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**EXCRETA DISPOSAL
FOR RURAL AREAS AND
SMALL COMMUNITIES**

E. G. WAGNER

J. N. LANOIX



World Health Organization

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1958

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FOR RURAL AREAS AND SMALL COMMUNITIES**

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Introduction

During the past several years there have been many developments in the field of disposal of human wastes, and many books have been written on this subject. The great majority of these books, however, deal almost exclusively with sewerage and sewage disposal as applicable to cities and large towns and communities. A survey of the relevant publications and of the few books devoted to rural sanitation reveals important shortcomings: in virtually all instances, they are confined to the study of one or a limited group of specific sanitation problems, such as latrines, wells, septic tanks, or a particular method of refuse disposal adequate for small communities. Very few publications deal comprehensively with the mechanics of getting sanitary excreta disposal facilities constructed and used properly, and with the factors involved in the process.

The persons primarily responsible for these aspects of rural sanitation are the public health administrators, the medical officers of health, the civil or sanitary engineers engaged in public health, and the sanitarians. It is to these that this monograph is addressed. They will find in it not only technical data relating to particular rural excreta disposal facilities, but also information on what is believed to be needed or to be done in order to achieve success in programmes of excreta disposal in rural areas and small communities. The role of the health department, the need for securing the active participation of the community and of the family, the planning of programmes, and the training of the necessary personnel are covered, as well as the latest accepted practices in excreta disposal for rural areas.

From their own experience and from their discussions with others of long experience and standing in rural sanitation work, the authors have formulated the following principles which appear to them to be essential in most countries to the success of sanitary excreta disposal programmes:

- 1. The object of any privy programme should be to get the family to assume responsibility for, and to solve, its own excreta disposal problems.*
- 2. The health department should contribute funds for materials or labour or both in order to encourage the family to build the first latrine and thereby to take the first important step in learning a new habit.*
- 3. The health department must train sanitary inspectors to work with the families in the communities on the educational and technical aspects of latrine construction, use, and maintenance.*

4. *The sanitation work should be under the general direction of a well-trained sanitary engineer who must be able to understand the problem of excreta disposal in its most elementary terms and the processes involved in effecting improvement in this fundamental of rural sanitation.*

This study is written largely on the basis of these four points. Although it is obvious that every problem is different and must be solved on the basis of each local situation, it is hoped that the information given herein will shed some new and helpful light on a problem which is very old, no matter in what part of the world it is found. An effort has been made to give enough detail to help those who are beginning in this work and, at the same time, to present some ideas and approaches which may be new to those with experience in rural sanitation.

It is hoped, too, that this monograph will serve as one of the links in the chain of efforts being pursued by the World Health Organization to stimulate environmental sanitation programmes at the local level in member countries.

A preliminary text covering certain aspects of excreta disposal without water carriage was first drafted by Mr E. G. Wagner, a short-term consultant to WHO, and was issued in 1955 as a mimeographed document. This text was circulated to forty experts in different parts of the world for their comments and suggestions. The thirty-eight replies received were much appreciated, and have greatly assisted in amending and revising the original text. (A list of the reviewers will be found in Annex 2, page 177.) The World Health Organization wishes to express its gratitude to these reviewers. Also, to the Serviço Especial de Saúde Pública of Brazil and the Institute of Inter-American Affairs, and to their staffs, the Organization gives sincere thanks for the use of their vast experience and for their frank and helpful criticism of the material.

BASIC CONSIDERATIONS

PUBLIC HEALTH IMPORTANCE OF EXCRETA DISPOSAL

Excreta disposal is an important part of environmental sanitation. Its provision is listed by the WHO Expert Committee on Environmental Sanitation⁴⁴ among the first basic steps which should be taken towards assuring a safe environment in rural areas and small communities, the others being the provision of an adequate supply of safe drinking-water and the control of insect and animal vectors of disease in places where these are of significance. In large areas of the world, and indeed in parts of every country, proper excreta disposal is among the most pressing public health problems.

The inadequate and insanitary disposal of infected human faeces leads to the contamination of the ground and of sources of water supplies. It often affords an opportunity for certain species of flies to lay their eggs, to breed, to feed on the exposed material, and to carry infection. It also attracts domestic animals and rodents and other vermin which spread the faeces; and it sometimes creates intolerable nuisances.

Relationship to Health

Poor excreta disposal is often associated with the lack of adequate water supplies and of other sanitation facilities and with a low economic status of the rural population. These conditions, all of which affect health, make it difficult to assess the role played by each component in the transmission of disease. However, it is well known that there is a relationship between the disposal of excreta and the state of health of the population. The relationship is both direct and indirect in character.

The direct effect is exemplified by the reduced incidence of certain diseases when proper disposal of excreta is practised. This group of diseases includes cholera, typhoid and paratyphoid fevers, the dysenteries, infant diarrhoeas, hookworm disease, ascariasis, bilharziasis, and other similar intestinal infections and parasitic infestations. These diseases lay a heavy hand on infants, whose immunity is low and whose vigour is often not great enough to cope with an infection after it becomes established. Further

TABLE I. INFANT MORTALITY AND MORTALITY FROM DIARRHOEA AND ENTERITIS FOR THE YEAR 1954*

Country	Infant mortality		Infant diarrhoea and enteritis	
	deaths, 0-1 year, total	rate per 1000 live-births	deaths ^a	deaths from diarrhoea and enteritis (%)
Egypt	81 407	179 ^b	43 517	54.7
Colombia	48 734	103	6 277	12.8
Guatemala	14 302	88	1 392	9.7
Portugal	16 898	86	5 126	30.3
Mexico	107 853	80	21 052	19.5
Costa Rica	3 820	79	772	20.2
Puerto Rico	4 482	58	1 088	24.3
Panama	1 745	53	241	13.8
Italy	46 104	53	5 168	11.2
Uruguay	2 428	51	440	18.1
Austria	5 023	48	391	7.8
Japan	78 944	45	5 689	7.2
Germany, Federal Republic	33 353	43	443	1.3
Israel	1 417	35	198	13.9
Union of South Africa (European population)	2 298	33	277	12.0
Canada	13 841	32	554	4.0
Finland	2 750	31	199	7.2
USA	106 791	27	3 590	3.3
Denmark	2 051	27	64	3.1
Switzerland	2 280	27	42	1.8
United Kingdom of Great Britain and Northern Ireland	17 160	25	428	2.5
Norway	1 343	21	37	2.7
New Zealand (exclusive of Maoris)	968	20	17	1.7
Sweden	1 968	19	21	1.0

* Taken from *Annual Epidemiological and Vital Statistics, 1954*.¹¹

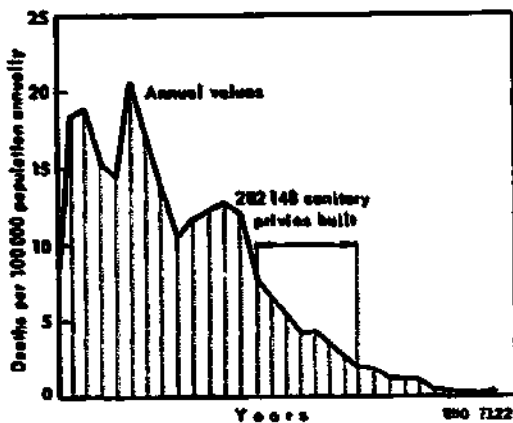
^a Figures given in this column do not include deaths due to enteric infections in the newborn (babies less than four weeks old).

^b Figure for 1953.

evidence of this direct relationship may be found in a comparison of figures for infant mortality from diarrhoeas and enteritis in various countries (see Table I).

A good example of the effect of sanitary excreta disposal on the incidence of typhoid and paratyphoid is given by Fair & Geyer:¹³ In the State of West Virginia, USA, when a privy construction programme was undertaken, the death-rate attributable to these diseases was cut by two-thirds and eventually was reduced to nil (see Fig. 1). It is stated, however, that improvements in other sanitary conditions probably occurred at the same time.

FIG. 1. REDUCTION IN THE DEATH-RATE FROM TYPHOID BY SANITATION OF EXCRETA DISPOSAL



Reproduced from Fair, G. M. & Geyer, J. C. (1954) *Water supply and waste-water disposal*, p. 26, by kind permission of John Wiley & Sons, Inc., New York.

The indirect relationships of excreta disposal to health are many, but they are generally associated with other components of environmental sanitation. Here mention may be made of the following :

1. The improvement of hygienic conditions promotes a state of well-being in the population which is conducive to its social development.

2. There is considerable evidence that the diminished incidence of excremental and water-borne diseases which results from improvements in environmental sanitation is accompanied by a marked decrease in morbidity from other dis-

eases the etiology of which is not directly related to either excreta or contaminated water-supplies.

3. Various economic benefits, such as those resulting from an increase in life expectancy, arise in connexion with the implementation of sanitation programmes.

4. Morbidity resulting from lack of even the simplest sanitation facilities adversely affects deployment of labour. When they are healthy, unemployed persons who are unable to find work in one place may readily emigrate to another where work is available. The sick cannot do so.⁴⁴

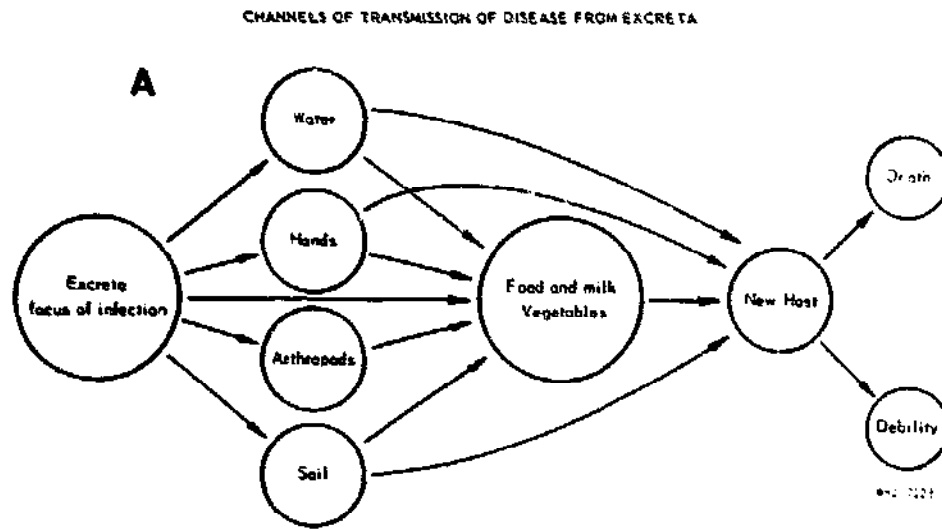
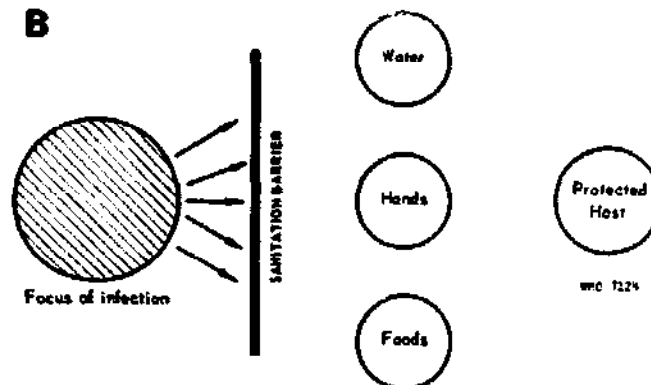
How Disease is carried from Excreta

Man is the reservoir of most of the diseases that destroy or incapacitate him. The faecal-borne infections and infestations already mentioned are the cause of tremendous losses in death and debility. It is interesting to note that all these diseases are controllable through good sanitation, especially through sanitary excreta disposal.

In the transmission of these diseases from the sick, or from carriers of disease, to the healthy, the chain of events, as shown in Fig. 2 A, is similar to that for many other communicable diseases. Anderson & Arnstein¹ state that, in order to transmit disease, the following factors are necessary :

- (1) a causative or etiological agent ;
- (2) a reservoir or source of infection of the causative agent ;

FIG. 2. TRANSMISSION OF DISEASE FROM EXCRETA

STOPPING THE TRANSMISSION OF FAECAL-BORNE DISEASES
BY MEANS OF SANITATION

- (3) a mode of escape from the reservoir ;
- (4) a mode of transmission from the reservoir to the potential new host ;
- (5) a mode of entry into the new host ;
- (6) a susceptible host.

The absence of a single one of these six conditions makes the spread of disease impossible. As may be seen from the diagram in Fig. 2 A, there are many ways in which the causative agent of enteric disease reaches a new host. In different parts of the world, different modes of transmission may assume various degrees of importance : in some areas, water, food, and milk may be most important ; in others, flies and other insects ; and, in still others, direct contact may assume a major role. What is most probable is a combination of all, and the sanitary worker must assume that this

is the case and guard against all modes of transmission. The technical objective of sanitary excreta disposal is therefore to isolate faeces so that the infectious agents in them cannot possibly get to a new host. Fig. 2 B shows the place where the sanitation officer might choose to erect a barrier to break the chain of disease transmission from excreta.

Extent of the Problem

A rapid investigation of sanitary conditions throughout the world would show how vast and important is the problem of excreta disposal. Even in countries such as Great Britain, France, and the USA, which by world standards may be considered prosperous and healthy, much remains to be done in this field. J. A. Scott³² states that in Great Britain, where 20% of the population live in rural communities, 23% of households do not have the exclusive use of a water-closet. In France, of 38 000 local authorities (municipal authorities) only 80 have sewage-treatment plants, and fewer than 1500 have any kind of sewerage system or refuse-disposal organization. In the USA, it was conservatively estimated in 1943 that 4 000 000 sanitary privies were needed in rural areas to serve 16 000 000 people, who lacked these fundamental necessities and who, for the most part, resided in areas having the highest incidence of typhoid fever, dysentery, and hookworm.³⁵

While similar figures are not available for other areas of the world, sanitary surveys and statistical data collected from a large number of countries give useful indications as to the extent of the problem. In India and Pakistan, faecal-borne diseases rank high among the most important communicable diseases. In the decade between 1940 and 1950 the record shows that 27 438 000 persons died in India from the enteric diseases. The incidence of hookworm was between 40% and 70% of the population, and it was estimated that more than 200 million people were infected. In Ceylon, it was estimated in 1943 by the health department that 70% of the population was infested with hookworm. In rural areas of North China, 81% of the population has been found positive for *Ascaris*, and 76% was estimated to be positive for *Entamoeba histolytica* (amoebiasis).³³ A similar situation prevails in British Honduras, in Central America, where the incidence among village schoolchildren was found to be over 60% for *Ascaris* and 50% for hookworm. Similarly, high incidences of enteric and helminthic diseases have been reported for large populations in countries of the Middle East, South-East Asia, the Western Pacific, Africa, and the Americas by J. C. Scott³³ and by Simmons et al.³⁴

In 1951, Dr H. van Zile Hyde²² wrote :

"The dire effect of this upon a rural nation was clearly brought home to me by a statement recently made by an American medical observer who stated that the worms

TABLE II. ESTIMATED COST OF TYPHOID FEVER AND OF DIARRHOEA AND ENTERITIS PER 100 000 POPULATION IN CERTAIN COUNTRIES FOR THE YEAR 1948

Country	Income per caput (US \$)	Typhoid fever		Diarrhoea and enteritis		Total deaths	Total cases	Funeral ex- penses ^a (US \$)	Medical care ^c (US \$)	Value of lives lost ^c (US \$)	Value of working time lost ^c (US \$)	Total cost (US \$)
		deaths ^a	cases	deaths ^b	cases							
USA	1 452	0.1	1	5.7	285	5.8	286	1 130	21 450	17 795	14 635	55 040
France	450	2.0	20	21.4	1 070	23.4	1 090	1 450	25 800	28 500	17 250	73 000
Portugal	140	8.6	86	195.2	9 760	203.8	9 846	3 930	72 300	66 800	48 200	191 230
Japan	98	1.3	13	88.0	4 400	89.3	4 413	1 200	22 650	18 500	15 200	57 750
Colombia	200	12.4	124	128.1	6 405	140.5	6 529	3 875	68 900	76 800	46 200	195 775
Ceylon	83	12.0	120	69.5	3 475	81.5	3 595	930	15 700	22 000	10 500	49 130
Dominican Republic	94	13.5	135	118.2	5 910	131.7	6 045	1 700	29 900	35 350	19 950	86 900
India ^d	54	58.6	234	65.8	3 290	124.4	3 524	925	9 840	40 700	6 600	58 265

^a Typhoid fever mortality rate assumed to be 10%.

^b Diarrhoea and enteritis mortality rate assumed to be 2%.

^c Funeral expenses based on \$200 in USA; ¹⁰ medical care costs based on \$75 per case in USA; ¹⁰ value of lives lost (ages 0-45) from typhoid and paratyphoid fevers estimated at \$15 500 and from diarrhoea and enteritis (ages 0-45) at \$2850 for USA. ¹⁰ Working time lost per case assumed to be two weeks, with a value of \$50 in USA. The estimated unit cost of funerals and medical care and the value of lives and working time lost for countries other than the USA were assumed to be in the same ratio to similar costs and values in the USA as the *per caput* income for those countries to that for the USA.

^d Mortality rates for typhoid fever and for diarrhoea and enteritis are not available for India. The rates and values listed are those for cholera and for diarrhoea and dysentery.

