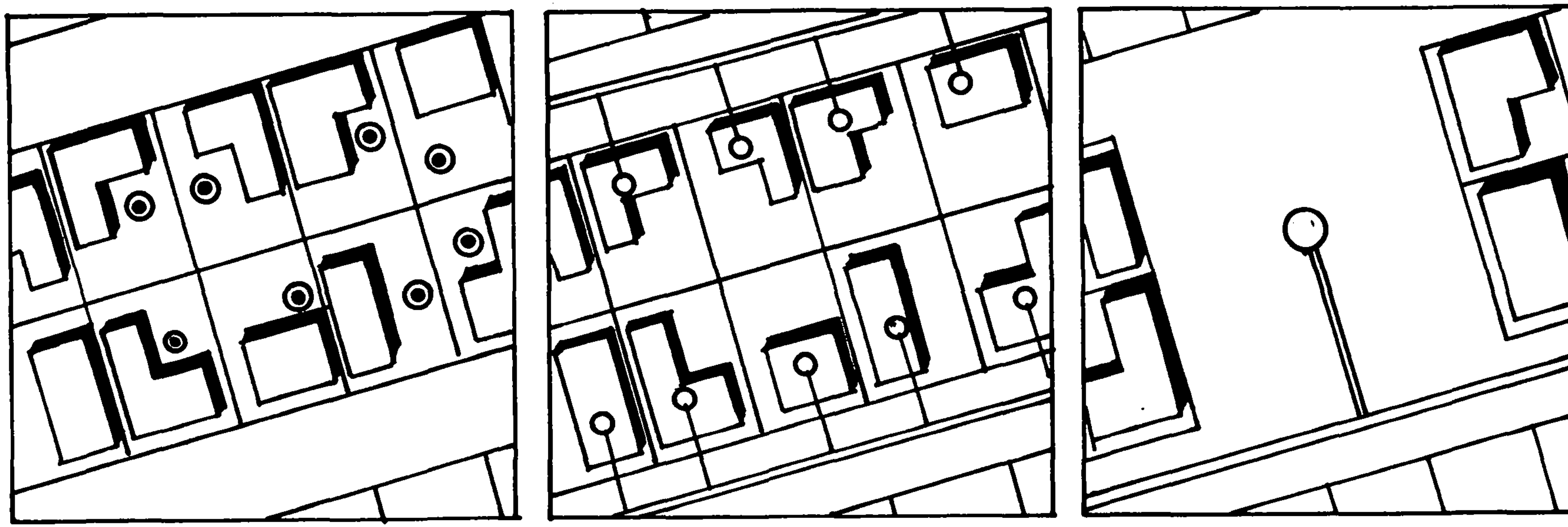
A compromise which permit the utilization of simple technologies is furnished by a centralized water supply with communal service connections. This system reduces the resulting quantities of wastewater to such an extent that no additional measures for disposal will be required.

This fact makes it evident that the water supply and sewage disposal system are directly connected with one another and have to be planned together.

The usual separation of planning and investment programs for the supply of water and wastewater disposal is most certainly an essential cause of hygienic problems attributable to an inadequate disposal of domestic wastewater.

W3

> If running water connections are installed in a house and/or if a water consumption of 50 litres per capita and day is exceeded, single stage latrines have to be complemented by sewer systems for the domestic sullage or to be replaced by a collection network with a sewage treatment plant.



Decentral by wells:

Soakage pits are feasible if a minimum distance of 30 m to the next well is kept

Central by water pipes:

No further danger of contaminating drinking water. Soakage pits are feasible. If water is piped to the house, a higher water consumption may occur. making sewers necessary.

Central by water taps:

No further danger of contaminating drinking water. Soakage pits are feasible; generally, water consumption is not very high, the necessity of sewers is limited.

Fig. 84 WATER SUPPLY SYSTEM INFU

3. Soil quality: Does the subsoil allow the construction of sufficiently deep and efficient seepage pits ?

S1 Any rock formations at the surface will exclude the construction of seepage pits and sewers. In this case other collecting systems have to be found which will guarantee the transportation of the excreta out of the settlements (cf. Section 2.1.7).

S2 If the rock is covered with a soil layer of 100 to about 300 cm, collection ducts can be built. The installation of seepage pits has in most cases to be ruled out and under certain conditions the construction of septic tanks with an overflow connection to a sewer would be possible (expensive solution).

S3 With a soil layer of more than about 300 cm, the construction of seepage pits will be possible provided that the soil is capable of absorbing water and that the bottom of the pit is above the ground-water level.

After having solved all these questions, a first step towards deciding on a sewage system can be taken:-

1. Single stage latrines are practicable without any problems (D 1/ W 2/ S 3)
2. Single stage systems as well as sewerage systems can be taken into consideration (D 2/ W 1/ W 2/ S 3)
3. Sewers are a must (D 3/ W 1/ W 3/ S 2)

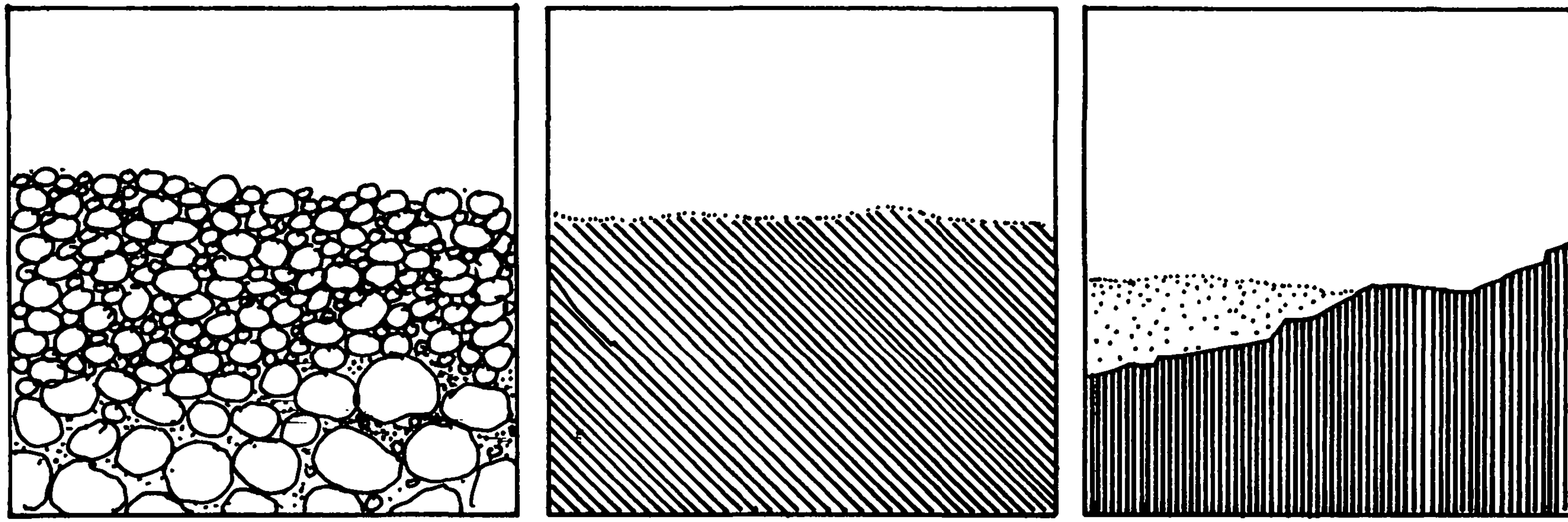
A special role has to be conceded for the use of biogas plants (cf. Section 2.1.5), because the employment of these plants requires the following conditions:

1. In addition to any human excreta, animal excreta and possibly vegetable wastes should be available in sufficient quantities;
2. The mean average temperature should not be less than 30° C;
3. A minimum quantity of water (about 10 litres per capita) must be available.

Decentralized plants (plants assigned to a single household) can be built if the characteristic features mentioned under

D 1/ B 2 or S 3/ W 1 or W 2 or W 3

are present.



Permeable soil:

Soakage pits and sewers are feasible

Impermeable soil:

Soakage pits are not feasible. Sewers can be built.

Rock up to ground level:

According to thickness of soil, the feasibility of soakage trenches and sewers is limited

Fig.85 SOIL STRUCTURE

INFU

Biogas plants can also be provided for higher population densities when the excreta is transported to a central collection place and treated there (D 2/ D 3).

b) System differentiation

Once the decision regarding the type of system to be chosen has been taken, the following aspects will assist in the dimensioning and differentiation of the system.