TABLE III. ESTIMATED PER CAPUT COST OF RURAL WATER SUPPLIES AND LATRINES AND COST OF TYPHOID FEVER AND OF DIARRHOEA AND ENTERITIS PER 100 000 POPULATION FOR CERTAIN COUNTRIES IN 1949

Country	Cost per caput of water supplies (US \$) ^a		Cost per caput at latrines (US \$) ^a		Total cost per 100 000 population (US \$)	Cost of typhoid fever and of diarrhoea and enteritis per 100 000 population (US \$)	Approximate number of years required for amortization of water supply and sanitation facilities from savings
	capital cost	main-tenance	capital cost	main-tenance			
USA	17.00	0.55	14.00	5.75	3 730 000	55 720	68
France	5.25	0.17	4.35	1.80	1 157 000	73 000	16
Portugal	1.65	0.05	1.35	0.55	360 000	191 230	2
Japan	1.15	0.04	0.95	0.40	254 000	57 750	5
Colombia	2.35	0.08	1.95	0.80	518 000	195 775	3
Ceylon	0.98	0.03	0.80	0.33	214 000	49 130	4
Dominican Republic	1.10	0.04	0.94	0.38	246 000	86 900	3
India ²⁴	0.63	0.02	0.52	0.21	138 000	53 265	3

^a This includes the cost of labour, materials, and equipment. These costs could be reduced considerably by the use of voluntary labour and materials available locally to the householder.

infesting the people of a certain semi-tropical country metabolize more of the produce of that country than do the inhabitants. Half the work of a sick peasantry, therefore, goes into the cultivation of food for the worms that make them sick."

It should be noted that, in many countries, more than 80% of the population live in rural areas and small communities and, as a general rule, have a low income. In most cases, all the elements of rural sanitation are absent, and indiscriminate fouling of the soil with human excrement is common. Such conditions are also often found in rural areas near towns, and aggravate the urban sanitation problems. The menace of inadequate excreta disposal is present so long as sanitary privies are lacking in a community.

The economic losses resulting from insanitation often reach staggering proportions. Atkins,^a analysing data available for several countries in 1949, found that infant mortality and mortality from typhoid fever, diarrhoea, and enteritis were in inverse proportion to the income *per caput*. He estimated the cost of these three diseases (see Table II) and the *per caput* cost of rural water-supplies and latrines (see Table III). He concluded that in each of the countries considered, except the USA and France, it would be possible to amortize within a period of five years

^a Atkins, C. H. (1953) *Some economic aspects of sanitation programmes in rural areas and small communities* (Unpublished working document WHO/Env.San./56)

the cost of rural sanitation facilities from the savings which would accrue from the reductions in typhoid fever, diarrhoea, and enteritis. Other advantages would result from the control and reduction in incidence of cholera, the dysenteries, ascariasis, guinea-worm, hookworm, and other enteric and parasitic diseases. In addition, there would be several indirect benefits, such as the convenience and saving of time which the facilities would offer.

Collateral Benefits of Proper Excreta Disposal

Certain public health programmes, when properly carried out, often yield important side benefits quite apart from those which they were expected to produce. Programmes of excreta disposal belong to this group. An example of this was given by Tisdale & Atkins³⁵ in 1943:

"The sanitary privy has a definite relationship to public health and in this connection the following points are significant:

"1. In areas [of the USA] where water carriage sewerage systems are impracticable the privy is the facility relied upon to break the transmission chain of intestinal diseases.

"2. Privy construction programs, originally undertaken in the hookworm and typhoid fever regions in the South thirty years ago, contributed substantially to the early development of full-time local health services. At present more than 1,800 counties in the United States have such services.

"3. The 3,000,000 sanitary privies constructed under the various work-relief programs have had an important effect in reducing the incidence of intestinal diseases.

"4. The close association of U.S. Public Health Service officials with state health departments in rural sanitation campaigns over a period of 30 years has been instrumental in developing the *esprit de corps* which now enables local, state, and federal health services to cope successfully with problems of sanitation, malaria, venereal disease, and industrial hygiene in critical war areas in America today.

"5. The fundamental principles of federal-state cooperation, successfully demonstrated in the rural sanitation programs, are now being applied throughout the field of public health. In addition, cooperative plans for public health work among selected population groups have been developed by the Public Health Service with other federal agencies. The Farm Security Administration's health and sanitation program is an example of federal cooperative health work."

Similar examples may be drawn from the experiences of Scott³⁸ in China and the World Health Organization in Taiwan, where attempts at solving the excreta disposal problem have been found to be linked with the development of satisfactory composting procedures. In these countries, as well as in Latin America, programmes of excreta disposal have led to the recognition of the need for team-work between the medical officer, the public health engineer, and the public health inspector.

SOCIAL AND PSYCHOLOGICAL IMPLICATIONS OF RURAL SANITATION PROGRAMMES

Community Participation

Experience available from all parts of the world leads to the conclusion that a programme of rural sanitation, of which sanitary excreta disposal is an essential part, cannot be successful without the participation of the local community. To be truly effective, environmental sanitation, which is a basic function of every integrated health service, needs the understanding, the support, and the active participation of the people concerned. Mere technical improvement of the environment without public education in hygiene and sanitation, based on local customs, traditions, and beliefs, has again and again proved futile.

One measure of the success of a rural sanitation programme is its power to sustain itself and grow. In order to achieve this success, it is necessary to find ways of gaining popular support and of overcoming popular objection. In both, health education of the public plays a major role. In the former instance, attention must be given to the structure and organization of a programme which will fit into the local social and economic system. More important still is the desirability of bringing the people into the programme as partners. In the pursuit of the second objective, the assistance of a competent health educator may be required. It is very likely that, even before reaching the stage of overcoming popular objection, the sanitarian may have to undertake the task of disturbing the age-old apathy and inertia which grip the people. For example, the fact that a community is without adequate excreta disposal facilities immediately suggests to a health worker the need for providing latrines. However, the community may not be ready for, or interested in, such facilities, or may be even hostile to them. To insist upon the immediate introduction of latrines into a community under such circumstances is not a wise move on the part of the sanitarian, who should always remember that "doing things to people and for people is easier, though in the long run more costly, and less effective, than fostering greater individual and local initiative, responsibility, and self-reliance on a well-informed basis".^a

This health education stage is admittedly the most difficult in the evolution of a privy scheme. Once it is successfully passed, the programme will move at a faster rate. For example, in the rural areas of several Latin American countries where community health programmes have been

^a Martikainen, A. H. (1956) *Co-operation for future progress in health education of the public*. In: *Report of the Third Conference of the International Union of Health Education of the Public*, Rome, vol. 1. (This paper also exists as a WHO unpublished document: WHO/MH/AS 124.56.)

going on for some time, privies are constructed almost exclusively by the families, with the health department supplying the necessary guidance and the concrete privy slab either at cost or gratis. In many places the demand for slabs is always greater than the supply.

Experience shows that the most important factor in getting the community to participate is to bring members from all its segments into the programme as partners. The people must, however, understand what the programme is all about. This may be achieved by working through the village council, if one exists, and if not, through a village committee set up at the planning stage and comprising prominent and respected leaders of the community. Further progress will come from the assimilation and use of scientific excreta disposal principles by the villagers themselves, and this can be realized only if they take part in the survey, planning, and conduct of the programme. One should expect that initial progress will be rather slow and that it may be necessary to plan the programme in successive stages stretched over a period of time.

The relation of health education of the public to the important subject of community participation in rural sanitation programmes has been studied by various authors, in particular by Foster,¹⁴ Derryberry,^{8, 9} and Ramakrishna.⁶

In recent years the expression "community development" has come into popular international usage to connote a complex of processes of which the two most important elements are the following:

"The participation by the people themselves in efforts to improve their level of living with as much reliance as possible on their own initiative; and the provision of technical and other services in ways which encourage initiative, self-help and mutual help and make these more effective."³⁵

As stressed earlier, the practical application of these principles is essential for lasting progress in rural sanitation. In addition, field experience shows that a specific local project or activity in sanitation initiated in response to a local demand can serve as a very practical basis for stimulating local interest and participation in attacking other basic problems, and thus act as an important spearhead for the promotion of community development.

Family Participation

Since one of the ultimate objectives of a sanitation programme in a community is to get the family to solve its own excreta disposal problems (within reason, of course), it is important that each family unit participate

⁶ Ramakrishna, V. (1956) *Role of health education in environmental sanitation programmes* (Unpublished paper prepared for the WHO Seminar on Environmental Sanitation, Beirut, Oct.-Nov. 1956)

in some way in its execution. Whatever the nature of the sanitation needs and related health problems, health workers can gain the interest of people by a sympathetic and practical approach to their problems. People who come to a health centre or dispensary (mobile or stationary) seeking treatment of intestinal disorders are usually receptive to suggestions as to how to avoid dysentery and diarrhoea. Full advantage should be taken of such opportunities to help make the people aware of the measures which can be applied at home and in the community to prevent these conditions. Practical demonstrations and discussions of latrine construction, aided by the use of visual media based on local situations—e.g., photographs, slides, posters, film strips, film exhibits, and others—may be particularly rewarding.

Once the family is willing to participate in the scheme and to learn a new habit, the public health inspector must be ready to offer a solution which is acceptable and as simple and economical as possible. When sanitation and personal hygiene become habits, the health programme will have made tremendous progress.

The sanitation work cannot be considered completed, however, after the construction of the first privy or latrine; in fact, it has just begun. The public health inspectors or public health nurses, as the case may be, must remain continuously in touch with the family to stimulate and educate its members into using and maintaining this facility, which often has been constructed after hard and time-consuming labour. The continued educational process involved requires the co-operation of the whole health department staff, which can consider that success has been achieved only when the family has accepted the privy as a part of its way of life, and is willing to maintain it, to rebuild it, and to move it to a new location, as necessity demands, and even to become a disciple in teaching the neighbours. It will be noted that time and continuity of staff and organization are essential for successful rural sanitation development.

Mention has been made of simple and economical solutions to the family's excreta disposal problems. Finding reasonable solutions is considered to be one of the keys to active family participation. These are not always easy to find. Undoubtedly there are places where nature, aided perhaps by man, makes it very difficult, if not impossible, to devise simple and economical facilities. In these situations, the sanitarian's ingenuity and ability are taxed to the limit. He must be resourceful in making use of available materials and in organizing the people of the community for the difficult tasks at hand. In some instances extra technical and financial assistance may be required from the health department. The family cannot be expected to perform difficult and complicated construction operations. Sanitarians and public health officers should strive to propose and design solutions that are within the means and ability of the people to operate, maintain, and replace. This is true of a simple

family privy, a village well, a public water-supply system, or large water-and sewage-treatment works.

As to actual modes of obtaining family participation, several systems have been tried in different countries with varying degrees of success. The best methods are those in which initial work and expenses are shared by the family and the health authorities or other agencies. Family contribution either may be financial in character or may take the form of labour and materials. Although financial contribution by the villagers, or by the local authorities, is highly desirable, it will be found advantageous in the early stages of a programme to secure the actual participation of the people in the work, which is being executed for their own benefit. People are more likely to put into daily practice those learning experiences in which self-initiative and self-help have played a part. The psychological advantages of self-help are considerable, even if the extent of the self-help is limited to the provision of manpower and locally available material.

In an effort to give proper importance to the construction of privies, use has been made in Latin America, with remarkable success, of simple contracts between the health department and the head of the family. The contracts state in simple, direct terms the obligations of each party, so that no misunderstanding can arise. This impresses on the family the importance which both parties attach to the privy as a vital element in household health. The application of this technique depends on a patient and enthusiastic health department representative, for it takes time to talk to each family and explain over and over the need for a sanitary privy and the benefits which can be derived from its daily use.

Another technique used with success in some countries in South-East Asia consists of "selling" the programme to respected leaders of the community and helping them, first, to install their latrines. The possession of a sanitary latrine thus becomes associated with a position of prestige in the community.

Role of the Health Department and Other Agencies

It is accepted as axiomatic in environmental sanitation that governments should take the initiative both in stimulating action and in providing the essential technical guidance.⁴⁴ For excreta disposal programmes the primary responsibility and authority for surveying, planning, organizing, and implementing wide-scale measures obviously rest with the health department. To do this job with any chance of success, however, the health department must secure the understanding, the support, and the participation of the villagers, as previously mentioned. It is also the responsibility of the health department to seek the co-operation of various interested government or private agencies, such as agriculture, education,

and public works departments, or large plantation estates, and to co-ordinate their activities in this field in order to ensure proper integration of their activities into the general health and community development programme planned for the area concerned.

When excreta disposal programmes are contemplated for the first time in a community, the health department should be prepared to spend more than the mere cost of required staff. The sum to be spent need not be large but will make it possible for the department to win the co-operation of individual families for the construction of the initial facilities. Experience shows that, if the health department does not enter into the programme with adequate funds, it may take many years to get to a point of complete community participation. On the other hand, by giving the sanitation work a good start in the form of partial financial assistance, the time can be greatly reduced. The funds spent in this manner will pay great dividends in the future. With money to buy materials, especially the types of materials unavailable locally, the public health inspector is in a position to offer something concrete, beside technical advice, to the family. He may then say: "If you will provide the labour for your privy, I will provide materials." Or he may offer part of the labour and part of the materials.

The health department is also responsible for organizing demonstration or pilot schemes of excreta disposal. Such demonstrations should be carried out first in health and welfare centres, in schools, and in residences of local health and sanitation officials. A demonstration plot of land suitably located and provided with sanitary excreta disposal units in various stages of completion is a desirable item in a planned sanitation improvement and training programme. The health department should also prepare and make available to the people and their leaders leaflets and manuals covering the design, construction, and operation of excreta disposal facilities that fit the conditions encountered in the areas concerned.

"Wherever bad construction, poor ventilation and lighting, lack of washing facilities, insanitary toilets, or similar deficiencies exist [in schools], children will be absorbing wrong ideas and learning harmful habits which may never be eradicated . . . Similarly, a well-built and well-kept latrine may be far safer as well as of greater fundamental education value than a porcelain and tile toilet which is allowed to become dirty and a nuisance." ⁴⁵

Mere classroom teaching of sanitation, unaccompanied by actual demonstration, will have little—if any—effect on children; but this is, unfortunately, common in many parts of the world. It is well known that children learn by doing and through example, two facts which can be used to advantage in leading schoolchildren into the practice of a sanitary way of living. It goes without saying that health workers should lead the way and give the proper example to the people by living and working in sanitary surroundings.

Under certain circumstances which require the use of community-controlled latrine construction services, the role of the health department may assume increased scope and importance. Such situations would arise, for example, in areas where crowding of houses or hard ground conditions make it necessary to put in some kind of collective sanitation facility, deep-bored holes inside houses, precast hand-flush installations in houses, or other types of excreta disposal systems which, because of physical circumstances, cannot be erected by the families themselves. In these cases a government, through its health department, may need to set up and maintain an efficient organization to carry out excreta disposal construction work. Here also the active participation and contribution of the local populations in the form of labour, materials, and money are absolutely required for the ultimate success of the excreta disposal programme. The people should never be led to rely entirely on the health department for the provision, maintenance, or renewal of their sanitary facilities, even when these must be built for them for special reasons, as explained above. An alternative solution which may sometimes be used involves the formation of construction co-operatives or health leagues by the people themselves under the sponsorship of the health department, which may supply financial and material assistance in addition to providing technical guidance.

Campaigns

In order to achieve efficiency and rapidity of execution, it is often tempting to carry out latrine construction work on the basis of campaigns. This method has a definite place in health programmes, and experience has shown that it can be successful under certain conditions. Campaigns will prove useful, however, only when there is good follow-up and continued health education and sanitary inspection. Under these conditions, the health department still has an opportunity to convince the families of the worth of the latrine and to persuade them to maintain it and replace it when the need arises.

In areas where there is a lack of organized community services in addition to a low economic level, there will be no follow-up inspection or health education, and the programme is likely to be a complete failure. It is uneconomical to spend money on latrine campaigns under such conditions, for rarely do the people use the privies in sufficient numbers, and even more rarely do they maintain or replace them. It has been reported, for example, that even where public acceptance of privy campaigns in areas of Latin America has been good, the privies have frequently been used as chicken-coops or grain silos. Experience after experience can be recounted in which a great deal of money and effort was expended only to have the situation return to its original unhygienic status after a rela-

tively short time because of the lack of continued health education and inspection by a well-organized and integrated sanitation service of a health organization.

One important aspect of latrine campaigns is the community interest and attention that are focused on the excreta disposal problem. Parallel situations exist in connexion with other health campaigns, such as malaria control and yaws campaigns. If advantage can be taken of this interest and if an adequate and permanent follow-up organization can be set up, the campaign technique can be a very successful method of getting latrines built and used. Under most conditions, however, the education and family participation method, although slow, is best.

Public Versus Individual Latrines

Public latrines, or "multiple units" types, are usually constructed in markets, camps, schools, factories, slum districts, and similar localities. They are also useful in other places where large numbers of persons congregate occasionally, provided that permanent and close attention is available to ensure cleanliness and proper operation.

Experience in all parts of the world indicates that, except in unusual circumstances, multiple units should never be substituted for the individual family latrine. True, it is cheaper and less troublesome to construct a few communal latrines in a community than to build a large number of individual latrines at the rate of one unit per family. In addition, a good solution to each family's excreta disposal problem is not always easy to find. For such reasons the construction of the communal type of excreta disposal facility was accepted in the past, even in urban communities. However, it was discovered after a few years' use that these public latrines were employed by only a portion of the population for which they were intended, the remaining group continuing the original practice of defaecating anywhere. It was then believed that two reasons for this situation were inadequate design and the lack of cleanliness. Attempts were made to improve these elements; but, in most instances, communal latrines, irrespective of the type of design, proved to be failures.

It should be pointed out that the community is generally made responsible for the maintenance of public units. Usually communal administrations are notoriously poor and ineffective at maintaining even the utilities that offer great convenience, such as water works and electric light systems, let alone a communal privy which many do not consider essential in any case. This does not mean that the construction of public latrines should be disregarded; but one should be warned against their limitations and the illusion that they will be automatically and efficiently maintained by the community. The truth is that the communal authorities

must be prodded on this important matter of maintenance as much as, or more than, the family. So long as the effort to ensure good maintenance must be made, it is decidedly better to spend it on the family, on whom there is hope of its eventually having the desired effect. Families will usually keep their own latrines clean and in proper operation with only occasional guidance from the public health inspector.

Public latrines, therefore, should be built only where absolutely necessary and should be designed to facilitate maintenance and constructed for permanence, as far as possible. They must be kept clean at all times, for, unless cleanliness is observed, they will not be used. Water and other materials must be available for use in keeping the latrines clean.

Since the objective of this monograph is the promotion of rural excreta disposal by the individual family, no attempt will be made to describe types of public latrines or urinals which are usually associated with them.

THE PRIVY METHOD OF EXCRETA DISPOSAL

FACTORS INFLUENCING PRIVY DESIGN

A rational approach to the problem of collecting and disposing of human excreta in rural areas assumes that the engineering aspects, while not as extensive as those associated with urban engineering schemes, still require the same careful marshalling of facts and application of painstaking analyses for their solution. There are several factors which influence the choice and the design of a system applicable to a particular community. Some are biological in character; others are of an engineering nature; and still others, which are of no less importance, involve careful consideration of human behaviour.

Decomposition of Excreta

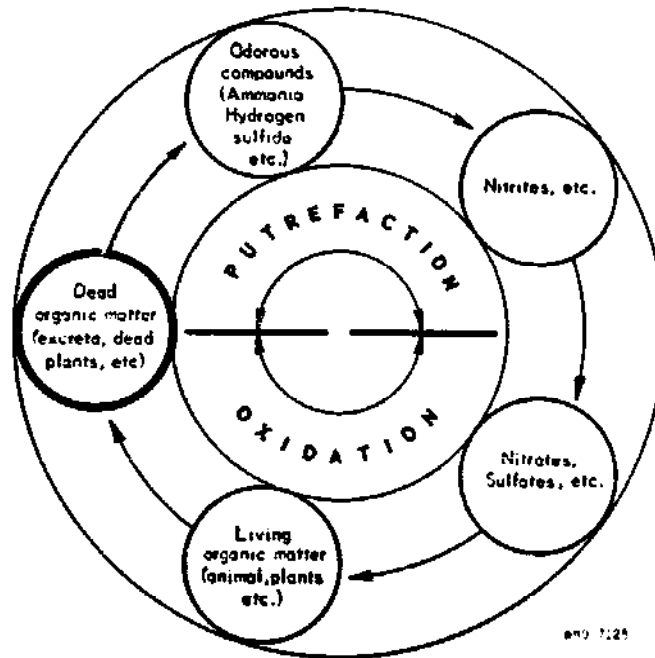
Excreta, wherever deposited, immediately start to decompose, and are ultimately converted to an inodorous, inoffensive, and stable product. In the design of excreta disposal facilities it is important for the health worker to know and understand how this process takes place and how it affects the material itself and the harmful organisms such material may contain. The sanitarian, in particular, is often called upon to explain in simple terms what actually happens to faeces and the health hazards involved in inadequate disposal systems.

The main actions of decomposition are to break down the complex organic compounds, such as proteins and urea, into simpler and more stable forms; to reduce the volume and mass (sometimes as much as 80%) of the decomposing material by the production of such gases as methane, carbon dioxide, ammonia, and nitrogen, which are dissipated into the atmosphere, and by the production of soluble materials which, under some circumstances, leach away into the underlying soil; and to destroy pathogenic organisms which in some instances are unable to survive the processes of decomposition or attack by the rich biological life of the decomposing mass.

Bacteria play the major role in decomposition; and bacterial action may either be aerobic—i.e., carried out in the presence of air—or anaerobic

—i.e., carried out in the absence of oxygen, generally in a fluid or saturated environment. The process may be entirely anaerobic, as it is in aqua privies, septic tanks, or at the bottom of deep pits, or entirely aerobic, as it is in certain composting operations. On the other hand, decomposition may consist of more than one stage, some anaerobic and some aerobic, depending upon the physical conditions encountered. For example, anaerobic processes may take place in a septic tank; but, as the liquid effluent is discharged into an underground tile distribution system, the water drains away, leaving much organic matter in the upper layers of the soil to be decomposed by aerobic saprophytic bacteria, which thrive in the top 60 cm of the soil.

FIG. 3. CYCLE OF NITROGEN



The process of decomposition applies to all dead organic matter of vegetable or animal origin, and particularly to their nitrogenous, sulfurous, or carbonaceous constituents. In the case of human wastes, a mixture of faeces and urine, which are relatively rich in nitrogenous compounds, the decomposition process is typically represented by the nitrogen cycle, which is shown in Fig. 3. In this cycle compounds are broken down first into ammonia and other simple products, and are then converted by nitrifying bacteria into nitrites and nitrates. The strong smell noted during the decomposition of urine is due to ammonia, which escapes before it has been converted into a more stable form. Decomposition may proceed very rapidly, the period varying from a few days in the case

of very carefully controlled mechanical composting to several months, perhaps up to nearly a year, under average conditions in a pit privy.

Conditions prevailing in decomposing faeces are generally unfavourable to the survival of pathogenic organisms. Not only do the temperature and moisture conditions inhibit the growth of pathogens, but also the competing bacterial flora and protozoa are predatory and destructive. Pathogens tend to die quickly when the humus-like end product of decomposition is spread out and dries. The bacterial pathogens probably do not survive more than two months in undisturbed privy contents. The ova of hookworm will remain viable for much longer periods, depending on moisture and air temperature: they may live up to five months in cool climates, much less long under tropical conditions. They will eventually hatch in the presence of air, and will produce larvae which may survive for several weeks in moist, sandy soils. *Ascaris* ova may live for two or three months in pit-privy material.

The final products of decomposition contain valuable soil nutrients and may profitably be used as fertilizers. Sometimes farmers complain of the small nitrogenous content of digested or composted night-soil. Indeed fresh excreta do contain more nitrogenous matter which, however, cannot be used by plants in their original composition. Plants can utilize nitrogen only as ammonia or as nitrites or nitrates, which are only produced during later stages of decomposition. When raw excreta are spread on the land, much of the nitrogen is transformed into volatile matter, which evaporates into the air instead of being used by plants.

Quantities of Human Faeces

The public health engineer or inspector is interested in the amount of the raw material which must be processed. Most studies on quantities of human waste have been made chiefly on a physiological basis and have given some information on the ranges and mean values of the quantities of excreta produced by individuals. A small amount of information based on actual field observations is also available but is of varying reliability. It is recognized that the quantities of human excreta produced may be influenced by local conditions, not only physiological, but also cultural and religious. An example may be the use of ablution water or other personal cleansing materials.

A review of published data shows that in Asia the amount of faeces is about 200-400 g (7-14 oz.) per person per day (wet weight), as compared to 100-150 g (3.5-5.3 oz.) per day for European and American countries. In North America a figure for pit-privy design is based on 1.5 cu. ft (42.4 l) per person per year where urine may leach away, and a figure of 19.5 cu. ft (552 l) per person per year for water-tight containers such as the vault

privy. In India, according to the *Manual of hygiene for the armed forces, 1953*,²⁵ the amount per person per day is 400 g (14 oz.) for faeces and 2300 g (81 oz.) for urine and cleansing water. According to O. J. S. Macdonald,¹⁹ in the tropics faeces will range from 280 g to 530 g (10-19 oz.) per person per day, and urine, depending upon temperature and humidity, from 600 g to 1130 g (1.3-2.5 lb.).

H. B. Gotaas,¹⁸ in a worldwide summary, gives the following data collected from various sources :

	Grams/person/day	
	wet weight	dry weight
Faeces	135-270	35-70
Urine	1000-1300	50-70
Total	1135-1570	85-140

A study in the Philippines indicated an average production of 665 g (1.5 lb.) of total excreta per person per day. It was noted that probably only a fraction of the urine was included in this figure.

It has been recommended that controlled observations be made in each country or portion of a country where there is reason to believe that deviation from the established norm may occur. These observations should be of such duration as to allow the measurement of possible seasonal variations, should include an adequate sample, and should be carried on under the direction of a responsible officer.

The available data being admittedly meagre, it has been suggested for design purposes that for total excreta the figure of 1 kg (2.2 lb.) (wet weight) per person per day should be used.

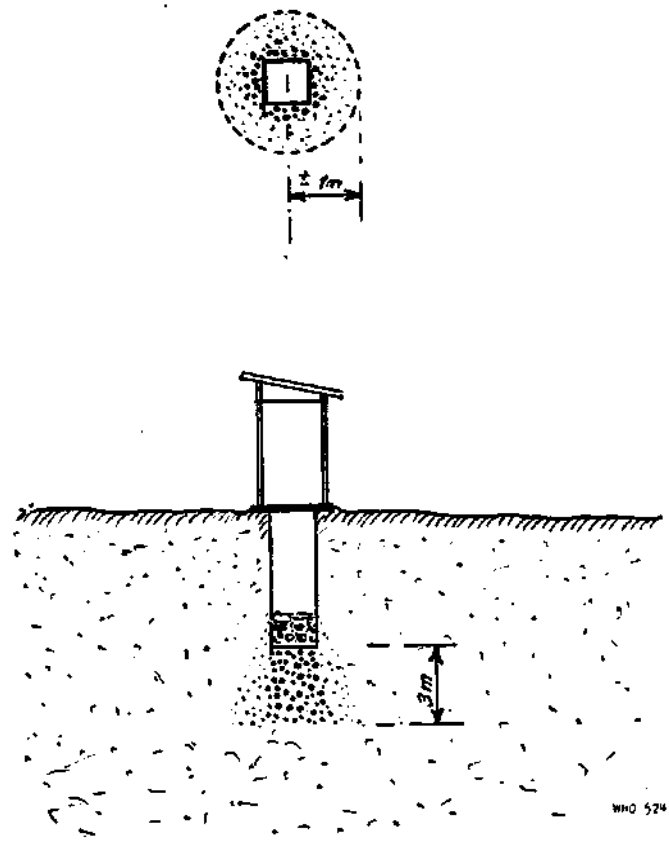
Soil and Ground-Water Pollution

The study of methods of pollution of the soil and water by excreta also provides useful information concerning the design of disposal facilities, especially their location with respect to sources of drinking-water supplies. After excreta are deposited on the ground or in pits, the bacteria, unable to move much by themselves, may be transported horizontally and downward into the ground by leaching liquids or urine, or by rain water. The distance of travel of bacteria in this way varies with several factors, the most important of which is the porosity of the soil (see Fig. 4, 5, 6). Their horizontal travel through soil in this manner is usually less than 90 cm (3 ft) and the downward travel less than 3 m (10 ft) in pits open to heavy rains, and not more than 60 cm (2 ft) normally in porous soils.²⁷

Gotaas and his co-workers,⁶ studying the artificial recharge of aquifers with reclaimed sewage and other waste waters in the State of California,

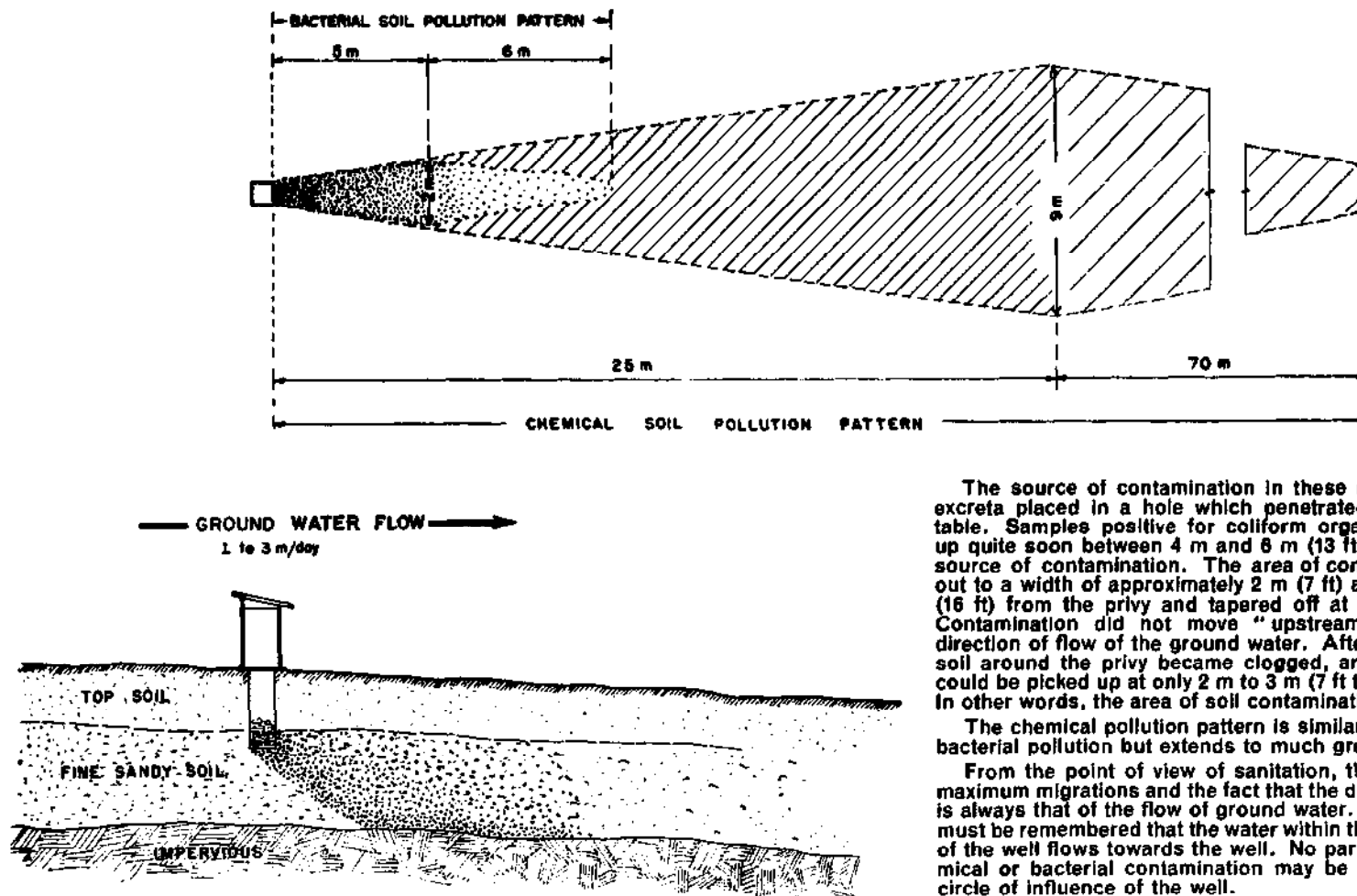
USA, found that bacteria were transported to a distance of up to 30 m (100 ft) from the recharge well in 33 hours, and that there was a rapid regression of bacterial count over this distance due to effective filtration and to bacterial die-off. They also found that chemical pollution travelled twice as fast. Recently, other workers,¹⁵ studying ground-water pollution in Alaska, noted that bacteria were traced to a distance of 15 m (50 ft) from the dosing well into which test bacteria were introduced. The width of the path of bacterial travel varied between 45 cm and 120 cm (1.5 ft and 4 ft). Regression then took place and, after a year, only the dosing well remained positive for the test organism. These investigations confirm the findings of other workers²⁷ to the effect that the contamination from excreta disposal systems tends to travel downward until it reaches the water table, then moves along with the ground-water flow across a path which increases in width to a limited extent before gradual disappearance.

FIG. 4. MOVEMENT OF POLLUTION IN DRY SOIL



In dry soil there is relatively little migration of chemical and bacterial substances. Laterally there is practically no movement; and with excessive washing (not common in privies or septic tanks) the vertical penetration is only about 3 m (10 ft). Where the contamination does not enter the ground water, there is practically no danger of contaminating water supplies.

FIG. 5. BACTERIAL AND CHEMICAL SOIL POLLUTION PATTERNS AND MAXIMUM MIGRATIONS*

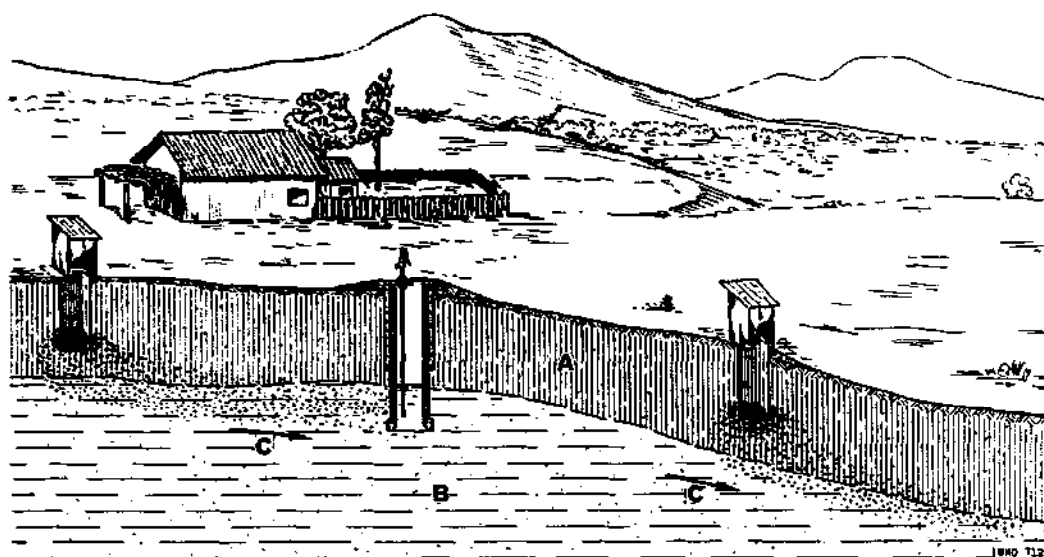
* Based on data from Caldwell & Parr^{4, 5} and Dyer, Bhaskaran & Sekar.^{10, 11}

The source of contamination in these studies was human excreta placed in a hole which penetrated the ground-water table. Samples positive for coliform organisms were picked up quite soon between 4 m and 6 m (13 ft and 19 ft) from the source of contamination. The area of contamination widened out to a width of approximately 2 m (7 ft) at a point about 5 m (16 ft) from the privy and tapered off at about 11 m (36 ft). Contamination did not move "upstream" or against the direction of flow of the ground water. After a few months the soil around the privy became clogged, and positive samples could be picked up at only 2 m to 3 m (7 ft to 10 ft) from the pit. In other words, the area of soil contamination had shrunk.

The chemical pollution pattern is similar in shape to that of bacterial pollution but extends to much greater distances.