Latrines

Type of installation

For reasons of comfort and easy servicing, the decentralized latrines in industrial plots has in principle to be recommended for the private redisential user who is exclusively and directly responsible for the plant and its cleanliness. He will also decide on the design standard and, therefore, also the costs. The installation can not be contaminated or made dirty by any stranger without control.

Nevertheless it will never be possible to do without any communal facilities, especially:

* in areas with a danger of flooding (the flood water can cause an overflowing of the latrines and washout the excreta to the surrounding area);

* in regions or areas with high public frequencies - public office hours - (for example markets, temple buildings, etc.);

* in quarters with very high population densities, unless sewer systems can be realized.

- Choice of the location

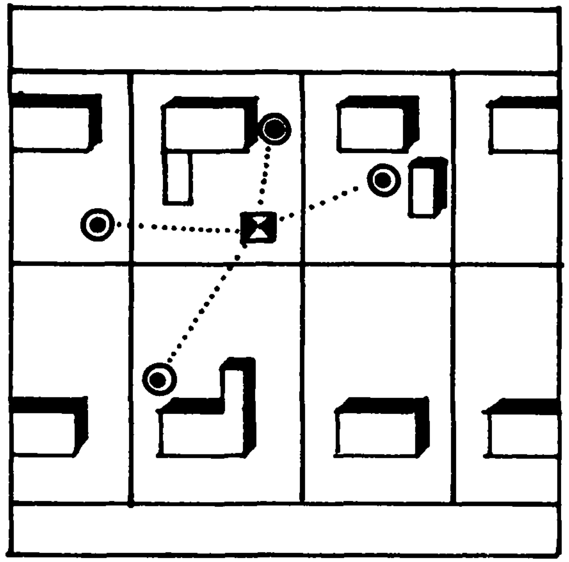
  Single stage latrines

  The distance to existing wells on the same or neighbouring plots should always be as far as possible (minimum 30 metres).

- Type of construction

  The foundations, the walls and the roof of the single unit and the collecting unit should be built according to the conventional and customary methods of construction of the region. As a general standard it should be affirmed that among the conventional methods of construction certain designs have proven to be extremely well adapted to the climatic, ecological and economic conditions and could be built on a self-help basis.

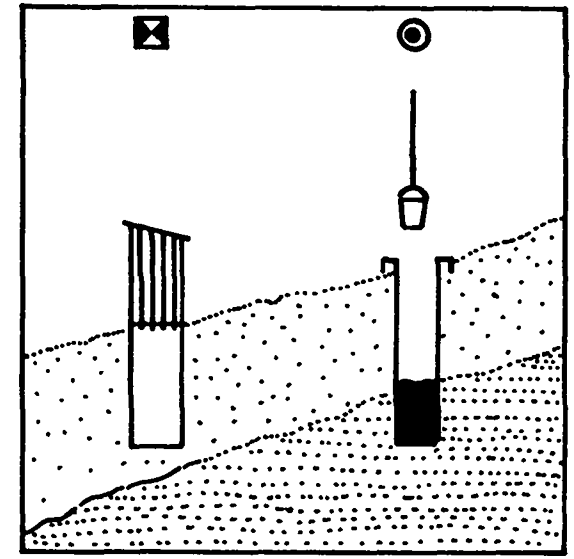
  In Section 2.1.2 there is a more detailed description of how the basic design of latrines should be arranged to satisfy different requirements depending on the conventional housing constructions of the region.



A sufficient distance
to any well on the same
or adjoining property
should be kept.
(at least 30 m)

⊙ well

⊠ toilet

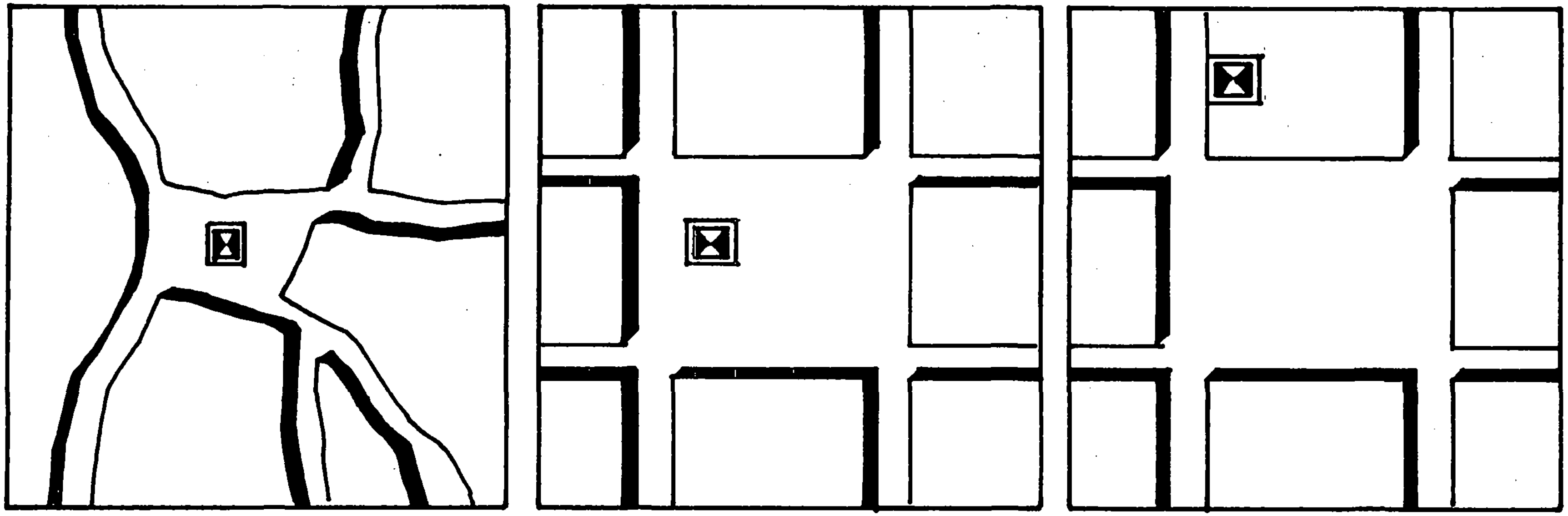


In all cases, latrine pits should
be excavated below any well.

Taking both conditions into account,
user's demands and wishes must also
be considered.

Fig. 86 POSITION OF LATRINES AND WELLS

INFU



The shortest possible distances for all users should be realized (central location)

The unit should be adapted to social conditions (e.g. religious demands), that means more

public or privacy

Fig. 87 LOCATION OF COMMUNAL TOILETS

INFU

- Kind of equipment and facilities

Single-stage latrines

A detailed description is given in Section 2.1. The installation of a water tap would in all cases be desirable, but will also cause infiltration problems because of the resulting high wastewater quantities which can only be solved with certain difficulties.

Communal sanitation facilities

In view of increasing the attractiveness of communal sanitation facilities, several tests have been made to combine the toilet with a public water supply consisting of showers and wash houses. This will, of course, increase the difficulties with maintenance and supervision and also necessitates additional disposal measures because of the resulting large quantities of wastewater.

To settle the question of supervision and maintenance, different solutions are possible of which, however, only of very little and partly contradictory experience is available:

* Subdivision of the installation into a number of private units which are individually used and cleaned. This solution is only suited to communal sanitation facilities in residentian areas where no outside users will be expected.

* Maintenance and control of the facilities by an attendant . A person to collect the fees for the use of the showers (example Maradi, actually under project and/or execution) must be engaged.

- Sewer systems

Choice of the system

Sewer systems can be constructed and dimensioned for

* overflowing water from septic tanks and domestic sullage, which means for wastewater without solid substances

* domestic wastewater mixed up with excreta (sewage)

In addition the wastewater sewers could be dimensioned to receive surface water.

The decision depends above all on the question of costs. Nevertheless, attention has to be paid to the following restrictions:-

* All the sewers intended for the transportation of wastewater with solid substances must have a minimum inclination (cf. Figure 44) and a minimum dilution. This means at the same time that an adequate quantity of fresh water has to be supplied to the area in order to prevent the sewers from clogging.

* The mixture of rainwater and wastewater is only advisable if rainfall is relatively frequent and uniform, i.e. level fluctuations are not too great. Dimensioning the sewers to receive peak rains is usually not worthwhile because the amount of water to be transported during the dry

seasons will be relatively modest and could therefore cause constriction in the sewers as a result of the deposition of solid substances.