From the point of view of sanitation, the interest is in the maximum migrations and the fact that the direction of migration is always that of the flow of ground water. In locating wells, it must be remembered that the water within the circle of influence of the well flows towards the well. No part of the area of chemical or bacterial contamination may be within reach of the circle of influence of the well.

FIG. 6. MOVEMENT OF POLLUTION IN UNDERGROUND WATER



A = Top soil

B = Water-bearing formation

C = Direction of ground-water flow

In the Netherlands, Baars² found that, unless accompanied by a considerable amount of water, bacterial contamination did not travel more than 7.5 m (25 ft) through fine sand.

On the surface of the ground, only the earth immediately surrounding the faeces is likely to be contaminated, unless it is carried further by surface water such as rain and irrigation water, blown away by the wind, or picked up by the hair and feet of flies or other insects and animals. It has been observed in pit latrines, however, that hookworm larvae, although unable to move sideways to any appreciable extent, are likely to climb upwards along the pit walls and reach the top surface of defective wooden or earthen floors, where they lie in wait for a person with bare feet.

Depending upon conditions of humidity and temperature, pathogenic bacteria and ova of parasitic worms will survive varying lengths of time in the ground. Pathogenic bacteria do not usually find in the soil a suitable environment for their multiplication, and will die within a few days. On the other hand, hookworm eggs will survive as many as five months in wet, sandy soil, and three months in sewage. Hookworm disease is transmitted through contact of the skin, usually bare feet, with soil containing hookworm larvae. Other parasitic diseases are also transmitted when fresh faeces or sewage is used, during the growing season, to fertilize vegetable crops which are eaten raw.

If ground water is located near a source of infection within the distances mentioned above, it may become contaminated by harmful bacteria and by putrid chemical substances originating in faecal decomposition. A

source of infection may be some excreta deposited on the ground near by, a pit latrine, a cesspool, or a leaky sewer or sewage disposal pipe. The contaminated ground-water, which is usually shallow, may be tapped by a well used for drinking-water and other domestic purposes and may lead to further human infection and diseases such as diarrhoeas, typhoid and parathyphoid fevers, cholera, and the dysenteries.

The effects of proximity of wells to latrines and the travel of faecal pollution through ground water have been investigated by various scientists. The studies of Caldwell & Parr^{4, 5} and of Dyer, Bhaskaran & Sekar^{10, 11} are classics which should be studied by all interested public health workers.

Location of Latrines and Other Excreta Disposal Facilities

Regarding the location of latrines with respect to sources of water supply, the following conclusions may be drawn from up-to-date information.

1. There can be no arbitrary rule governing the distance that is necessary for safety between a privy and a source of water supply. Many factors, such as slope and level of ground water and soil-permeability, affect the removal of bacteria in ground water. It is of the greatest importance to locate the privy or cesspool downhill, or at least on some level piece of land, and to avoid, if possible, placing it directly uphill from a well. Where uphill locations cannot be avoided, a distance of 15 m (50 ft) will prevent bacterial pollution of the well. Setting the privy off to either the right or the left would considerably lessen the possibility of contaminating the ground water reaching the well. In sandy soil a privy may be located as close as 7.5 m (25 ft) from a properly constructed household well if it is impossible to place it at a greater distance. In the case of a higher-yielding well, not less than 15 m (50 ft) should separate the well from a latrine.

2. In homogeneous soils the chance of ground-water pollution is virtually nil if the bottom of a latrine is more than 1.5 m (5 ft) above the ground-water table. The same may be said if the bottom of a cesspool is more than 3 m (10 ft) above the level of the ground water.

3. A careful investigation should be made before building pit privies, bored-hole latrines, cesspools, and seepage pits in areas containing fissured rocks or limestone formations, since pollution may be carried directly through solution channels and without natural filtration to distant wells or other sources of drinking-water supplies.

Regarding the location of latrines with respect to dwellings, experience shows that the distance between the two is an important consideration in the acceptability of the sanitary facilities. The location of latrines,

private or communal, at a considerable distance or away and uphill from dwellings has been observed to mitigate against their regular use and proper maintenance. A latrine will more likely be kept clean if it is close to the house or other building which it serves. Fig. 7 gives an example of proper location of latrines with respect to wells and dwellings.

FIG. 7. WELL AND PRIVY LOCATION IN A RURAL COMMUNITY



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Other considerations are as follows :

1. The site should be dry, well drained, and above flood level.
2. The immediate surroundings of the latrine—i.e., an area 2 m (6.5 ft) wide around the structure—should be cleared of all vegetation, wastes, and other debris. This recommendation may be ignored, however, in the initial stages of sanitary development of rural areas where it is necessary, for example, in order to secure acceptability of the latrine by the local population, to avoid disturbing the natural bush-type surroundings which were previously used for defaecation.

Fly Breeding in Excreta

The role of flies in the transmission of faecal-borne diseases has already been mentioned. The common housefly lays its eggs preferably in horse and stable manure, but will also do so in exposed human excrement and any other decaying organic matter. It crawls and feeds on this material, picking up filth and live organisms on its hairy body, as well as bacteria which pass unharmed through its alimentary tract and are often deposited later on human food. Besides the housefly, various other flies (bluebottle fly, greenbottle fly) may also breed in human excrement and decaying matter. In temperate climates, excreta-borne diseases are usually more

prevalent during the warmer months when flies are most numerous and most active.

In designing a latrine, attention must be paid to means of preventing fly breeding. In so doing advantage may be taken of the fact that flies have a positive phototropism and, therefore, are attracted by light and shun darkness and dark surfaces. The best latrine is one in which the excreta are promptly flushed away into a closed pit or tank underground. Other types of latrine would also be effective in this respect if all openings leading to the excreta, including the seat, were kept clean and closed when not in actual use. This is not usually the case.

Attempts have been made to attract and trap flies which have hatched in latrine pits. These attempts have apparently not been successful, as the mechanisms involved (inverted glass bottle, perforated cans, or others) do not seem to last or stay in place very long.

Disinfectants are of little use in pit latrines because they are quickly neutralized by the organic matter. They also have the disadvantage of interfering with bacterial decomposition and reduction of excreta.

Certain inorganic chemicals may be added to latrines as larvicides to control fly breeding—namely, sodium fluosilicate, sodium arsenite, or borax (sodium tetraborate). A 2.5-cm (1-in.) surface layer of 10% borax in each latrine has proved highly effective in India.

Among the organic chemicals, either PDB (paradichlorobenzene) or ODB (orthodichlorobenzene) has proved an effective larvicide and ovide; the latter is used in home latrines in Japan. The use of aldrin, dieldrin, chlordane, BHC, or DDT in faecal matter leads rapidly to the development of resistance to these chlorinated hydrocarbon insecticides by the larval and adult houseflies. Spraying of inside walls of latrine superstructures with aldrin and dieldrin has been found to increase housefly production by as much as fifty times.²⁶

Hole Covers

The subject of a cover for a hole or seat is an interesting but controversial point in the design of latrines. There is no doubt that a cover is desirable, and in some places necessary, to prevent ingress of flies and other vermin and, also, to reduce odours. However, in all the literature on public health subjects, and on excreta disposal in particular, no case has been reported where covers have been successfully used and kept in place over a period of months or years. Even in countries, such as the USA, where people in general are highly conscious of sanitation, the problem of seat covers has not been solved.

Self-closing covers have not been successful because the condensation which takes place on the under-side of a closed seat is objectionable to the users. Covers that are hinged to the slab or riser are usually left in the

open position. Covers not hinged to the slab are seldom replaced on the hole and are soon carried away by children. Hinges of even the most rugged design soon become broken. More complicated types of cover have been tried, the principle being that the door of the privy will not open to let the user out if the cover is not closed. This type has failed because it is too complicated for the people and discourages them from using the privy, or they soon learn to get rid of the cover in some way.

In view of the above, the drawings in this document do not include seat or hole covers, except for Fig. 8, which shows a simple type of cover. This problem is left to each health department to weigh and try to solve in the light of the local situation. In the Amazon Valley of Brazil some 20 000 installations have been constructed ; and, because the fly population is not too great, no attempt has been made to put hole covers on the squat type of privy slabs. But where there are many flies, some attempt should be made to cover the holes and prevent the flies entering and breeding in the pits.

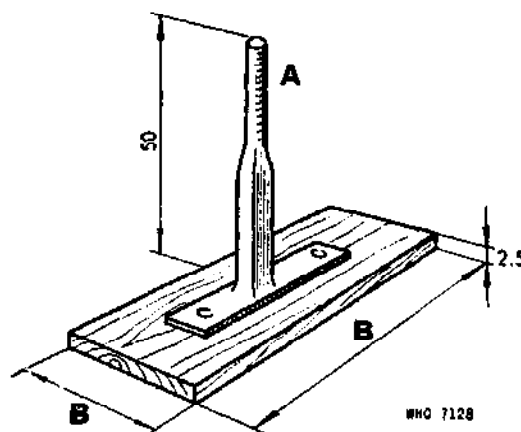
The successful use of hole covers will probably result only from a long and concentrated educational programme.

Engineering Factors

The selection, design, location, and construction of excreta disposal installations require the application of some engineering knowledge. Such knowledge may assume major importance in certain areas because of peculiar physical factors and difficulties. The nature of ground formations is often the governing factor in the selection of a type of installation. In areas containing rocks, boulders, or fissured limestone and, also, where ground water is high or caving of pits occurs, the public health officer and the sanitarian may require the assistance of the engineer to find adequate and economical solutions to these engineering problems.

The selection and proper use of local materials are also of engineering significance in the construction and cost of privies on a mass scale. The use of bamboo for pit curbing and for the reinforcement of concrete

FIG. 8. SIMPLE HOLE COVER



- A = Long handle is a special feature. Top part is likely to remain clean.
- B = Width and length to suit size and shape of hole, which will be covered, not plugged.

slabs¹⁷ and the use of sand-stabilized earth¹⁸ are examples in point. In every area it is desirable that field research and experiments be carried out to discover the best possible use of cheap, locally available materials.

Finally, the selection of design features which can be handled by local labour is an important engineering consideration. Local skills should be utilized to the greatest possible extent. It is fairly obvious that, if the type of installation selected cannot be built by the villagers themselves, the privy scheme will be limited to the construction of a very few installations by imported labour.

This brief outline of the engineering problems which are likely to be faced by most health departments in the execution of large-scale privy campaigns and other sanitary installations points to the need to have a few full-time public health engineers on the health department staff. These engineers may be detailed from the centre as required to assist rural health units in solving such problems.

Human Factors

In all matters of excreta disposal, human factors are as important as technical features. People, especially inhabitants of rural areas, will not use a latrine of a type which they dislike, or which does not afford adequate privacy or, finally, which cannot be kept clean.

Regarding the type of latrine which should be selected, the preliminary sanitation and sociological survey will indicate the types of facilities, if any, in use in the area. The first step in design will therefore be to try to improve the existing system, retaining as many as possible of its "sociological" features. Two examples may be cited to illustrate this important point. Water-flush-type latrines with risers and seats, though best from the sanitary standpoint, have not normally been found acceptable by people who are used to defaecating in the bush in a squatting position. In another instance, people readily accepted pit privies which were built within a thatch and bamboo enclosure without a roof, as they preferred to squat in the open air. Everywhere in the world people have certain taboos with respect to the collection and disposal of human faeces. While it is impossible in one document or textbook to study them all, the health worker should pay much attention to them and should avail himself at all times of the assistance of experienced health educators, social anthropologists, or sociologists to discover the right approach to the solution of the excreta disposal problem of rural communities.

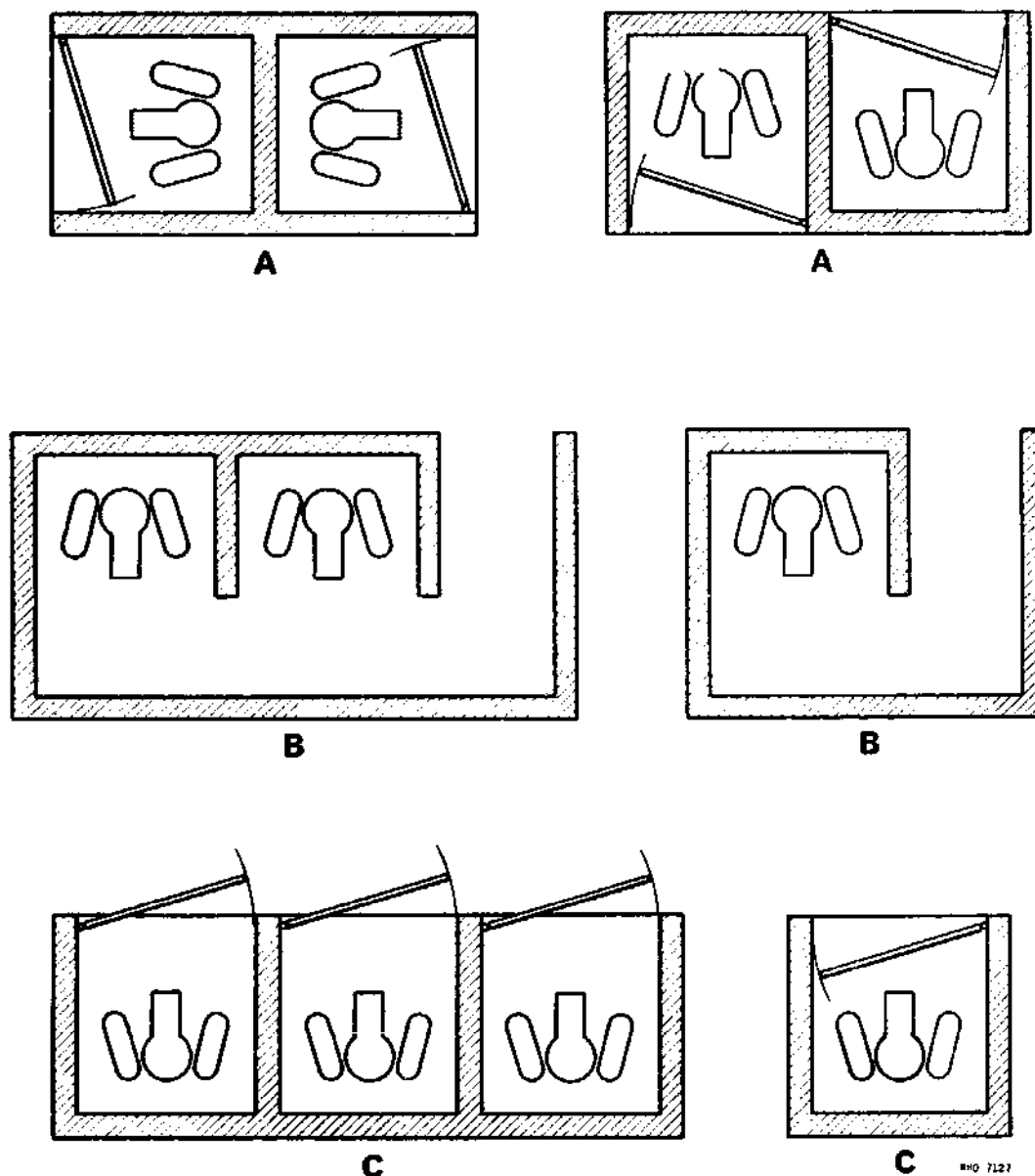
The next important human factors to be considered are the matters of privacy and of separation of the facilities provided for men and for

¹⁸ Youssef, M. S. (1953) *Suggestions for improving building materials used by Egyptian farmers* (Unpublished paper prepared for the Egyptian Government)

women. Various systems have been designed to provide privacy; they are shown in Fig. 9, together with those for separating the sexes. It will be noted that latrine doors should preferably open inwards.

A latrine, whether of the family or communal type, the design of which does not allow easy cleaning will also not be acceptable to most people.

FIG. 9. PRIVY DESIGNS ENSURING PRIVACY AND SEPARATION OF THE SEXES



- A = These two layouts ensure complete separation of the sexes.
- B = Semi-private installation. Snail-type entrance. Defaecation may take place in corridor passage when latrine floor is dirty.
- C = Preferred types, ensuring complete privacy.

In this respect, smooth, hard-surface floors of concrete, cement, brick, or similar material are best because it is easy to flush them with water.

A latrine which is designed for too large a number of people will probably get dirty quickly and remain so, with the result that late callers will prefer to go and defaecate around the latrine building or in a neighbouring bush. A one-hole latrine is adequate for a family of five or six persons. For communal latrines in camps, markets, and similar places, one hole should be provided for every 15 persons; and in schools, one hole for every 15 girls and one hole plus a urinal for every 25 boys.

Cost Factors

As pointed out before, the type of latrine to be recommended to a community or to a family should be simple, acceptable, and economical to build, to maintain, and to replace when the need arises. While there are simple and acceptable types of latrines fulfilling the three conditions mentioned, there are none which are at the same time cheap to build, to maintain, and to replace. Oddly enough, the systems which are most expensive to build (water-flush latrines) are the cheapest in the long run, because of their long life, and are the easiest and most economical from the maintenance standpoint.

General experience reveals one very important fact: in selecting or designing a type of latrine, cost should not be the dominant factor. It is necessary to strike a middle way after careful consideration of all the elements involved, giving preference to those factors which are conducive to a sanitary environment and to acceptability by the family.

EVALUATION AND SELECTION OF VARIOUS EXCRETA DISPOSAL SYSTEMS

Criteria for Selection

The problems of selecting a type of sanitary installation for a particular rural community are manifold and without a clear and simple answer. It has become evident that, in planning a permanent solution to an excreta disposal problem, many inter-related factors must be considered, among them cultural patterns, religious customs, climatological and geological conditions, economic standards, political and social organization of rural communities, general and health education, skills of local populations, and the availability of construction materials and personnel for technical supervision. What originally may appear on the surface to be a simple

problem has often, upon more careful examination, been found to be a relatively complex one.

The selection of the type of installation best suited to local needs must take into account the element of cost. Water-carried sewerage systems with flush toilets are very expensive and far beyond the economic possibilities of most rural areas. At the other extreme, it is possible for everyone to relieve himself in the most primitive manner at no cost whatsoever; but this method is disastrous in terms of sickness and death and resulting economic loss. Therefore, between these two extremes a solution should be found that will give the most in health protection and, at the same time, will be within the economic possibilities of the people to construct and maintain. Every sanitation worker should carefully consider this aspect of the problem, not only as it applies to privies, but also as it relates to every other type of sanitary improvement. The health department, through its staff, should assist each family in finding the proper solution, by painstaking efforts where necessary. Of course, it is relatively easy to decide on a privy campaign for a rural area from a health department office situated far away in the state or provincial capital simply by choosing a design that appears to be satisfactory because it has been used somewhere in the world. This is the kind of privy programme which has resulted in empty, abandoned, and unused installations in so many places.

As might be expected, a review of the literature reveals that a great variety of excreta disposal methods are in use in the world. Latrine characteristics are often very different. However, from a purely technical standpoint, it is generally agreed that a latrine or other disposal method should satisfy the following seven requirements (adapted from Ehlers & Steel¹²):

1. The surface soil should not be contaminated.
2. There should be no contamination of ground water that may enter springs or wells.
3. There should be no contamination of surface water.
4. Excreta should not be accessible to flies or animals.
5. There should be no handling of fresh excreta; or, when this is indispensable, it should be kept to a strict minimum.
6. There should be freedom from odours or unsightly conditions.
7. The method used should be simple and inexpensive in construction and operation.

Main Types of Installation

The two types of installation which come closest to fulfilling the above seven requirements are the pit privy and the aqua privy.

The pit privy is used almost exclusively throughout the Western hemisphere and Europe and is common in parts of Africa and the Middle East. With a minimum of attention to location and construction, there will be no soil pollution and no surface- or ground-water contamination. The excreta will not be accessible to flies if the hole is kept covered; but, even when the hole is left open, the fly problem will not be very great since flies are not attracted to dark holes and surfaces. A good superstructure helps to keep the sun's rays and light from shining into the pit. There is no handling of the material. Odours are negligible, and faeces are normally out of sight. The pit privy is simple in design and easy to use, and does not require operation. Its life span will vary from five to fifteen years, depending upon the capacity of the pit and the use and abuse to which it is put. Its chief advantage is that it can be built cheaply, in any part of the world, by the family with little or no outside help and from locally available materials. It has few disadvantages, and it can play a major role in the prevention of filth-borne diseases.

The aqua privy is a modification of the "septic privy", which originated in the USA about fifty years ago. It is being used in increasing numbers in countries in Africa, the Middle East, and South-East Asia. If the tank is water-tight, the soil as well as the surface- and ground-water cannot be contaminated. Flies are not attracted to the tank's contents, and there are no odours or unsightly conditions. It may be located close to the house. Faeces and sludge, together with stones, sticks, rags, and other debris which may be thrown in, accumulate in the tank and must, of course, be removed at intervals. If the tank's capacity is sufficient, however, handling of its contents can be kept to a minimum. The aqua privy requires daily additions of water to keep it operating properly. The small amount of water needed is normally supplied by the water used for anal cleansing and for cleaning the slab and the drop pipe or funnel. This privy needs a little maintenance, but it is a permanent type of installation. It is more expensive to construct than the pit privy.

Mention may be made here of the water-seal slab which gives its name to a latrine called "water-seal" or sometimes "pour flush" latrine. In actual fact, it is not a separate type of excreta-disposal installation but is rather an interesting modification of the usual latrine slab or floor. The water-seal slab may be installed over a pit (such as that of a pit privy) or a water tank (such as that of an aqua privy). With proper operation and maintenance, the water seal will keep both flies and odours away. For this reason it may be installed advantageously as a part of the dwelling, preferably near the back of the house and with an outside entrance. It is obvious that its small trap will not withstand abuse. The water-seal slab is extensively used in the South-East Asia region, where anal cleansing with water is widely practised.

Less Desirable Types of Installation

The bored-hole latrine is a variation of the pit privy. The pit is smaller in cross-section but deeper. Its capacity, however, is much less than that of the usual pit privy, and this results in a shorter useful life. Because of its depth—as much as 6 m (20 ft)—the pit often penetrates the ground water, which it contaminates easily. There is no soil or surface-water pollution, however; and no handling of excreta is involved. The fly hazard is increased because of the chances of pollution of the upper walls of the hole, immediately below the opening. Caving of the pit's walls often constitutes a serious disadvantage. It is cheap and easy to construct when the necessary tools are available. It is widely used in many parts of the world, especially in the Middle East and in South-East Asia.

The bucket latrine, or box-and-can privy, has been extensively used in the past in Europe, the Americas, and Australia; it is still used in many countries of Africa, South-East Asia, and the Western Pacific. Its use is decreasing, however, even in these areas. Although, theoretically and under unusually efficient control, it should be possible to devise and operate a bucket-latraine system in a hygienic manner, experience everywhere shows that, in actual practice, this is not the case. As usually operated the bucket-latraine system attracts flies in enormous numbers, not just at the latrine site but all along the conveyance route to the disposal ground itself. There is considerable handling of the excreta. Regarding this system it may now be safely stated that insanitary handling of the buckets and night-soil is the rule, although exceptions may be found in a few properly operated and supervised systems. The hazards of soil pollution and of surface- and ground-water pollution are ever present. There are usually considerable odour and unsightly conditions. Although the initial cost of a bucket latrine is not high, the cost of operation makes it, within a few years, the most expensive type of installation. Its use is justified only in areas, the Western Pacific, for example, where excreta are needed as soil fertilizer. Even here it is believed that the conventional bucket-latraine system should be considerably improved or replaced by a latrine such as the compost privy mentioned below.

Feuillées and *trench latrines* are commonly used in some territories in Africa, in camps, and at times of emergency. As stated by Médecin-Général Sanner,³¹ the *feuillées* are installations which may be relatively satisfactory or grossly insanitary, depending upon whether certain precautions are observed or neglected. These precautions (which will be described later) depend for their application upon the user and, in most cases, are not followed in actual practice. The system thus frequently results in violations of the most fundamental standards of sanitation, the most important of which are, in this particular instance, soil pollution and accessibility to flies and animals. Its use is not recommended.

The "overhung privy" is often used in limited areas that are frequently or periodically covered with water, especially the sea. This applies to coastal fishing villages in some countries of South-East Asia and the Western Pacific and in a few other places. The criteria listed above do not apply exactly. New criteria were considered at the WHO Seminar on Sewage Disposal held in Ceylon in August 1955. The most important factors in this case are the degree of salinity of the receiving water, its depth, and the degree of possible dilution. This type of installation should be considered only as a last resort under unusual circumstances.

Installations for Special Situations

The compost privy has been used in areas where it is desirable to compost safely in the privy itself a mixture of faeces and other organic wastes (straw, kitchen wastes, grass clippings, etc.). To serve this purpose, two or more pits are required, and consequently the cost is greater than for ordinary pit latrines. If poorly constructed and operated, this privy may attract flies, which may breed in the material. Also, odours may be a problem. The compost privy is simple to build but requires some operation and maintenance. Since the pits are used alternately, handling of their contents is kept to a minimum and is done after their decomposition and reduction by anaerobic bacteria. The humus-like product is stable and safe and is a good soil fertilizer.

The chemical toilet is an efficient installation which fulfils all the above-mentioned criteria except the one which pertains to cost. It is, relatively speaking, very expensive both in initial cost and in operation. Its chief advantage is that it may be placed inside the dwelling. It is frequently used in rural houses and schools of the economically more favoured areas of the world.

THE PIT PRIVY

Description

The pit privy (as shown in Fig. 10 and 11) consists of a hand-dug hole in the ground covered with either a squatting plate or a slab provided with riser and seat. A superstructure or house is then built around it.

Design and Function of Its Parts

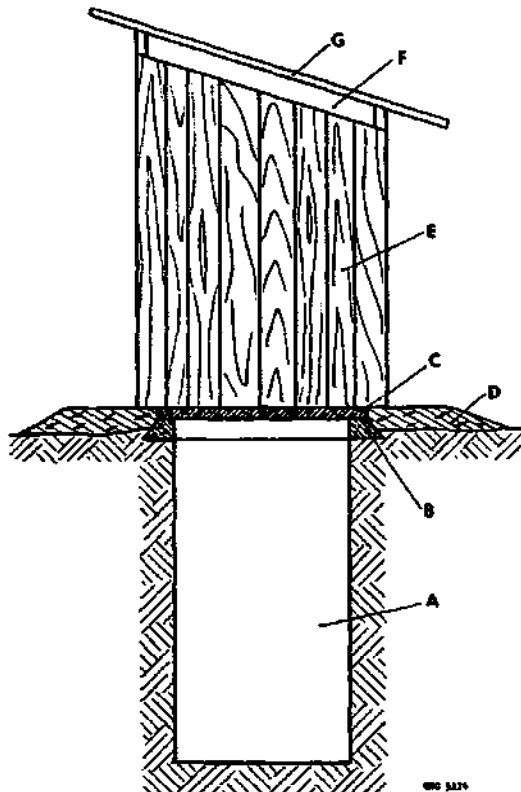
The pit

The function of the pit is to isolate and store human excreta in such a way that no harmful bacteria can be carried therefrom to a new host. The pit is usually round or square for the individual family installation

and rectangular for the public latrine. Its dimensions vary from 90 cm to 120 cm (36 in. to 48 in.) in diameter or square. Common figures for family latrines are 90 cm (36 in.) diameter or 1.06 m (42 in.) square. For public installations, the pit will be 90 cm to 100 cm (36 in. to 40 in.) wide ;

its length will depend upon the number of holes provided. The depth is usually about 2.50 m (8 ft), but may vary from 1.80 m to 5 m (6 ft to 16 ft). In Iran, and elsewhere, some pits have been dug to a depth of 7-8 m (23-26 ft) in soils which are very stable (see Fig. 12-15).

FIG. 10. VARIOUS PARTS OF A SANITARY PRIVY



- | | |
|-----------|---------------------------|
| A = Pit | E = House, including door |
| B = Base | F = Ventilation |
| C = Floor | G = Roof |
| D = Mound | |

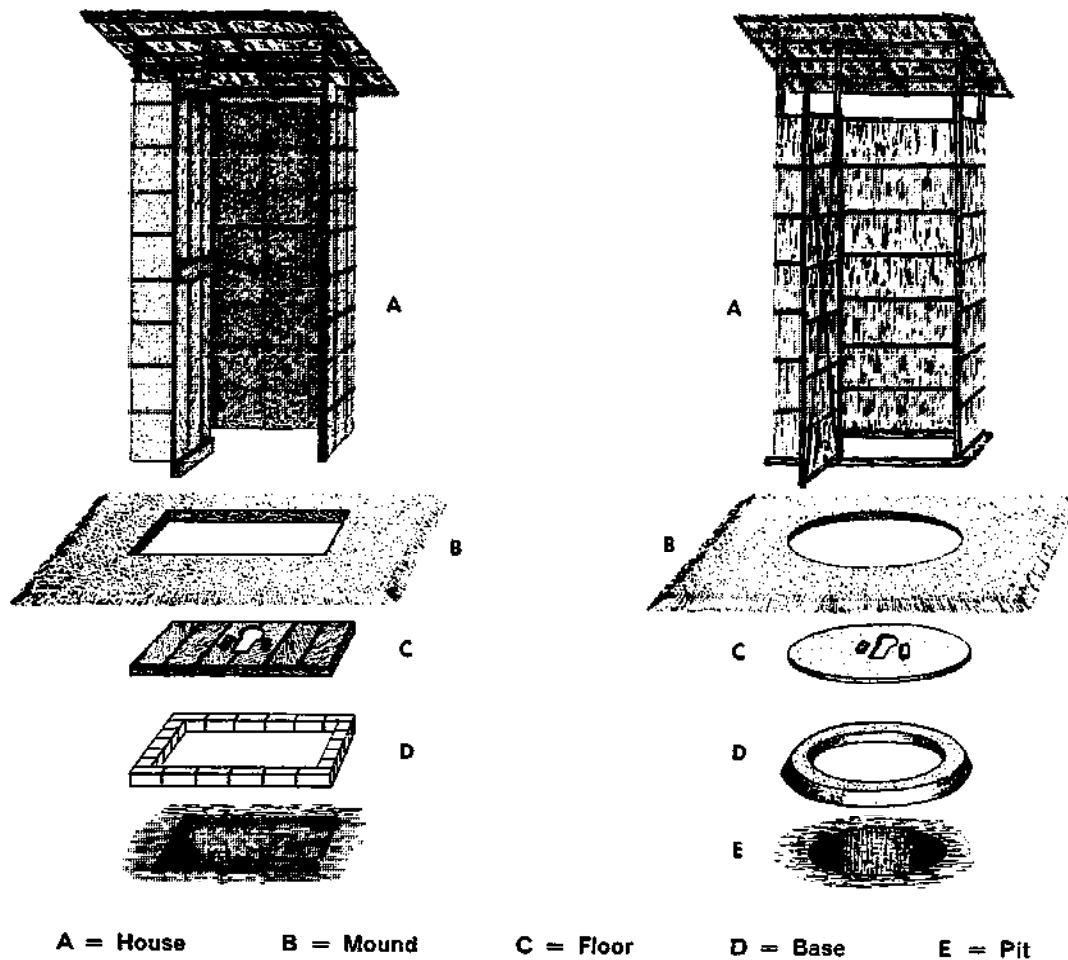
Life of a pit

One of the very important aspects of the pit is its useful life. The longer a pit privy will serve a family without being moved or rebuilt, the more certain is the health protection which it can give and, therefore, the more value it has to the family and community. It is important, by increasing the capacity and efficiency of privy pits, to extend their useful life and thereby to reduce the annual cost per person of the installation. The life of a privy depends on the care with which it is built, the materials used in its construction, and the time required for the pit to fill.

The critical factor, usually, is the time required for the pit to fill ; this, in turn, depends on the method of anal cleansing and on the volume of the pit and the conditions within it. By the word "conditions" are meant the efficiency of bacterial decomposition and the degree of abuse to which the pit is subjected (i.e., the stones, sticks, mud balls, garbage, coconut husks, etc. thrown into it).

In deciding on the volume of a pit, it is necessary to consider whether the pit will be wet or dry, i.e., whether it will penetrate the ground-water table or not. In either case, however, it is essential to remember that the decomposition process starts as soon as the excreta are deposited in the pit and that, through decomposition and compaction, the volume of the slowly accumulating sludge is smaller than the total amount of excreta

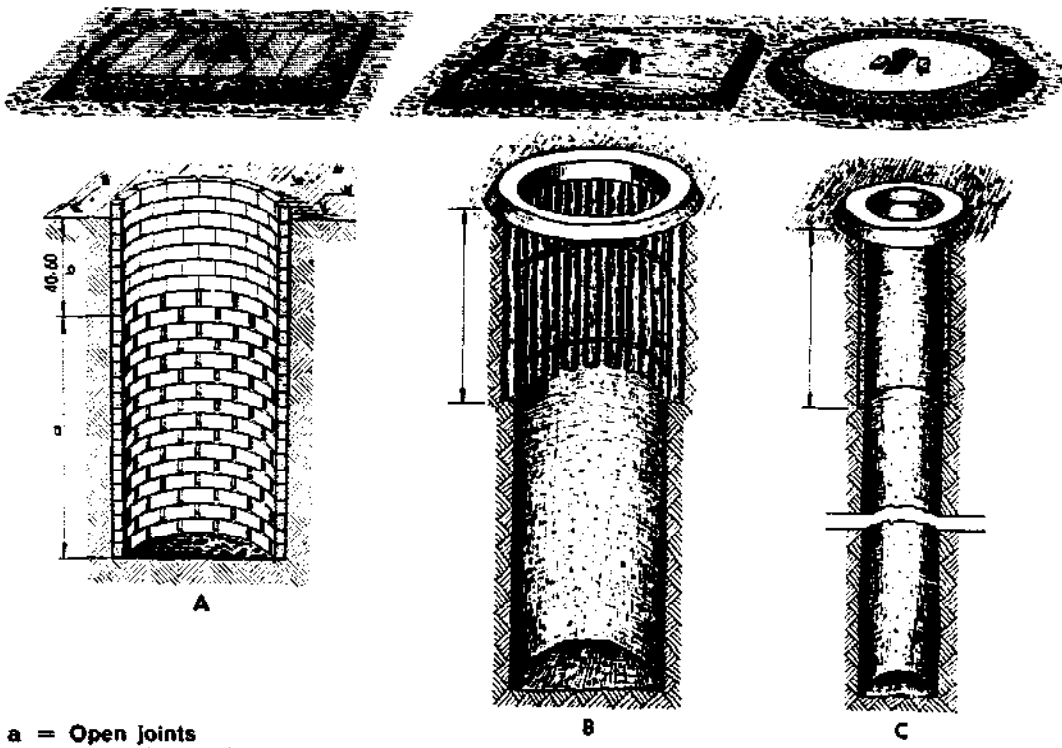
FIG. 11. THE PRINCIPAL PARTS OF TWO TYPES OF SANITARY PRIVY



deposited. Strictly speaking, the rate of accumulation of digested sludge and of partially digested excreta is not directly proportional to the amount of excreta added each year. This phenomenon is illustrated graphically in Fig. 16. From this graph, which is based on approximate data only, it will be noted that, after the digestion process has been well established, the actual volume of material in a wet pit might be reduced in time to approximately 10% of the total waste (faeces and urine) deposited. This graph is very approximate, however, and may need to be substantially modified in the light of experience in different areas. These data should be developed in each country by controlled field observations carried out over a number of years. Only in this way can reliable figures be obtained as a basis for future design of latrine capacity. The following considerations are based on data contained in the report on the aforementioned WHO-sponsored seminar on sewage disposal.^a