Position of the sewers

As a matter of principle, the ducts should be arranged in such a way that the necessary inclination can be reached without the installation of pumping stations.

This requires an exact knowledge of the topographical situation:-

* Subdivision of the area into zones with a slope of more than 1 per cent, between 0.5 and 1 per cent and smaller than 0.5 per cent,

* Division of the areas into catchment areas for collecting sewers without pumping stations,

* Checkup of the road network according to the direction and inclination of the slopes. The sewers should always be built below areas easily accessible to the public authorities in order to carry out any construction or repair work necessary without any problems. This will, of course, very often bring along the problem that the existing settlement structure might not be serviced without certain modifications including very high costs. In order to avoid rapid modification of the settlement structure, which results in many negative side effects for the inhabitant, it might perhaps be necessary to change sometimes over to less efficient and less comfortable intermediate solutions, for instance to suitable located communal sanitation facilities.

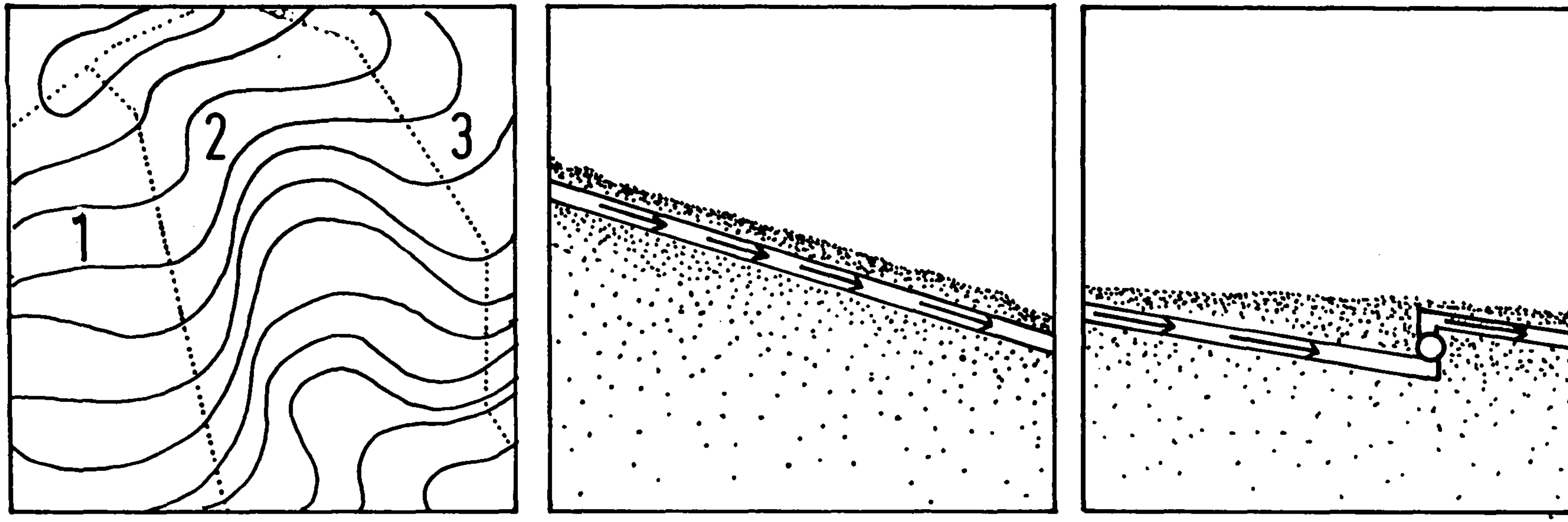
Within the scope of a redevelopment scheme it should be possible, over a suitable period of time, to create a settlement structure which will be compatible with the requirements of an appropriate sanitary technology.

- Location for sewage treatment plants

The choice of the most suitable type of installation has been explained in section 2.2. This decision, however, also depends on the possible locations. Wastewater disposal systems for existing settlements are subject to more severe restrictions than for development schemes. The optimum location for a certain type of installation is in most cases already being used for other purposes; which makes it necessary to choose other less locations or install another treatment technology.

Universally valid standards for this decision procedure cannot be established because so many factors have to be taken into consideration. For this reason it is only possible to describe how this process could or should be carried out.

1. Rough localization of the area where the sewage treatment plant is supposed to be installed.



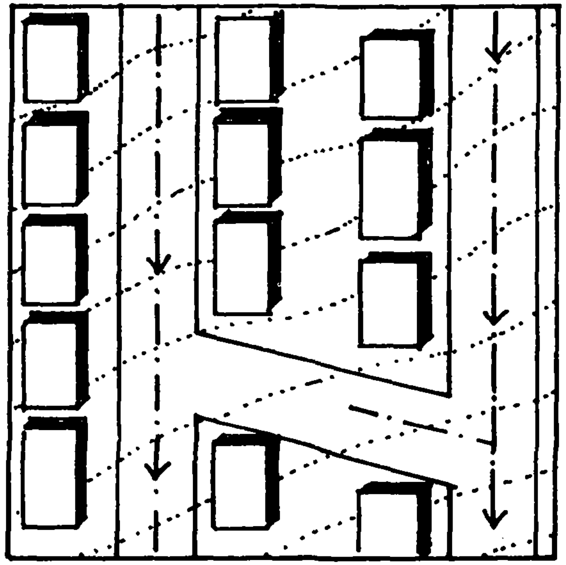
Subdivision into drainage areas:

Sewers are able to drain the areas 1/2/3 seperately without pumps

Sewage flows at an inclination of 1 %

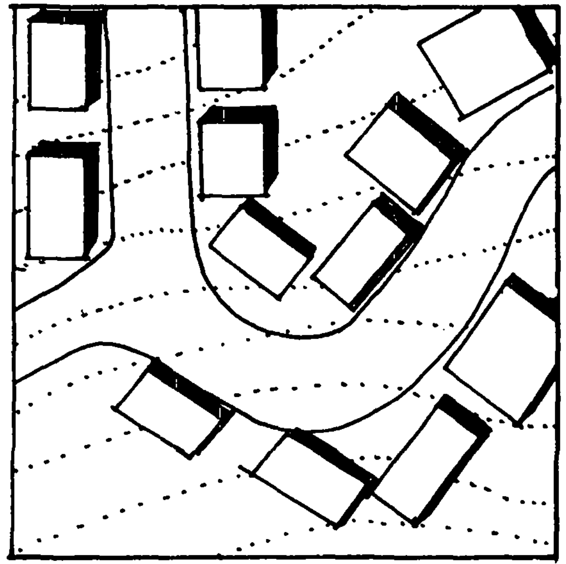
Sewage does not flow at an inclination of 0.5 %; sewers must be additionally inclined and lifted, if necessary.

Fig. 88 | TOPOGRAPHY (IMPORTANT FOR INTERCEPTING SEWERS) | INFU



Advantageous

All streets are inclined, allowing sloped parallel sewers under the road surface.



Disadvantageous

Sewers can only partly be parallel to the streets, as there would otherwise be reversals of slope.

Fig. 89 SETTLEMENT STRUCTURE (Development System/Slopes) INFU

2. Survey of all the existing utilities and land use and their development requirements. Are there any free areas available ?
   What kind of utilities or activities could perhaps be shifted, and where to?
   What costs would such a measure entail ?
   Are there any social hardships connected with such a shift ?

3. Comparison of eventually available areas which satisfy the surface requirements of the plant.

4. Eventually search for alternative locations and/or alternative installations and/or systems. For example: Decentralized small units or centralized large-scale plants ?

5. Possibilities of integration of the plant into the location.
   Will there be any intersection of important roads ?
   Can any impairment of neighbouring activities be expected?
   For example: As a result of odour nuisances, loss of image, etc. ?

6. Decision for a system.

Development of new areas

The essential difference between the redevelopment of built-up areas and the development of new areas is given by the fact that for the latter a large number of factors concerning wastewater treatment and disposal can still be altered, and so adapted to the requirements of infrastructure planning.

This applies for:

- the location of the settlement
- the population density to strive for
- the network planning potential pipe routes
- the type of water supply

In the case of new development areas it might be possible to enforce building regulations conforming with the conditions to provide a definite kind of sanitation facility (for example a septic tank with a preset type of design) in order to exclude health risks from the start and to avoid public infrastructure measures for the wastewater disposal. This possibility is particularly common, as far as the building regulations are concerned for areas in developing countries with low population densities and in upperclass residential areas.