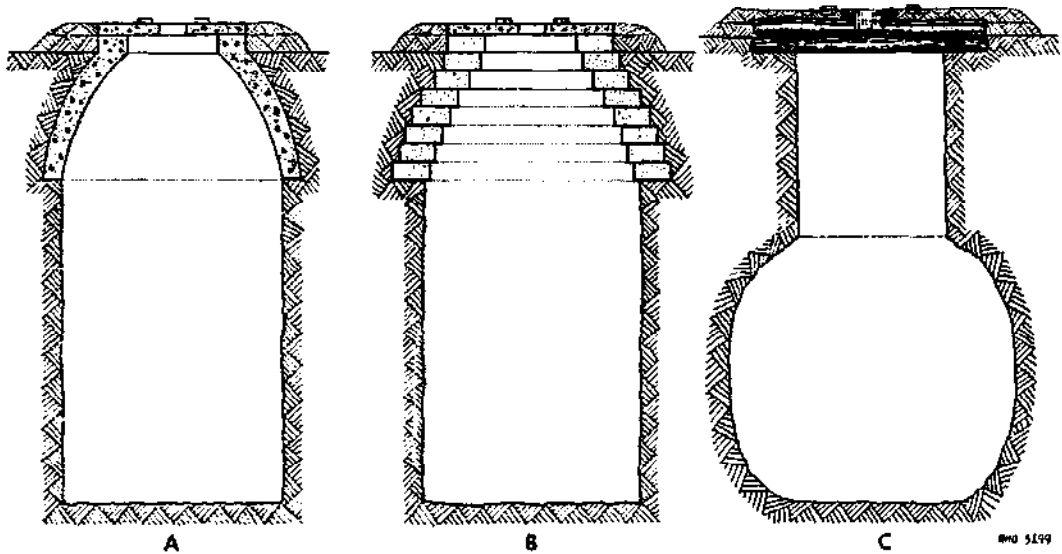
^a *Report on Seminar on Sewage Disposal (Rural and Urban)*, Kandy, Ceylon, 1955 (Report issued by the WHO Regional Office for South-East Asia, New Delhi)

FIG. 12. VARIOUS COMBINATIONS OF DIFFERENT TYPES OF PIT, PIT LINING, BASE, AND FLOOR



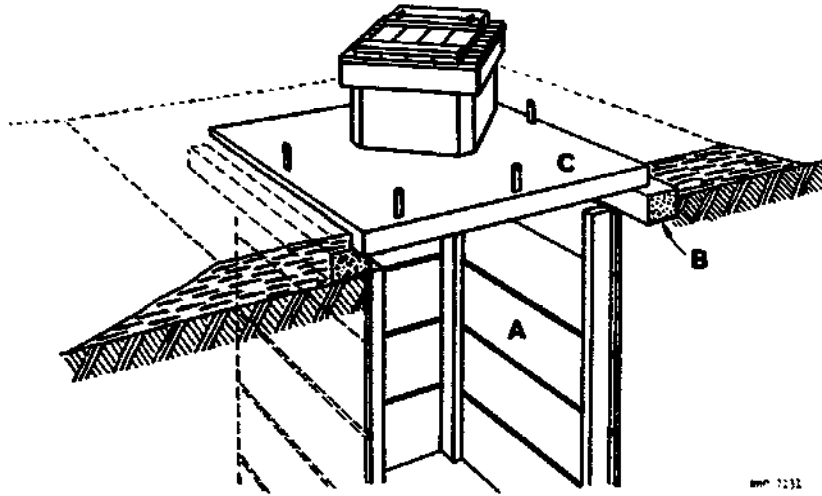
- a = Open joints
- b = Joints laid with mortar
- A = Square pit with brick lining and base and wooden floor
- B = Round pit with partial lining of cut tree limbs, soil-cement base, and built-up floor
- C = Bored pit with concrete lining, base, and floor

FIG. 13. LARGE-VOLUME PITS WITH SMALL FLOORS AND SUPERSTRUCTURES



- A = Large diameter or square pit with soil-cement cone at top to reduce size of opening and accommodate small floor (Cone may be of any material which will provide the strength to support the weight on top.)
- B = Similar to A, but with brick
- C = Pit showing enlarged lower portion to provide increased volume; practicable only in very stable soil

FIG. 14. TYPE OF PIT, PIT LINING, BASE, AND FLOOR RECOMMENDED BY THE US PUBLIC HEALTH SERVICE

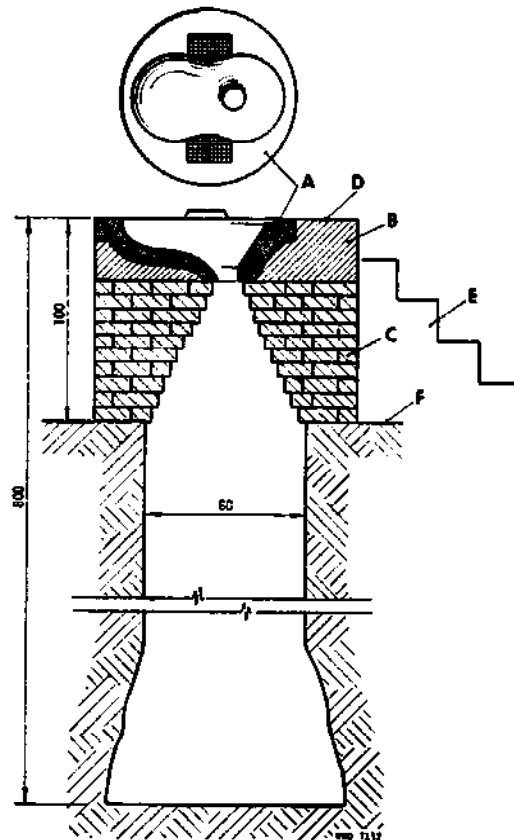


- A = Wooden pit lining, 2.5 × 15 cm (1 × 6 in.) boards. About 1.2 cm (0.5 in.) space left between boards below top two
 B = Concrete sill
 C = Concrete floor and riser

Adapted, by permission, from United States Public Health Service (1933) *The sanitary privy*, Washington, D.C. (Revised type No. IV of *Publ. Hlth Rep. (Wash.)*, Suppl. 108).

In wet pits, assuming that the daily production of one litre (approximately one quart) of excrement contains 100 g (3.5 oz.) of dry solids and that digestion for one year under wet-pit conditions will reduce this mass by 80%, a total of 20 g (0.7 oz.) of dry solids will remain. Further assuming an 80% moisture content in the digested sludge, one arrives at the figure of 100 g (3.5 oz.) of wet sludge after a one-year digestion period.

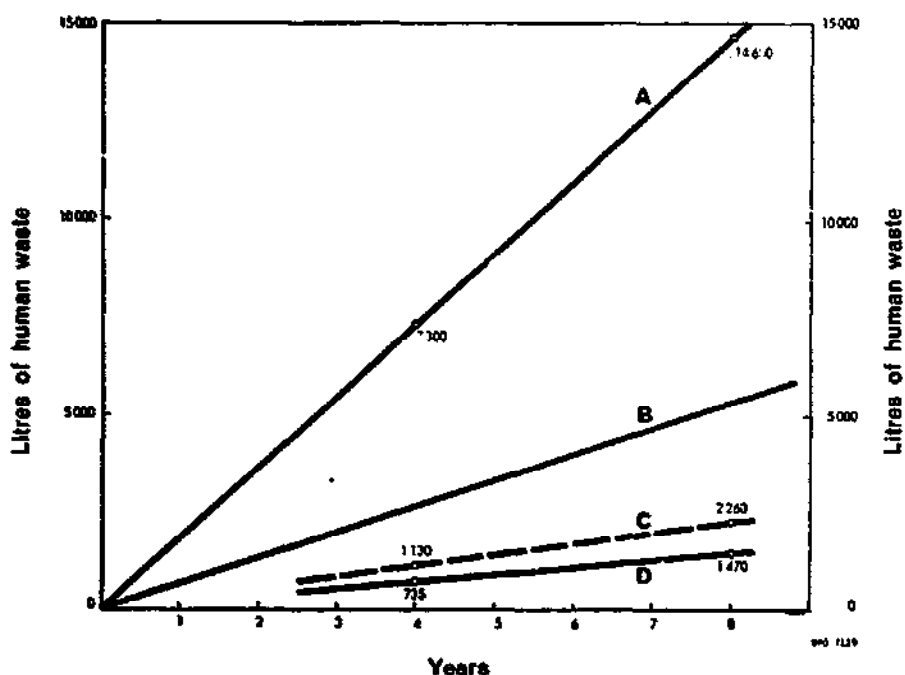
FIG. 15. TYPE OF RURAL PIT PRIVY DEVELOPED BY TCA* IN IRAN



- A = Round, reinforced concrete slab. Can be easily rolled to privy site without breakage. Water is used for anal cleansing
 B = Lime-mud mixture
 C = Brick or stone masonry
 D = Floor of privy
 E = Steps leading to entrance door
 F = Original ground-level

* Technical Co-operation Administration of the USA

FIG. 16. SLUDGE ACCUMULATION IN PIT LATRINES



- A = Human waste (liquid and solid) deposited in pit by a family of five (at the rate of one litre, or quart, per person per day)
 B = Corresponding amounts of solid wastes alone (approximately)
 C = Rate of accumulation of sludge, by volume, in dry pit
 D = Rate of accumulation of sludge, by volume, in wet pit

This amounts to 36.5 l (1.3 cu. ft) per person per year. Thus, a family of five would require sludge-storage space of 184 l (6.5 cu. ft) per year.

Actual observations on wet-pit latrines in West Bengal, India, where ablution water is used, gave a figure of 25 l (0.88 cu. ft) of sludge per person per year. In the Philippines, where solid cleansing materials are used, a wet-pit figure of 40 l (1.4 cu. ft) was obtained.

It is recommended that for the design of the effective capacity of wet-pit latrines a provision of 37 l (1.3 cu. ft) per person per year should be allowed. If cleansing materials such as grass, stones, mud balls, coconut husks, or similar solids are used, it is recommended that this figure be increased by 50% to a total of 57 l (2.0 cu. ft) per person per year.

It is recognized that digestion of solids is less rapid and less complete in dry-pit latrines than in wet-pit latrines. Actual observations in the Philippines indicate a reduction by dry-pit digestion of about 50% in volume per year. In the absence of more accurate data, this rate is tentatively accepted. In Brazil, a privy of one cubic metre (35 cu. ft) of effective capacity will serve an average family of five for four years; this represents a capacity of 0.05 m³ (1.75 cu. ft) per person per year. Somewhat lower figures have been found in the USA, but higher figures are reported from areas where different types of anal cleansing materials are employed. For

design purposes, a provision of 0.06 m³ (2 cu. ft) per person per year is recommended, to be increased by 50% in cases where the types of personal cleansing materials normally employed might indicate that such an allowance is necessary.

It is further recommended that, where practicable, wet pits should have a minimum depth of 3 m (10 ft). With regard to pit storage capacity, it is desirable to design for as long a period as possible, i.e., for 10-15 years. However, it is recognized that, from the standpoint of cost, or because of difficulties in supporting pit walls in unstable soil formations, it might sometimes be impossible to attain this objective. Nevertheless, it is strongly recommended that pits should be designed for a life of at least four years.

TABLE IV. WET-PIT VOLUME AND DEPTH* FOR RURAL LATRINE WITH AN ASSUMED CROSS-SECTIONAL AREA OF 9 SQUARE FEET AND INTENDED FOR A FAMILY OF FIVE

Service life	Personal cleansing material			
	water		solid	
	volume (cu. ft)	depth (ft)	volume (cu. ft)	depth (ft)
4 years (minimum)	26	3	40	4.6
8 years	52	5.8	80	9
15 years (maximum)	97	11.8	150	16.6

* Depth given is effective pit depth, and 1-2 ft (30-60 cm) are usually added to obtain overall depth of pit.

Table IV shows the pit volume and dimensions for household latrines for families and gives varying periods of service life based on wet-pit conditions. Table V presents similar data for dry-pit conditions.

These tables show that, where there is little possibility of maintaining water in pits or holes, a pit privy with the largest possible volume is best. From the economic standpoint, the deep pit, although higher in initial cost, will prove to be a profitable investment.

Finally, one factor that also influences the cross-sectional area of the pit, although to a lesser extent, is the size of the floor that covers it. The size of the floor slab depends much on the type of material from which it is built. This matter is discussed in a later section (p. 52).

When the level of excreta comes to within 50 cm (20 in.) of the ground surface, the pit should be closed and filled with earth. A new pit should be dug, preferably near the old one, and the superstructure moved over it (or rebuilt, as the case may be). The faeces in the old pit should be left

TABLE V. DRY-PIT VOLUME AND DEPTH* FOR RURAL LATRINE WITH AN ASSUMED CROSS-SECTIONAL AREA OF 9 SQUARE FEET AND INTENDED FOR A FAMILY OF FIVE

Service life	Personal cleansing material			
	water		solid	
	volume (cu. ft)	depth (ft)	volume (cu. ft)	depth (ft)
4 years (minimum)	40	4.5	60	6.7
8 years	80	9	120	13.3
15 years (maximum)	150	16.6	—	—

* Depth given is effective pit depth, and 1-2 ft (30-60 cm) are usually added to obtain overall depth of pit.

to decompose anaerobically for 9 to 12 months, after which the digested material may be easily removed and utilized as soil fertilizer. The cleaned pit may then be re-used.

To prevent mosquito breeding in wet pits, it may be desirable to add a cupful of kerosene each week to the pit, or to spray it with Malariol^a or a 5% solution, emulsion, or suspension of BHC (benzene hexachloride) or dieldrin. No disinfectants should be added to the pit.

Lining of pit

It is often necessary to provide a pit lining to prevent the sides from caving in. This is true especially in rainy seasons where privies are dug in fine-grained alluvial soils, sandy soils, and similar formations, or when they penetrate deeply into ground water. Even in stable soil formations, it is desirable to line the top 40-60 cm (16-24 in.) of the pit in order to consolidate it and to prevent it from caving in under the weight of the floor and the superstructure.

Materials commonly used for this purpose include bricks, stones, concrete blocks, laterite blocks, adobe materials, lumber, rough-hewn logs, split cane, and bamboo. When the first five materials mentioned above are used, they are laid with open joints over most of the walls' height and with mortar near the top of the walls, the reason being that with these materials the lining also serves usefully as a base for the floor. Brick linings (see Fig. 13) should preferably be round, not square, as they then develop arch action and are much stronger for the same wall thickness. Wooden logs and bamboo should be used exclusively to support the walls

^a Malariol is the proprietary name for a blend of oil (70% diesel oil and 30% gas oil), often referred to as "anti-malarial mixture"; it is made by Shell Chemicals Ltd, London.

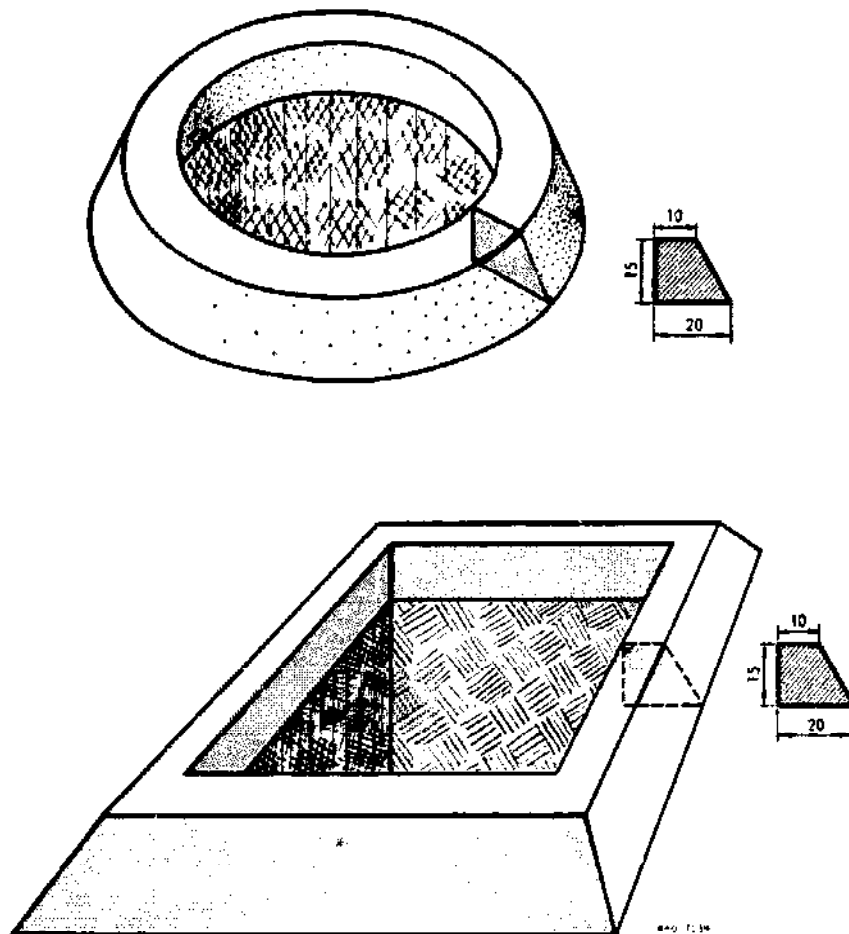
of the pit, not as a foundation for the floor. Rough-hewn logs will, of course, last longer than bamboo linings; both, however, may be tarred in order to increase their useful life. The use of rot- and termite-resistant woods is recommended wherever possible.

Where a lining is necessary, it is often given to the family by the health department, along with the floor or slab.