It would be wrong to assume that with this method there will be more hygienic problems in future settlement areas. Most settlement growth still goes on without any planning or control. In most of cases, the authorities are understaffed and the possibiltities of an efficient control of settlement growth are limited because of confusion as to who is responsible, lack of money, and very often even because of lack of suitable legislation or the political will to use it.

3.2 Institutional and organizational aspects

With regard to the installation of simple sanitary facilities as described in this manual, co-operation between the public health authorities and planners, technicians and other specialists and the communities and local administrations is possible and desirable. Numerous reports on experience gathered in countries of the Third World indicate that the transformation and improvement of the hygienic living conditions of the population can only be achieved with their comprehension and active participation, and that local behaviour and customs have to be taken into consideration.

The activation of the population may, however, be very time consuming. But it has been proved that all following projects can be executed faster and more successfully, because ... "to do something f o r other people is of course easier, but in the long run more expensive and not so efficacious as the encouragement and intensification of the individual and local initiative, of the responsibility and the reliance on the basis of partnership". (6)

1. The responsibilities of state organizations

   The main objective for the introduction of simple sanitary facilities by the state organizations is constituted by a cost saving installation of such plants which could be reached by a co-operation of the population. These costs are determined by:

   - Personnel for maintenance and operation of the installation
   - Demonstration materials such as pamphlets, pictures, films,
   - The procurement of materials (purchase and transportation),
   - The accompanying campaigns,
   - The personnel for the maintenance and the operation of the installation, unless this work can be performed by the population.

   The instruction and training of the population should represent an essential part of the program in order to guarantee a long lasting and independent servicing and operation without the presence of external specialists.

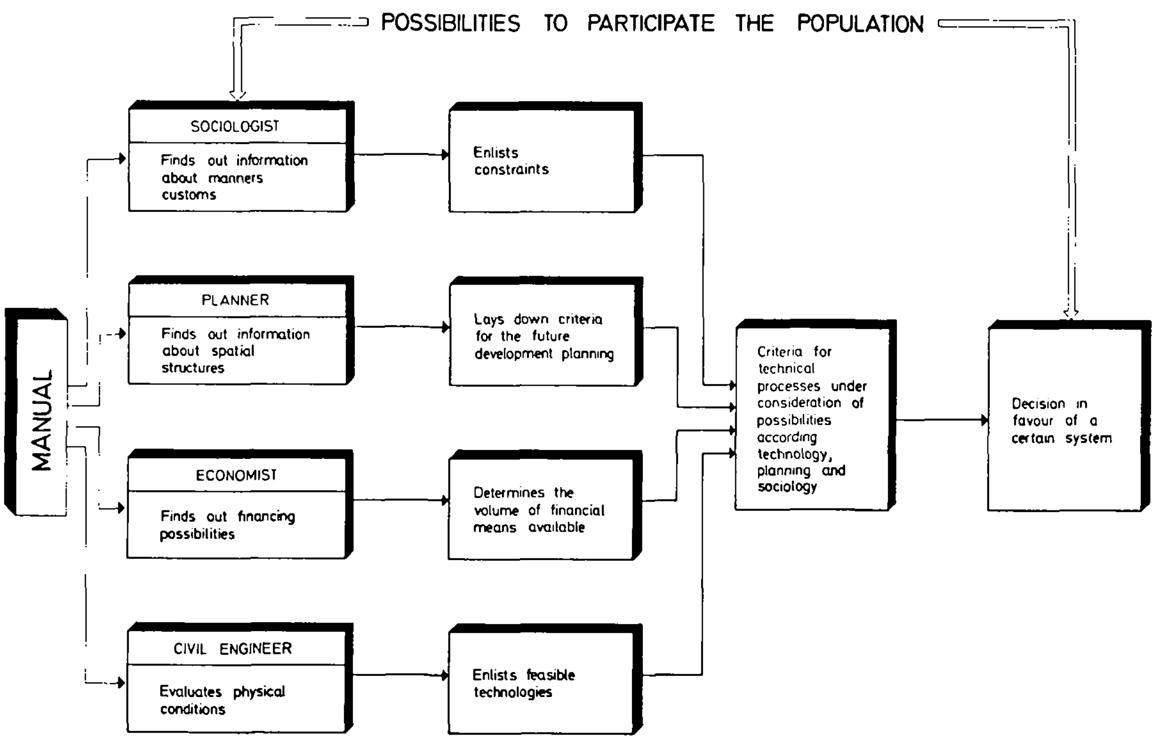
   During the preliminary stages of the planning, all the sociologists, planners, economists and engineers should co-operate in order to obtain the basic informations regarding

   - the general health situation within the community,
   - the existing water supply and disposal systems, as well as the local practice of excreta disposal,
   - the material and installations available which could be used for the execution of the project,
   - the readiness of the population to be integrated into the project by active co-operation or financial contributions,

- experience already gained by members of the community during the execution of other projects.

- the possibilities of the community to organize the maintenance and operation of the installations and, the waste disposal, through its own initiative.

The following diagram gives a general idea of the activities of the individual specialists and the areas in which the population can participate in an active way (Fig. 90).



Taking local behaviour patterns and customs into consideration is absolutely imperative for the success of the project. As this was done, the installation of toilets and showers failed in some villages in Africa, for example, because they had been integrated into the houses at the street front. For traditional reasons, however, it was usual to install these facilities as far as possible from the view of passers-by, at the back of the yard. As a result they were used for other purposes or as store rooms.

In Uganda, the inhabitans of a village were even afraid to use latrines because their fixed location and accessibility gave the witch doctors the possibility of casting a spell over their excreta. Some planners of toilet facilities by-passed this fear by giving the population the advice to drill the pits as deep as possible and to cover the excreta with grass or by other means in order that the witch doctors would no longer be in a position to reach the excreta. By doing so, a technical improvement was achieved without disregarding any cultural conceptions. (94).

2. The role of self-help organizations, community representatives, etc.

To encourage the readiness to participate, intense contact between representatives of the state organizations and the population is absolutely necessary to integrate them as early as possible into the project. This contact could be established, for example, by town district groups or cooperative societies, that is with already existing organizations whose members have already committed themselves in active and independent way to change their own living conditions, for example through the construction of schools and the like (95).

The activity and success of these groups can have a snowball effect for all not yet organized or still hesitating members of the community, and animate them to participate. (96) It is of particular importance to win the confidence of the village seniors in the project because the judgement of these seniors within the community has far-reaching effects, and their opinion is often adopted. All self- help projects carried out with success will encourage continuation of the work and create new initiatives.

It took, for instance, more than one year before the inhabitants of a favela on the outskirts of Saulo Paulo could be induced to assist in the construction of a youth and child centre which had been designed and was being executed the personal initiative of a teacher. On the occasion of the inauguration of this centre the inhabitants expressed their idea of building a health centre, and within six months it was possible for them to erect the building on their own. (96). The prerequisite for the participation of the population of any project is to inform them thoroughly on all aspects regarding the improvements and benefits of such installations, for example through the visual media, photographic and film material or even by the inhabitants talking with members of other villages where similar projects were carried out with success. The public health authority should single pilot demonstrations facilities at central places, for example in schools or hospitals in order to explain the construction and the technique of such an installation.

3. Role of the family

Because of the fact that the family is the real target group for the introduction of sanitary facilities it must be recommended to engage the family in the project in the early stage of the projecting phase of data acquisition in order to be able to take into account in due time their suggestions and concerns.

If the families are prepared to co-operate in the projects as an active party, the contribution of every family can be discussed on the occasion of a village meeting, for example. The results should be recorded in a schedule. It must cover the following points:-

- An estimation of the expenditure of time for the duration of the project.
- The required financial expenditure,
- The necessary quantities of material and the provision of it.
- The nature of the participation of the family, that means either in form of any financial contributions, which is of course dependent on the general income level, or by offering manpower and working time and/or provision of material (94). Preference should be given to the last possibility because the personal service of the family will be rewarded with the installation of the facility and at the same time a better identification with the facility built by their own efforts can be develope.

It might be practical to conclude either with the majority of the members of a community as one group or with every single family a formal contract by which all the reciprocal duties are clearly explained. In Latin-American countries, for example, contracts had been concluded with certain families where all the commitments of the contracting parties had been set down by simple and easy to understand formulations. These are: The provision of building materials by the public health authority at no cost but for a return service of a fixed number of man-hours in the "something for something" contract. These contracts accentuated the importance of the sanitary facilities as a constituent part of daily life and identified the family as a necessary and serious partner.

By comparison, in Southeast Asia the representatives of the state health authorities sold to the single heads of family the construction plan of a latrine and gave them their support during the installation and the provision of material. The possession of a sanitary facility became an object of prestige in the community and animated all neighbouring families to follow up this example (6).

With the installation of the sanitary facilities, however, the program can in no case be regarded as completed because the benefit can only be guaranteed by a following up continuous and proper maintenance. To achieve this, an extensive training is just as necessary as a continuous contact of a representative of the state organization with the users in order to guide them in the right utilization. The project can not be judged successful until the sanitary facilities have become a foregone conclusion and an indispensable utility in everyday life.

Table 91 shows a schematic representation of the individual institutions and organizations and their functions.

Level	Institution	Function
National	Legislation	Judges on the earmarked development policy
	Ministry of Health	Establishes the quality standards and will check them
	Department of Trade and Industry, Ministry of Labor, Ministry for Planning, etc.	Long-term planning; trying to find national and international sources of financing
	Committee for Public Affairs	Plans the development strategy, establishes priorities, comments on tariff and training questions
	Ministry of Finance	Finances the project
Federal State, Province, etc.	State Department for Public Affairs or Planning Board	Plans the details, establishes the communities, organizes the data survey, material and personnel schedule
	State Department for Water Supply and Wastewater Disposal Public Health Authority	Converts the national policy, proposes construction guidelines. Supervises, assists and instructs the local institutions, assists in the maintenance and the operation of small scale systems.
Local	Municipal administration	Gets guidelines for construction and building (unless given by state organizations). Services and operates the plants and trains the staff
	Committees for the water supply and wastewater disposal in small communities or cooperatives, selfhelping groups, families	Constructs; Services and operates; Trains.

3.3 Benefit of the facilities

Excreta and waste water are to blame for the spreading and transmission by infection of most the diseases in developing countries.

This correlation can be shown by means of the bilharzia parasites (cf. Fig. 92), - a disease called schistosomiasis - which about 150 to 250 million people suffer from. This disease is encountered mainly in Africa, the Euphrates and Tigris valleys, in parts of Israel, North Syria, Arabia, Iran and Iraq, but is also widerspread in Puerto Rico, Venezuela, Guyana, Brazil, the Antilles, Taiwan, parts of China, the Philippines, Japan and some other countries.

In recent years, substantial funds have been made available for the development of the drinking-water supply, whereas the disposal of the resulting waste water remained far behind a desirable parallel development. In some cases the extension of the water-supply system has lead, whenever proper water disposal was not provided at the same time, to a propagation of diseases. There are a number of reasons represent the basis for such a development (97):

1. The collection and the treatment of human excreta is regarded as an unhygienic and sometimes economically unproductive work.
2. Many technological attempts require large capital assets and are far beyond all financial possibilities.
3. In many cases the right incentive and motivation of the competent governmental and administrative authorities is missing.

This section deals with the positive effects of a proper treatment of excreta and wastewaters and should at the same time deliver more arguments for a propagation of the proposed installations.

The most important diseases which can result from insufficient waste disposal are listed and described in detail in (13).

An answer to the following question seems to be of particular importance:

> "If the environmental conditions in a given residential area are improved by the construction of excreta and sewage treatment plants, by which factor will the morbidity rate then be diminished and could this immediate benefit be expressed in monetary values ?"

Exemplary for a series of tests to establish the economical costs of an unfavourable environment situation due to an insufficient sewage and excreta treatment, the following three examples are given:

- In 1969, WAGNER and LANOIX tried to estimate the costs caused by diarrhoea that especially with children under 2 years of age this disease is often fatal. As the consequences can hardly be evaluated from an economic point of view, no statements could be made.

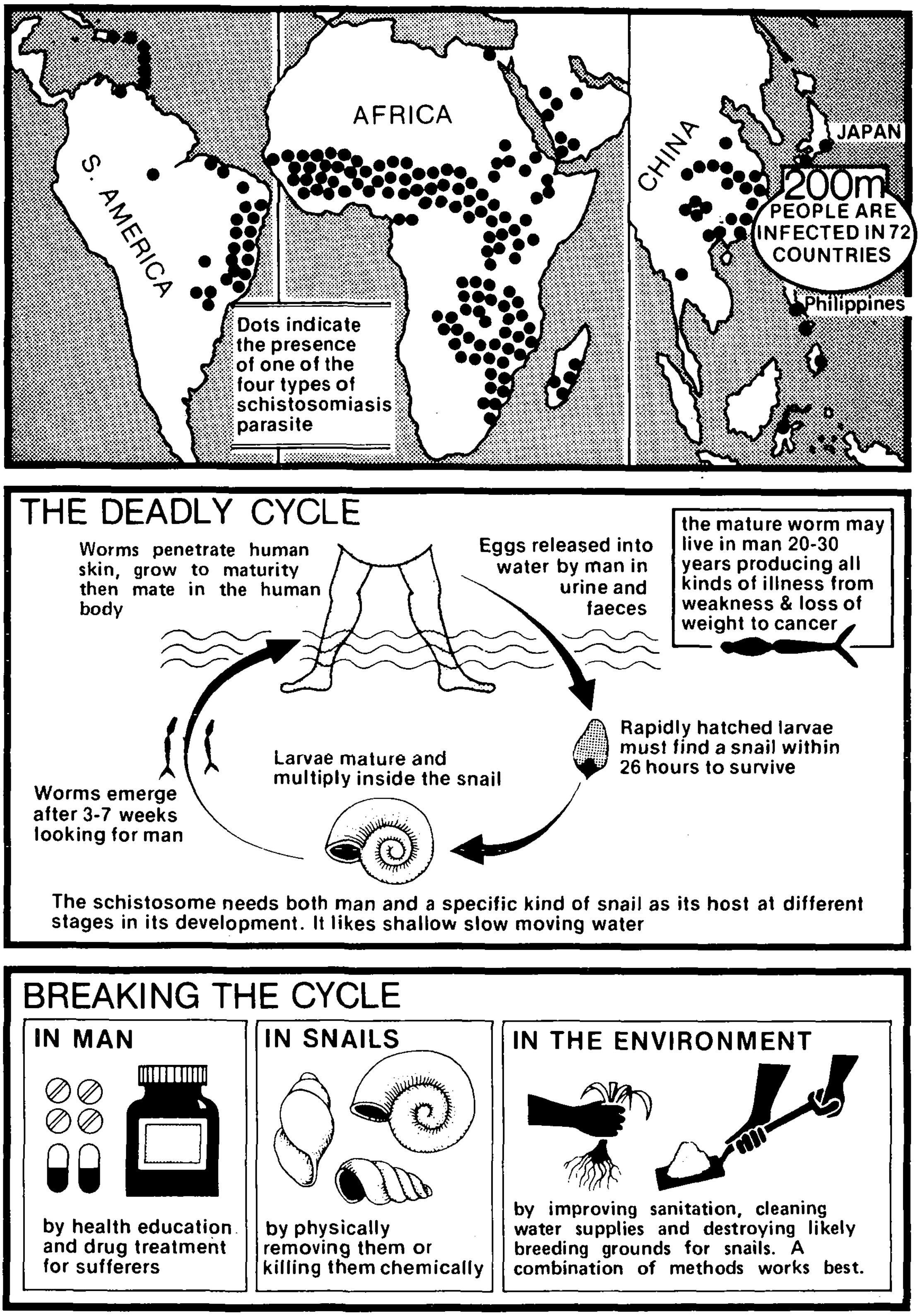


Fig. 92 **Schistosomiasis** (A water-borne disease also known as bilharzia) INFU -100-

- In 1978, MOORE and LATHAN examinded the economical costs in Kenia caused by an infection with Ascaris eggs. The losses due to a surplus consumption of foodstuff, inability to work and costs for medical treatment were calculated with US $ 4.4 million per year, but with a range of variation of 50 per cent.

- In 1979, SUNDARESAN and HANDA (98) examined the inhabitants of some villages in India attacked by nine different worm parasites. The result obtained is shown in the following tables 93 and94.