The base (Fig. 17-19)

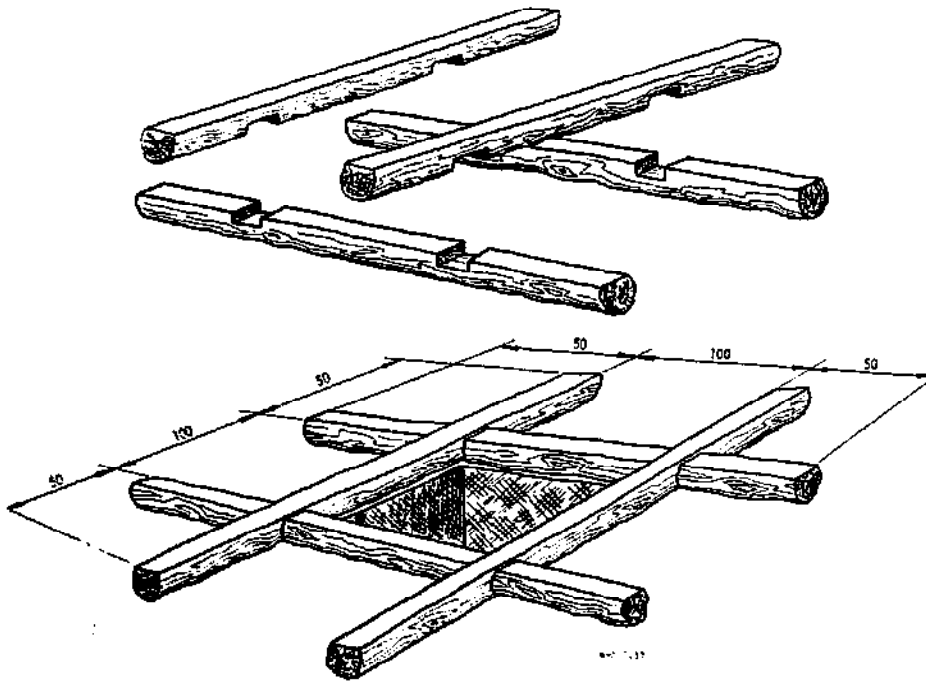
The base serves as a solid, impervious foundation upon which the floor can rest. It also helps to prevent the egress of hookworm larvae. Properly made of a hard, durable material, it helps to prevent the entrance of burrowing rodents and of surface water into the pit. Pit lining in most cases will serve as a base although it may need to be strengthened at the ground surface.

FIG. 17. TYPICAL ROUND AND SQUARE BASES
(BUILT WITH SOIL-CEMENT OR CLAY)



Measurements shown are in centimetres.

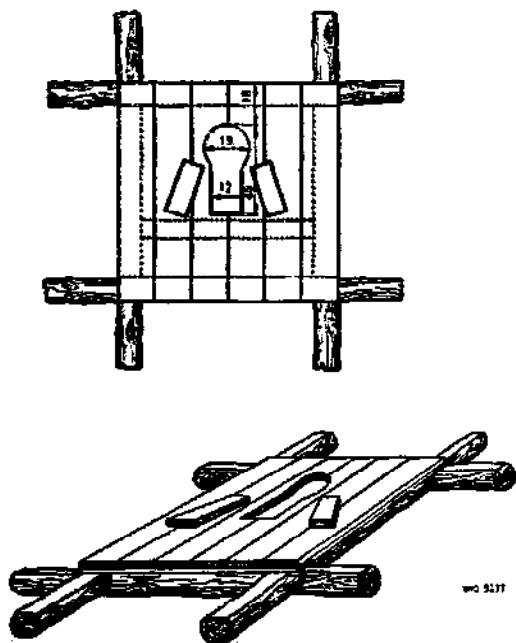
FIG. 18. A HEWN-LOG PRIVY BASE



Measurements shown are in centimetres.

The foundation should be at least 10 cm (4 in.) wide on top in order to provide a good surface for the floor to rest upon, and 15 cm (6 in.)

FIG. 19. HEWN-LOG BASE WITH WOODEN FLOOR



Measurements shown are in centimetres.

or more at the bottom in order to give a stable contact with the ground. Its shape will be that which will fit the pit (see Fig. 17 and 18). The base should be high enough to raise the floor 15 cm (6 in.) above the level of the surrounding ground, thus, with the mound, protecting the pit from flooding.

The following materials may be used in the construction of the base :

(a) plain or reinforced pre-cast concrete—same mix as floors ;

(b) soil cement—5%-6% cement mixed with sandy clay soil and tamped at optimum moisture content ;

(c) clay—tight clay, well tamped at optimum moisture content ;

- (d) brick—mud-dried, burned, adobe, etc.
- (e) stone masonry ;
- (f) rough-cut logs—hardwood, termite-resistant.

The floor (Fig. 20-32)

The floor supports the user and covers the pit. It should be constructed so as to fit tightly on the base, with a minimum of small cracks and openings between the surfaces. The squat-type plate or slab for pit privies has been found to be the most suitable for rural conditions in most parts of the world. However, in many countries a slab provided with a riser and seat may be found to be more acceptable. This aspect of slab design requires careful consideration. An eminent health educator and social anthropologist has stated that customary posture in defaecating is perhaps the single most important fact bearing on the acceptance or rejection of privies.

The floor or slab should normally extend to the superstructure walls, as a peripheral earth strip might be soiled and become a medium for hookworm infestation. It should be made of a durable, impervious material with a hard surface which will facilitate cleaning. Materials commonly employed include :

- (a) reinforced concrete ;
- (b) reinforced concrete with brick filler ;
- (c) wood ;

FIG. 20. HEWN LOGS TO FORM HOLE AND FOOT-RESTS

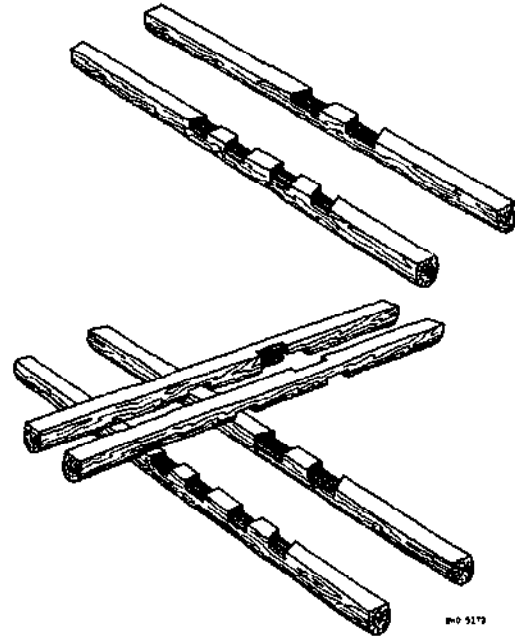
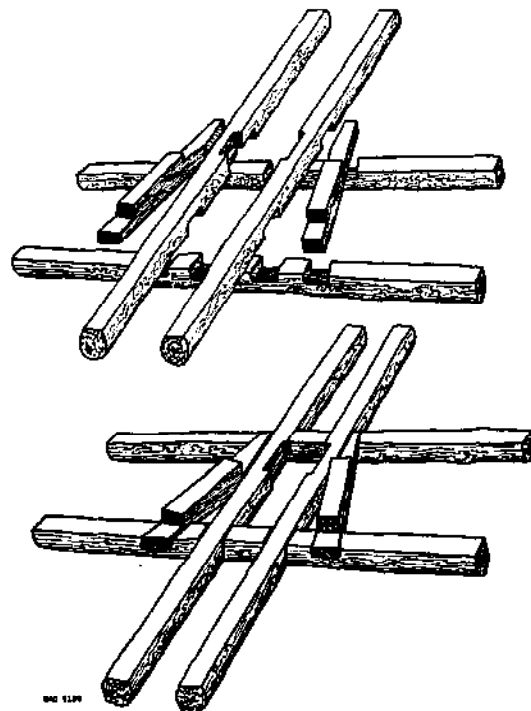


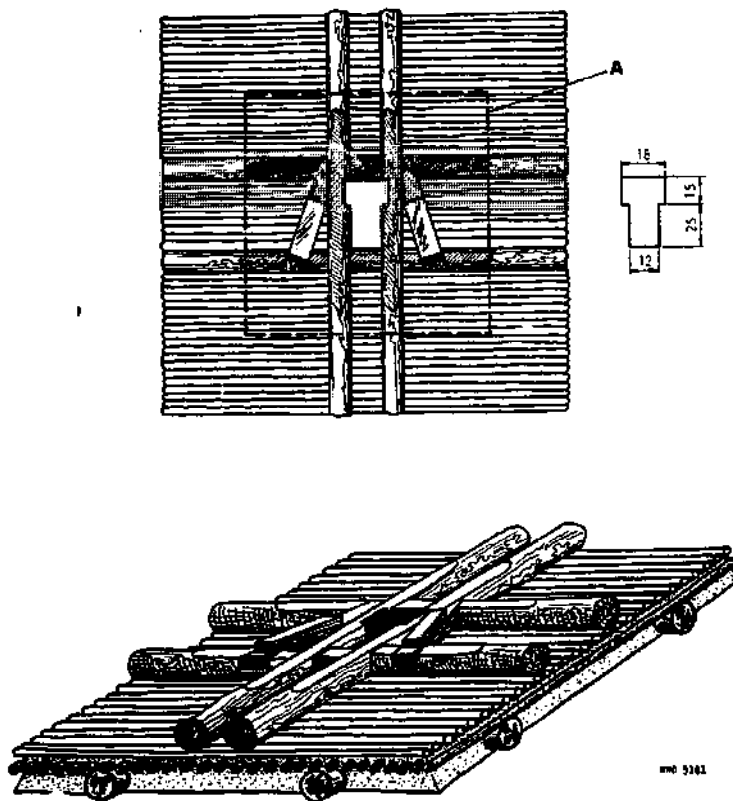
FIG. 21. HEWN LOGS FORMING HOLE AND FOOT-RESTS, ASSEMBLED AND UNASSEMBLED



(d) built-up floor of small-diameter wooden poles with chinks filled by mud or soil-cement mixture.

The consensus of opinion is that concrete is, in the long run, the most practicable, most acceptable, and cheapest material for the privy floor. Wooden floors come next in the line of preference. "Built-up" floors, as shown in Fig. 22-24, are less desirable because they are difficult to keep clean and, as they get soiled (especially by children), are likely to spread hookworm.

FIG. 22. HEWN LOG FORMING HOLE AND FOOT-RESTS SHOWN IN PLACE UPON SECOND LAYER OF TREE LIMBS IN BUILT-UP FLOOR

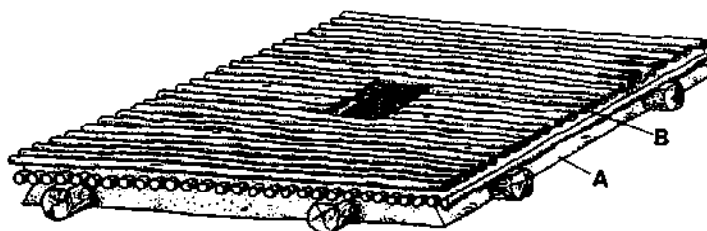
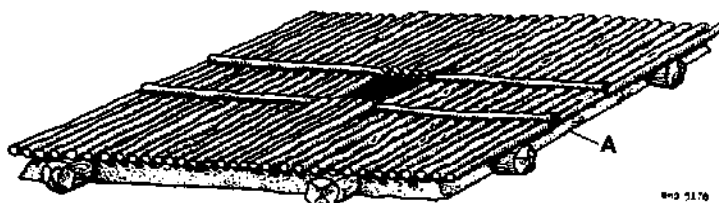


Measurements shown are in centimetres.

A = Limits of pit

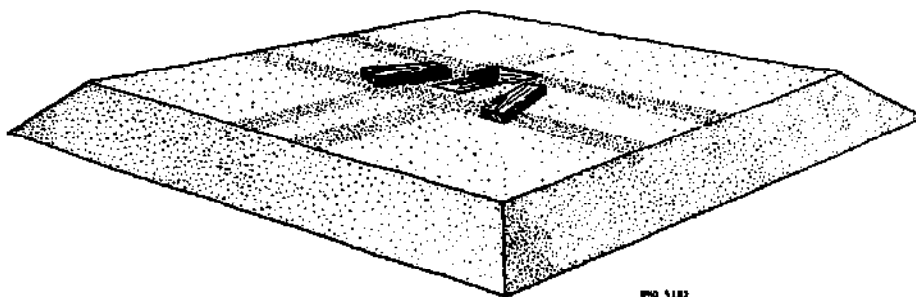
Latrine slabs or floors may be round, square, or rectangular. When slabs are to be made or cast at a central shop, it is advantageous to adopt a standard shape and size in order to facilitate production. The size of concrete slabs, which influences to a certain degree the cross-sectional area of the pit and the size of the superstructure, is governed by their weight and by the difficulty of transportation (where this applies).

FIG. 23. BUILT-UP FLOOR OF SMALL-DIAMETER TREE LIMBS PLACED OVER HEWN-LOG BASE



- A = Fill in with compact earth all around after the base is placed and before covering with tree limbs
- B = First layer of limbs is covered with 5 cm (2 in.) of dense earth, followed by another layer of tree limbs

FIG. 24. COMPACT EARTH FINISHING THE BUILT-UP FLOOR

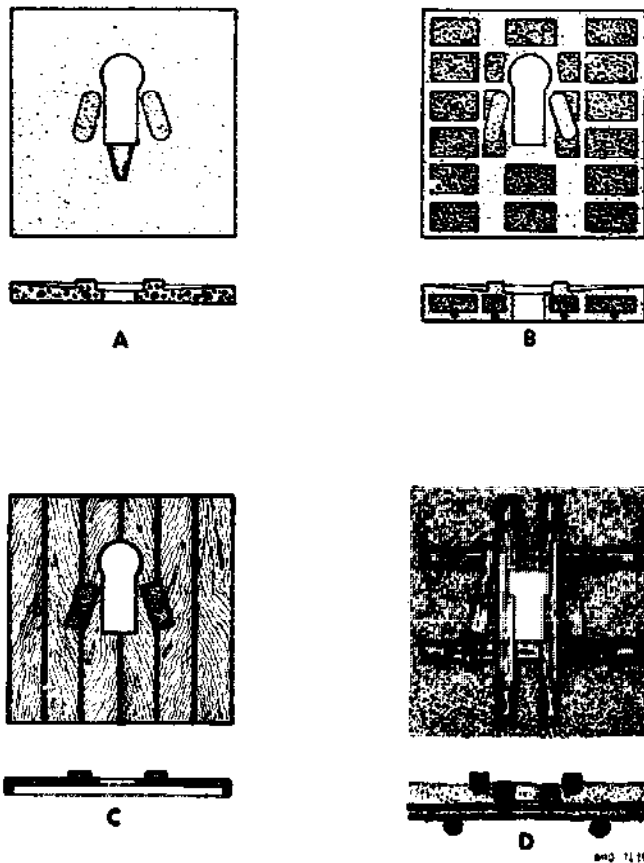


All factors considered, appropriate dimensions for concrete slabs may be 100×100 cm (39×39 in.) in over-all size. Such a slab will weigh approximately 136 kg (300 lb.) if the average thickness is 6.35 cm (2.5 in.). Smaller slabs, 91×91 cm (3×3 ft), have been built where it is easy to complete the floor at the site with a cement surface. Round slabs, 91 cm (3 ft) in diameter, have also been used. Their advantage is that they may be rolled to the latrine site instead of being transported. Fig. 25 and 26 show various types of floor made of lumber, wooden poles and reinforced concrete. Fig. 27 shows a round concrete slab 91 cm (3 ft) in diameter.

The thickness of slabs also varies a great deal in practice. In order to reduce weight, the tendency, of course, has been to reduce the thickness

to a minimum consistent with safety. In this respect, however, much depends on the quality of the concrete and the reinforcement available (see p. 73). When these factors are satisfactory, the slab may be 6-7 cm (2.3-2.7 in.) thick on its edges and 5 cm (2 in.) thick at its centre. A slab 1 m square will then weigh approximately 130 kg (286 lb.). The surface

FIG. 25. VARIOUS TYPES OF FLOOR



- A = Reinforced concrete
- B = Reinforced brick-mortar
- C = Wood
- D = Floor built up with tree limbs and earth

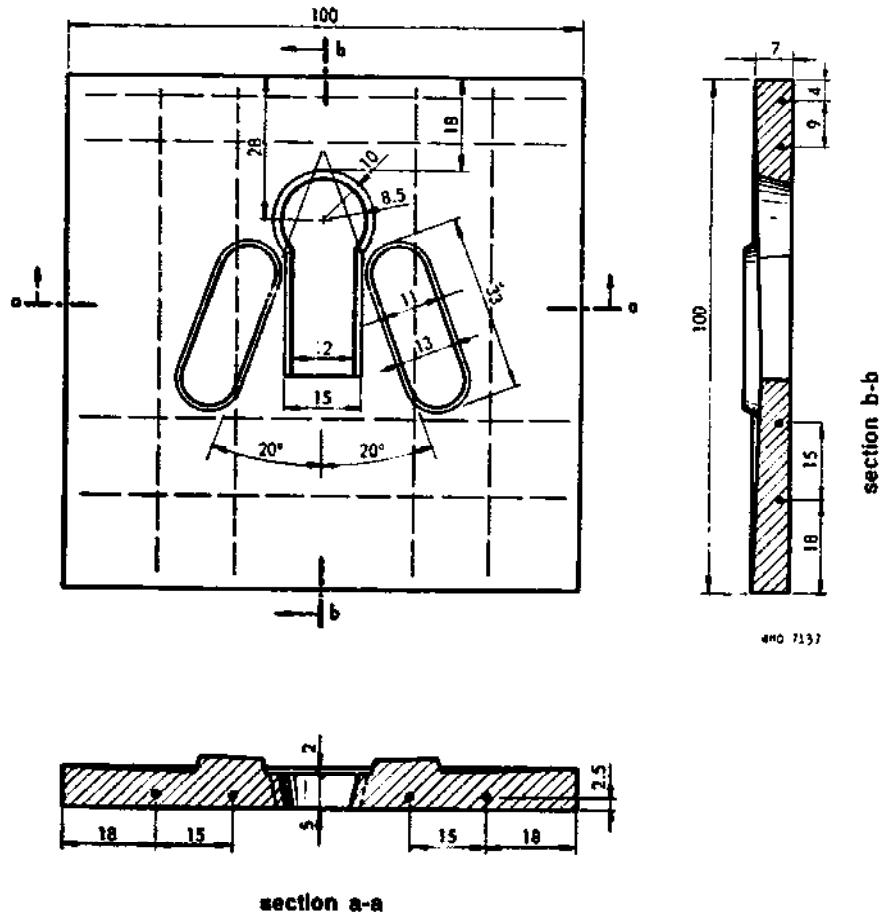
of the slab will slope towards the hole, which is an advantage in Asian countries where water is used for anal cleansing. Where solid cleansing materials are used, the slab may be of uniform thickness throughout, but not less than 6 cm (2.3 in.) thick.