Village	No. examined	No. infected	Per-cent	Families examined	Families infected	Per-cent
Mahalgaon	206	153	74.2	38	37	97.3
Mahadula	281	173	61.6	44	43	97.7
Khursapar	272	148	54.4	51	47	92.1
Burujwada	594	416	70.0	116	114	98.2
Fedri	174	109	62.6	47	40	85.1
Asoli	199	155	77.9	58	54	93.1
Avandhi	627	400	63.8	114	104	91.2
	2353	1554	66.0	468	439	93.8

Figure 93 Populationwise and familywise distribution of Parasites in some villages in India (98)

The distribution of the frequency of the parasites found among the rural population, in dependency of the age of the persons examined is shown in Table 101,(94)

Parasites	Age range (in years) 0 - 1	2 - 5	6 - 15	More than 16	Total	Per-cent
1. *E. histolytica*	11	72	209	417	709	30.7
2. Hookworm	3	24	112	496	635	27.5
3. Giardia	9	83	148	182	422	18.3
4. Ascaris	0	42	113	114	269	11.6
5. *H. nana*	1	65	86	19	171	7.4
6. Trichomonas	1	6	12	29	48	2.0
7. Enterobius	0	2	9	12	23	1.0
8. Trichuris	0	2	6	4	12	0.5
9. Strongyloides	0	0	6	13	19	0.82
No. of infections (all types)	25	296	701	1 286	2 308	1.35
No. of infected persons	22	114	554	864	1 554	
No. examined	59	211	843	1 240	2 353	
Per cent prevalence	37.2	54	65.7	69.6	66	

Figure 94 Agewise prevalence of parasites (98)

The examinations proved that 66 per cent of all the persons registered were infected, sometimes even attacked by multiple infections (average: 1.35 diseases per each person).

In India, millions of people, a high percentage of the total population, suffer death every year as a result of diseases provoked directly or indirectly by poor hygienic conditions (99).

SUNDARESAN and HANDA found out that as a consequence of diseases attributed to a poor sewage disposal and water treatment theoretically about 1.8 billions of working hours are lost per year. The treatment of the patients and the loss of production due to the diseases cause costs of 550 million US $ per year.

In the course of a parallel examination made by SUNDARESAN and HANDA, two groups of farm workers were compared with one another. The one (test group) worked on an agricultural area which was irrigated with wastewaters and the other (check group) on fields where the irrigation was made with preliminary purified waste-water. Both groups were examined for different diseases, the result of which is given in the two following tables in the figures No. 95 and 96.

Diseases	Test group %	Check group %
Gastroenteritis	45.6	13.0
Fever	19.6	4.3
Anaemia	50.3	23.6
Anthema	22.3	4.0

Figure 95 - Frequency of different diseases suffered by farm workers

	Test group		Check group	
	number	%	number	%
Total number of the examined persons	1,178		3,429	
Positive findings	937	79.5	978	29.0

Figure 96 - Frequency of worm infections suffered by farm workers

This example shows very clearly that the health of the human being is largely dependent on the quality of water consumed and this in turn on the kind of sewage and excreta treatment.

The indications regarding the economical costs available today (cf. above) can only be regarded as reference points and are encumbered with a lot of mistakes.

The disadvantage of the stated examinations are given by the fact that they were always orientated according to the given situation and not based on conclusive comparative results from areas with proper infrastructure installations. On the other hand, however, the selection of the locations is very important for the quality of the results because it must be possible to take into consideration all the secondary influences. Influences which have no direct connection with a better treatment of the sewage and excreta. The best way to do this would be given by the comparison of the situation before and after the introduction of measures for the protection of the environment in a given project area.

In accordance with the investigations carried out by the World Bank, only an evaluation procedure for each proposed installation can be made at this very moment.

Benefficial primary effects of proper treatment of sewage and excreta

The estimation is made according to a point system ranging from 0 to 10, whereby the value 0 is given when no sanitary facilities are available and the value of 10 when "optimum" facilities are in operation.

1. Pit latrines (cf. Section 2.1.2) are in general used in all those areas where only small quantities of water are available. On the other hand, however, this system will, in principle, set a limit for the possibilities of the personal hygienics. It has to be added that these latrines are not equipped with an overflow and will normally not produce any exploitable product (for example fertilizer) which means that the risk of a contamination of fields and receiving waters can practically excluded, but only under the condition that the pits have been built according to the standards set down in this manual

   Hygienic rating: 9

2. Composting toilets (cf. Section 2.1.3) satisfy similar conditions as pit latrines, but they produce fertilizer which could present a danger to health in case of an insufficient detention period in the composting chamber. This risk is, however, in general more accentuated to the continuous composting plants.

   Hygienic rating: 8 (Composting by charges)

   Hygienic rating: 2 (Continuous composting)

3. Toilets connected to aqua privies and septic tanks (cf. Section 2.1.4) both produce effluents which could have a negative influence on the environment, either in the form of sludge or as overflow water. This depends on the retention time in the tanks and also on the subsequent purification. The procedures differ from one another above all by the arrangement of the tanks. In the case of the aqua privies, the tank is positioned directly under the toilet which generally constitutes a hygienic disadvantage. In addition, the two chamber tank of septic tanks offers a better equalization at peak times. While emptying, however, both systems can cause health problems.

   The overflow of septic tanks can in general be regarded as not so disquieting.

   Hygienic rating: 6 (Aqua privies)

   Hygienic rating: 7 (Septic tanks)

4. Biogas plants (cf. Section 2.1.5): If properly dimensioned, the operation of biogas plants will not cause any health problems.

   Hygienic rating: 10

5. Communal sanitation facilities (cf. Section 2.1.6): The major hygienic problems of communal sanitation facilities are often due to poor maintenance.

   Hygienic rating: 2

6. Bucket latrines (cf. 2.1.7): The health risks have already been emphasized, when excreta is collected in buckets and transported in them. In densely populated residential areas, however, this system is sometimes the only possible solution.

   Hygienic rating: 4

   Disposing of excreta by means of tank trucks, however, involves only minor factors deleterious to health. The frequent emptying and the problems due to the subsequent depositing and/or purification in comparison to septic tanks leads to the following rating:

   Hygienic rating: 8

7. Waste water transportation systems (cf. Section 2.2.1): Purely from a health point of view, there are virtually no reservations against closed waste water transportation systems.

   Hygienic rating: 10

   As an alternative solution to this system, open drains have been proposed: their disadvantages, however, are the possibility of direct contact between the population and the waste water and the formation of breeding places for mosquitoes etc..

   Hygienic rating: 4

8. Waste water stabilization ponds (cf. Section 2.2.2): The retention period of sewage in waste stabilization ponds is very long so that pathogens are to a very large extent eliminated. Many of the problems referred to and found in existing ponds are due to a wrong dimensioning and poor maintenance.

   Hygienic rating: 9

9. Activated sludge process (cf. Section 2.2.3) The retention period of the waste water in these systems is relatively short, compared to the time in waste stabilization ponds which has consequences not only for the hygienic quality of the outflow but also for the quality of the resulting sludge. The estimation of the health benefit of these plants is, therefore, desisively dependent on the kind of the subsequent treatment methods.

   Hygienic rating: 8

Beneficial secondary effects of proper treatment of sewage and excreta

Usefull secondary effects, for example the improvement of soil quality, the development of new sources of energy and food, etc. have been considered in detail in the section dealing with the technology of the various plants.

In this domain judgement is also passed on the systems to the same point system ranging from 0 to 10. If, apart from the hygienic advantages related to a proper treatment of wastewater and excreta and hence the resulting positive consequences are that no further useful effects can be expected, the value 0 is taken, whereas the procedure with the highest useful secondary effects will be estimated at 10 points.

1. Pit latrines: These installations are in general intended exclusively to remove excreta and do not offer any useful secondary effects as defined above.

   Rating: 0

2. Composting toilets produce a fertilizer which is, of course, of a poorer quality than that produced by biogas plants due to the lower content in nutritious substances.

   Rating: 8

3. Aqua privies and septic tanks: The sludge of toilets of this type can only be used after a further treatment on drying beds and will then present a similar quality as that of the composting toilets. The water outflow is not suitable for irrigation purposes.

   Rating 6

4. Biogas plants: In many tropical countries, mostly women spend nearly half the day or more to collect firewood from far away places. The burning wood releases fumes in the houses which are deleterious to health.

   Without any consideration of economical problems which could occur during the construction of biogas plants, they also bring along several ecologically relevant advantages, i.e.:

   a) The organic raw material, for example cow dung, is generally obtained from very limited areas situated close to the house. This will considerably reduce the expenditure on labour for the collection. The working capacities set free can then be utilized for other purposes, for example to plant and reap fruit.

   b) The continuous deforestation of large areas prevents the formation of a stable layer of humus, this entails that the agricultural acreage will become smaller and smaller being exposed to erosion.
   The propagation of biogas plants and/or the abolishment of the energy source "wood" in favour of biogas will satisfy, in combination with the high quality fertilizer, the requirement to improve the soil quality.

   c) Biogas burns with a considerably lower development of fumes which means a decrease of the bronchial diseases.

   Rating: 10

5. Communal sanitation facilities: Useful secondary effects of the disposal or treatment of excreta in communal sanitation facilities depend on the choice of the procedure and can, therefore, not be judged in this connection.

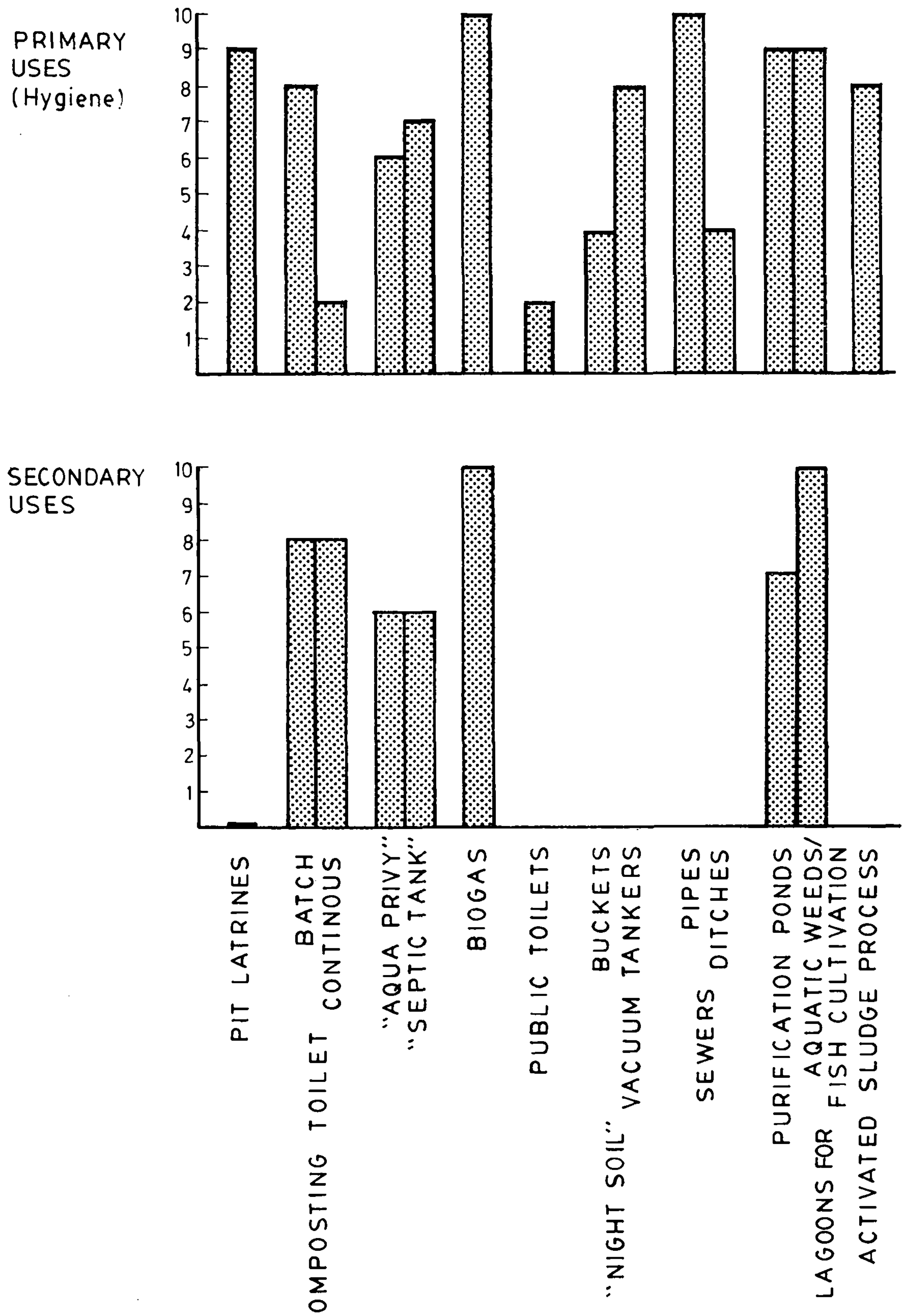


Fig. 97

EVALUATION OF PRIMARY AND SECONDARY USES OF FAECAL AND WASTE WATER TREATMENT PLANTS

INFU

6. Bucket latrines: The collection of excreta allows a centralized treatment after transportation and the useful secondary effects can, in dependency of the choice of the treatment procedure, be very high. The procedure itself serves only the purpose of excreta collection and is therefore not rated in this connection.

7. Wastewater transportation systems: For these systems the same criteria as already mentioned for toilets with collection tanks also apply.

8. Waste stabilization ponds: The outflowing water can be used for irrigation purposes and will, therefore, contribute to increase the crop yield. A re-use of sludge is not of great importance because it is drawn off only after very long intervals of time.

Rating : 7

- Wastewater fish ponds
  In addition to waste stabilization ponds, valuable food for human beings and for animals can be obtained with these installations which will contribute on a medium or short-term basis to better nourishment of the population.

Rating : 10

- Aquatic plant ponds
  Useful secondary effects of these systems are largely dependent on the nature of the water weeds used. Some of them do not or barely have a further use (bulrush), whereas others are compostable (water hyacinths) and, last but not least, there are also aquatic plants which could directly or after a certain drying process be used as animal fodder (water lentils) and, in some cases, even as foodstuff for human beings (water spinach). For this reason it is not even possible to give any final and generally valuable estimation because the points range between 0 and 10.

9. Activated sludge process: The outflowing water should never be used directly for irrigation purposes. The exploitation of the sludge depends on the kind of subsequent treatment ; it is therefore not possible to make any final assessement.

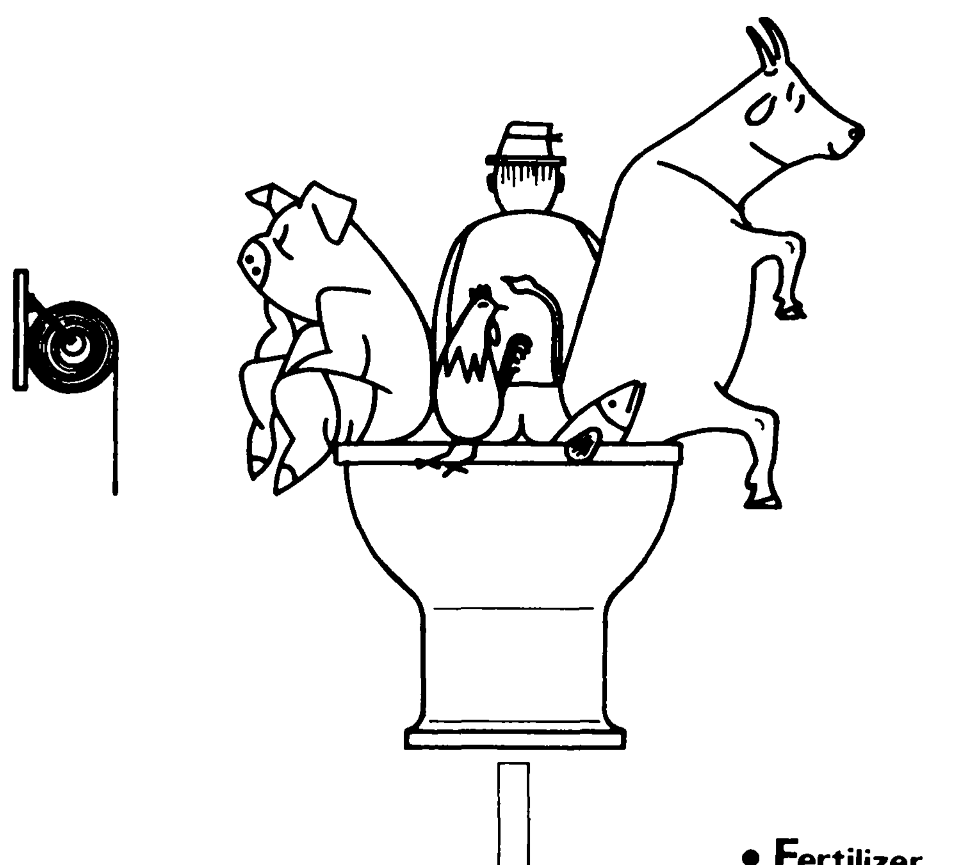
4 Summary and recommendations

4. Conclusions and recommendations

The technologies for the treatment of wastewater and excreta dealt with in this manual represent possible solutions for the rural areas of developing countries which are characterized by poverty, lack of infrastructure and unsatisfactory environmental hygiene.

The choice of the proper, that means "adequate", procedure depends on a whole series of factors - besides the acute financial restrictions - which have been considered as a prerequisite for acceptance, propagation and an independent maintenance of the installations.

Pit latrines, for example, are the most cheapest system, they can be installed nearly everywhere and are in the first line subject to only a few planning parameters, especially the density of population and the ground - water level.
In contrast to biogas plants however, it is not possible to achieve useful secondary effects with these systems which may be to obtain fertilizers or raw materials to develope energy.



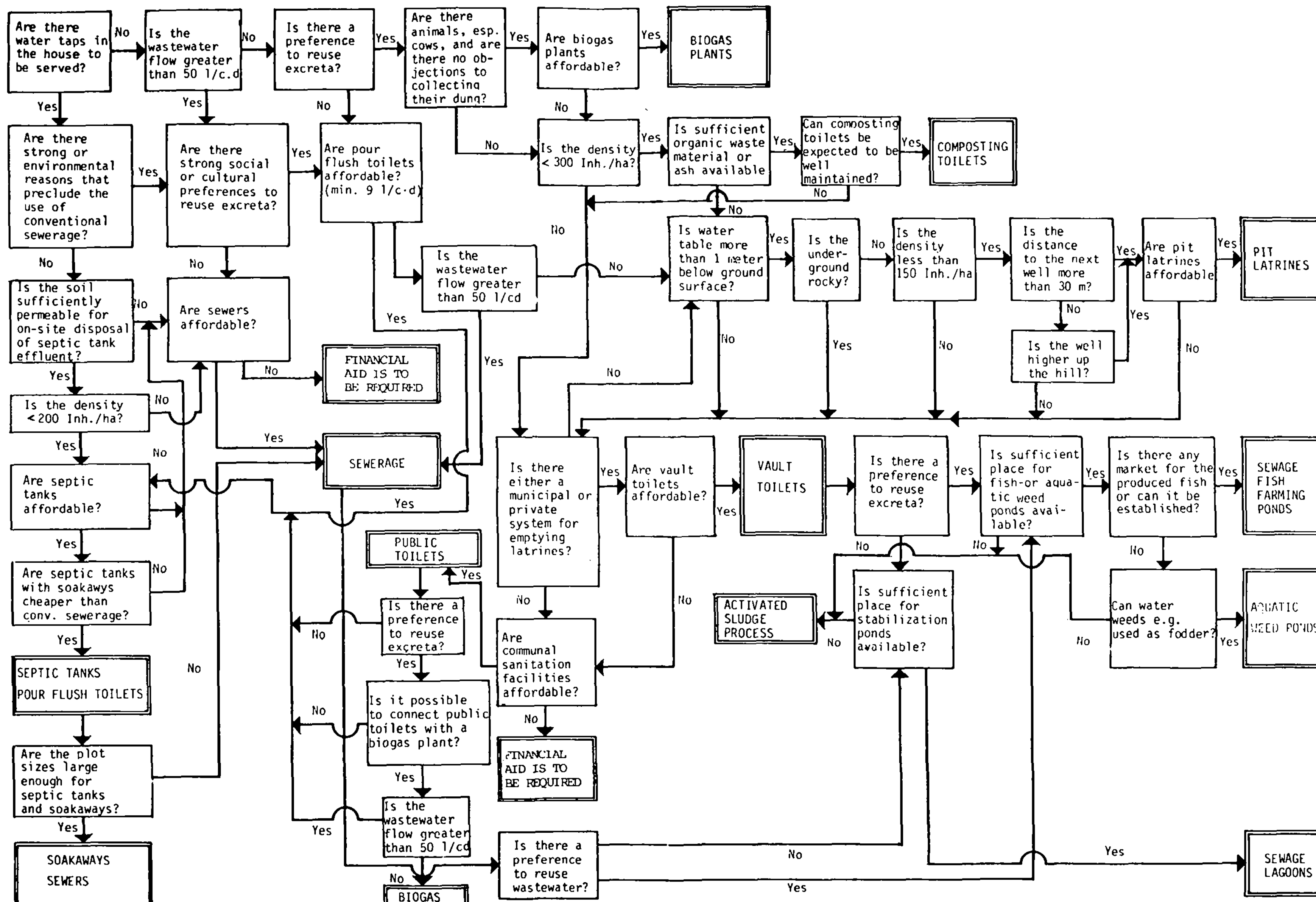
Other procedures, especially those described in the manual installations, are necessary in all cases where very high population densities and where the removal fo excreta in tank trucks or the disposal of wastewater in sewers can no longer be avoided. In rural districts, however, these prerequisites are only found in very few cases which means that the sewers plus sewage treatment systems conventionally used in Europe will only be applicable in exceptional cases.

The lack of capital funds, the generally substantial shortage in energy reserves and the necessity to create new nourishment resources lead to the recommendation to utilize every possibility to re-use wastewater and excreta and correspondingly to propagate simple technologies.

The aquatic plant ponds and fish ponds represent, for example, appropriate systems; they are cheap, simple and highly efficient if maintained properly.

The following flow diagram should be regarded as the first step to help choosing adequate procedures and it also contains the most important factors which have an influence on the selection. The most important, but by far not all considerations have been included. For every project a survey and study of the situation must be carried out on the spot in which further relevant considerations have to be observed and included in the selection process.

Each question in the diagram, which starts with the square in the top left-hand corner, has been set in such a way that it can be answered in this rough method of proceeding with yes or no, so that after going through the whole flow diagram in the direction the answers state, a system proposal is finally reached.


Are there water taps in the house to be served?
Is the wastewater flow greater than 50 l/c.d
Is there a preference to reuse excreta?
Are there animals, esp. cows, and are there no objections to collecting their dung?
Are biogas plants affordable?
BIOGAS PLANTS
Are there strong or environmental reasons that preclude the use of conventional sewerage?
Are there strong social or cultural preferences to reuse excreta?
Are pour flush toilets affordable? (min. 9 l/c·d)
Is the density < 300 Inh./ha?
Is sufficient organic waste material or ash available
Can composting toilets be expected to be well maintained?
COMPOSTING TOILETS
Is the soil sufficiently permeable for on-site disposal of septic tank effluent?
Are sewers affordable?
Is the wastewater flow greater than 50 l/cd
Is water table more than 1 meter below ground surface?
Is the under-ground rocky?
Is the density less than 150 Inh./ha
Is the distance to the next well more than 30 m?
Are pit latrines affordable
PIT LATRINES
Is the well higher up the hill?
FINANCIAL AID IS TO BE REQUIRED
Is the density < 200 Inh./ha?
SEWERAGE
Is there either a municipal or private system for emptying latrines?
Are vault toilets affordable?
VAULT TOILETS
Is there a preference to reuse excreta?
Is sufficient place for fish-or aqua-tic weed ponds available?
Is there any market for the produced fish or can it be established?
SEWAGE FISH FARMING PONDS
Are septic tanks affordable?
Are septic tanks with soakawys cheaper than conv. sewerage?
PUBLIC TOILETS
Is there a preference to reuse excreta?
Are communal sanitation facilities affordable?
ACTIVATED SLUDGE PROCESS
Is sufficient place for stabilization ponds available?
Can water weeds e.g. used as fodder?
AQUATIC WEED PONDS
SEPTIC TANKS
POUR FLUSH TOILETS
Is it possible to connect public toilets with a biogas plant?
FINANCIAL AID IS TO BE REQUIRED
Are the plot sizes large enough for septic tanks and soakaways?
Is the wastewater flow greater than 50 l/cd
SOAKAWAYS
SEWERS
BIOGAS
Is there a preference to reuse wastewater?
SEWAGE LAGOONS

5 Annex

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