Where it is not possible to cast concrete slabs in place and where the problem of transportation is serious, the possibility of casting the slab in four parts may be considered. Fig. 28-32 show how such a slab may

be built and installed. This procedure is particularly useful for large concrete slabs.

The shape and size of holes for floors with seats are fairly standard in European and American countries. With respect to squatting plates,

FIG. 26. SQUARE CONCRETE SLAB FOR PIT AND BORED-HOLE LATRINE

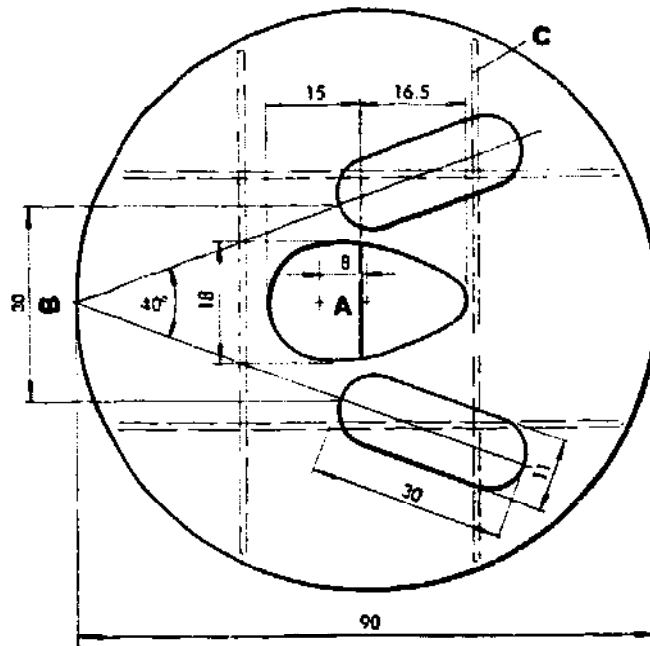


Measurements shown are in centimetres.

however, the literature shows a wide variety of hole dimensions, often with conflicting claims regarding their particular merits. The important considerations are :

1. The opening should be large enough and shaped so as to minimize—or better, prevent—soiling of the floor. An opening having an effective length of about 38 cm (15 in.), preferably more, will satisfy this requirement.
2. It should not be so large that small children may fall into the pit. An opening having an effective width or diameter of 18 cm (7 in.) or less will satisfy this requirement.

FIG. 27. CIRCULAR SLAB FOR BORED-HOLE LATRINE *



*0 6529

Measurements shown are in centimetres.

* Built in East Pakistan. See also Fig. 52.

- A** = Centre open hole 2.5 cm (1 in.) back of centre if slab is 80 cm (31 in.) in diameter ; centre open hole 8.0 cm (3 in.) back of centre if slab is 90 cm (35 in.) in diameter
B = Between back centre foot-rests
C = Reinforcement

Notes on construction of slab

Concrete for slabs should be not weaker than 1 part cement to 6 parts aggregate, with a minimum of water.

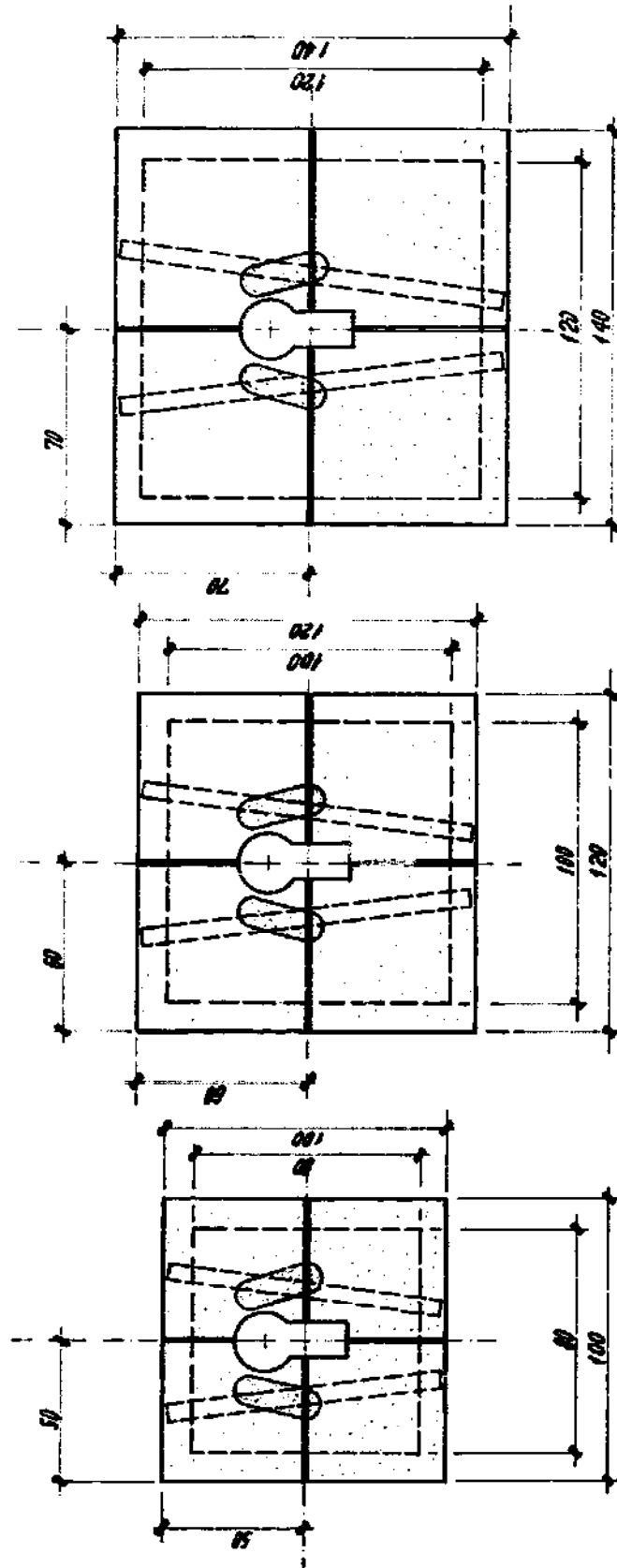
Slab is reinforced with strips of bamboo of timber quality. Reinforcing strips are about 2.5 cm (1 in.) wide, have had inner, weaker fibres stripped away, and have been soaked in water overnight before use.

Slabs are cast upside down in one operation. Base of form is of wood with indentations for foot-rests. Base of form is encircled by sheet metal strip which makes outer wall of form. Side walls of hole form and foot-rests are made with slight slope so as to come out easily. Form for open hole is removed when concrete has taken initial set. Slabs are removed from form in about 40 hours and stored under water, preferably for 10 days or more. Since these slabs are round, they may be rolled some distance when conveyance is difficult.

In communal installations, the number of openings will depend on the number of people to be served. It is good practice to provide one hole for not more than 15 users, preferably one for each 10-12 persons.

It is often recommended that squatting plates should be provided with slanting foot-rests to minimize the possibility of soiling the floor. Foot-rests usually form an integral part of the squatting plate and should be designed to be used by both adults and children. When foot-rests are not properly built—for instance, when they join the floor at a sharp angle or are excessively long, etc.—they make it difficult to clean and scrub the floor.

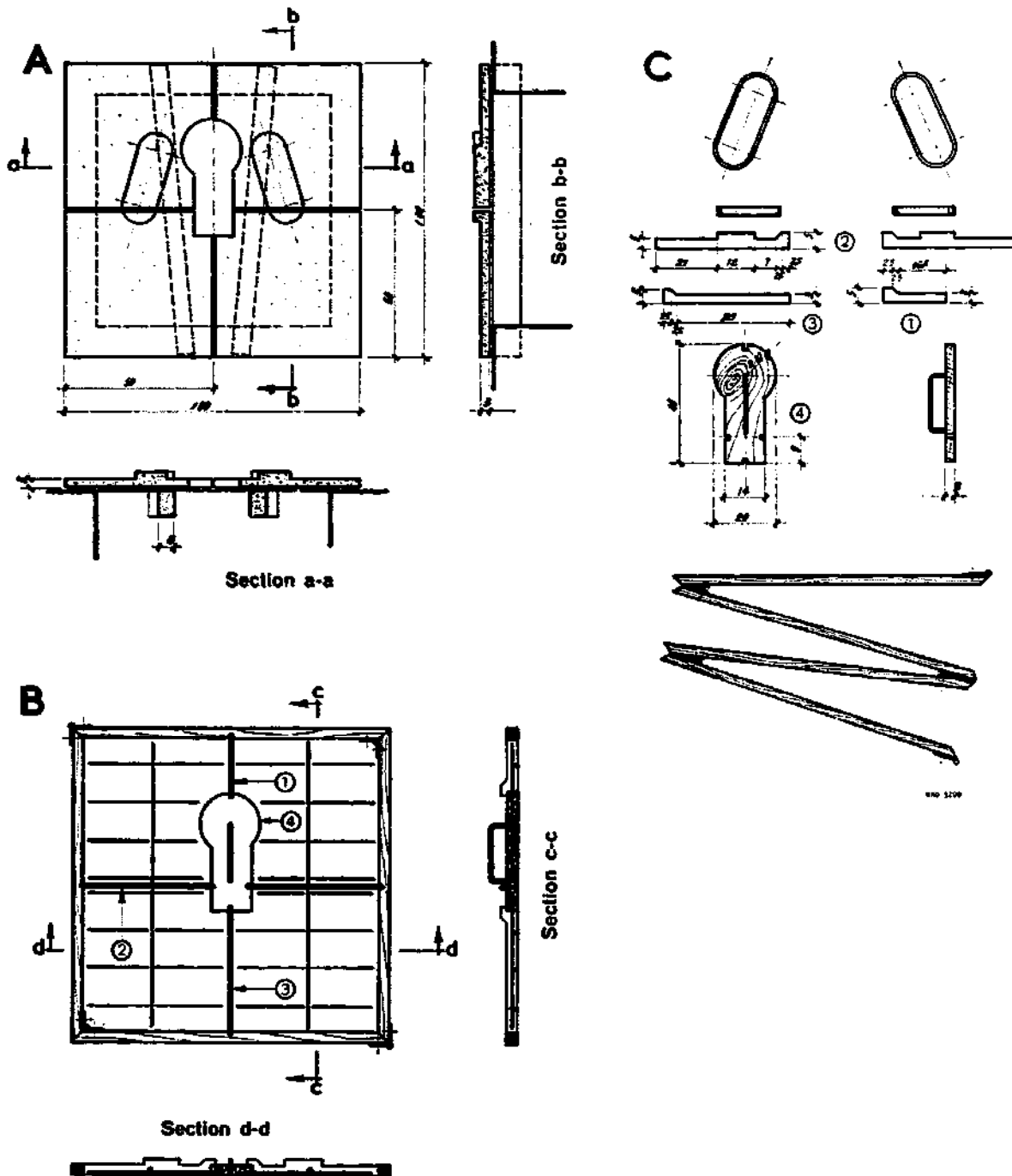
FIG. 8. FOUR-PART PRIVY FLOORS



Measurements shown are in centimetres.

The four-part privy floor can be made in various sizes. The larger the floor, the larger the pit, so the longer it will last, either with or without composting. All details are the same as those shown in Fig. 29, with altered dimensions. Reinforcement should be adapted to slab size. Joints are sealed with cement mortar.

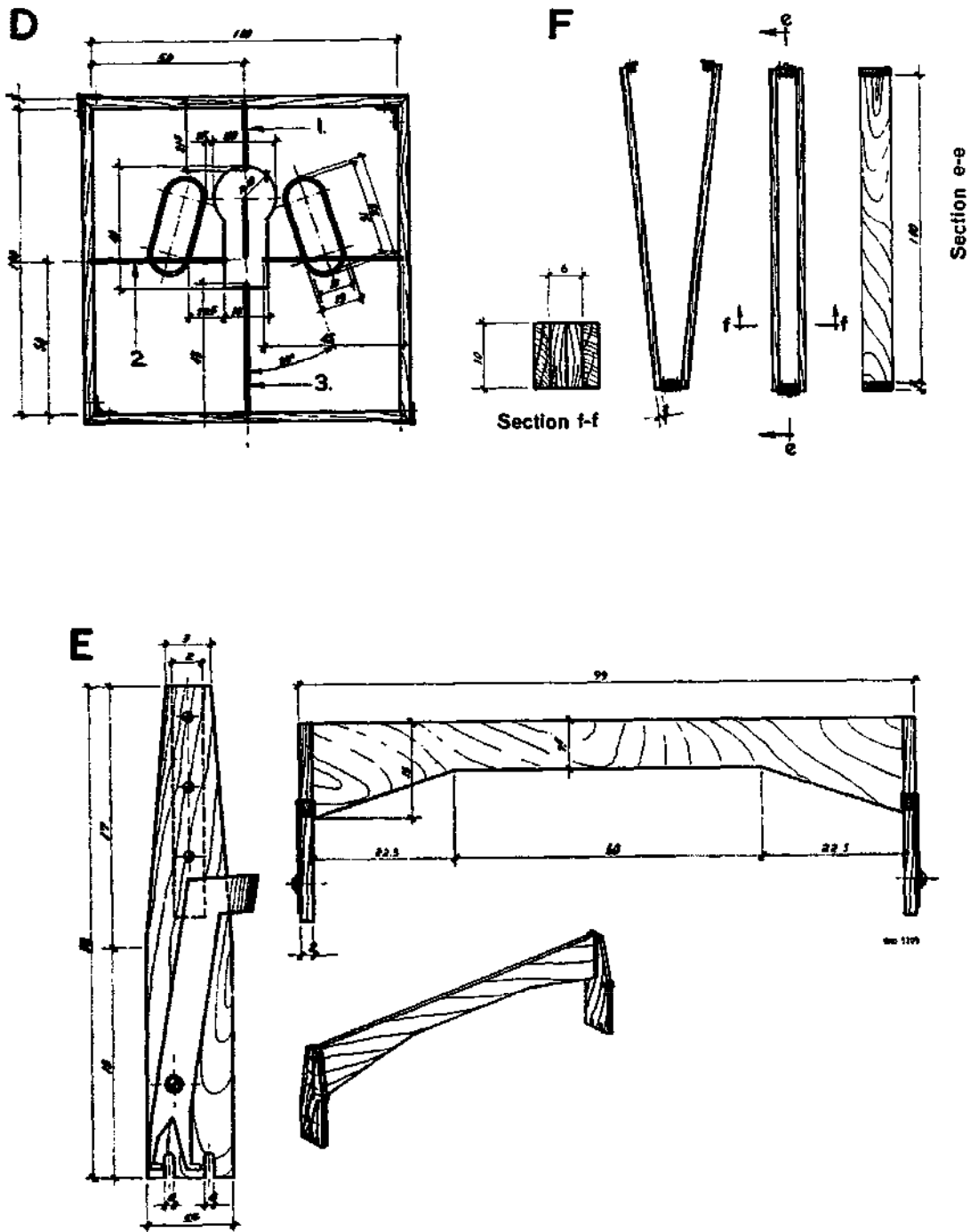
FIG. 29. DETAILS OF FOUR-PART PRIVY SLAB 100 CM (39 IN.) SQUARE



Measurements shown are in centimetres.

- A = Finished floor
- B = Floor form without foot-rests ready for pouring but with reinforcement shown in place
- C = Complete set of forms

FIG. 30. DETAILS OF FOUR-PART PRIVY SLAB 100 CM (39 IN.) SQUARE
(CONTINUED)

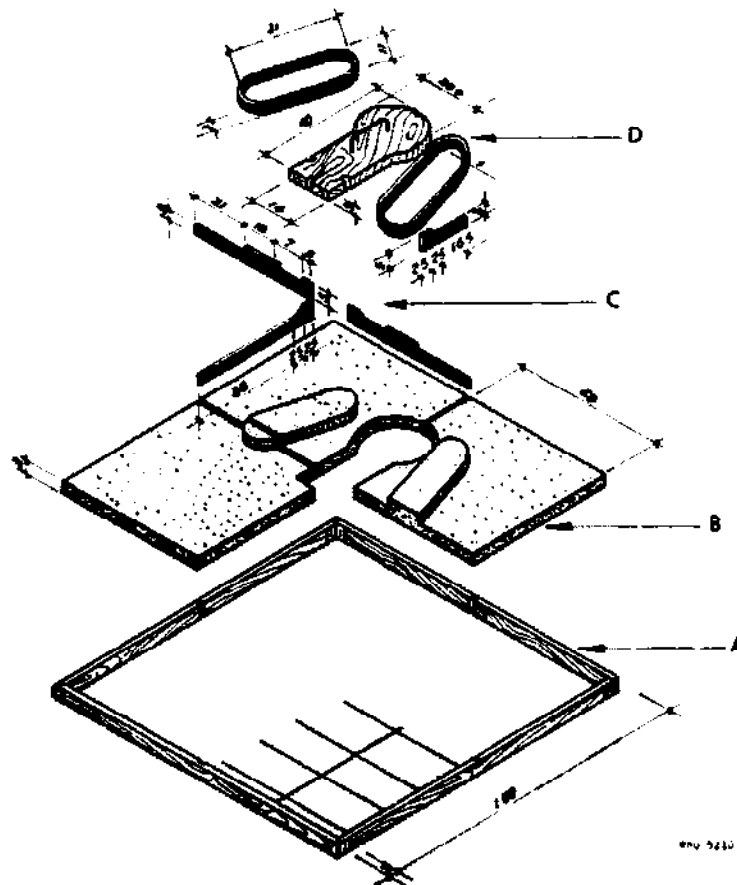


Measurements shown are in centimetres.

- D = Floor form ready for pouring, with foot-rests included
- E = Form for holding steel in place while pouring beams
- F = Beam forms

Another factor which bears upon the acceptance or rejection of a privy by the users is the free distance from the opening to the back wall of the latrine. When this distance is too small, the back of the user will rest against the wall, which may not at all times be very clean and free

FIG. 31. FOUR-PART PRIVY SLAB, SHOWING FORMS

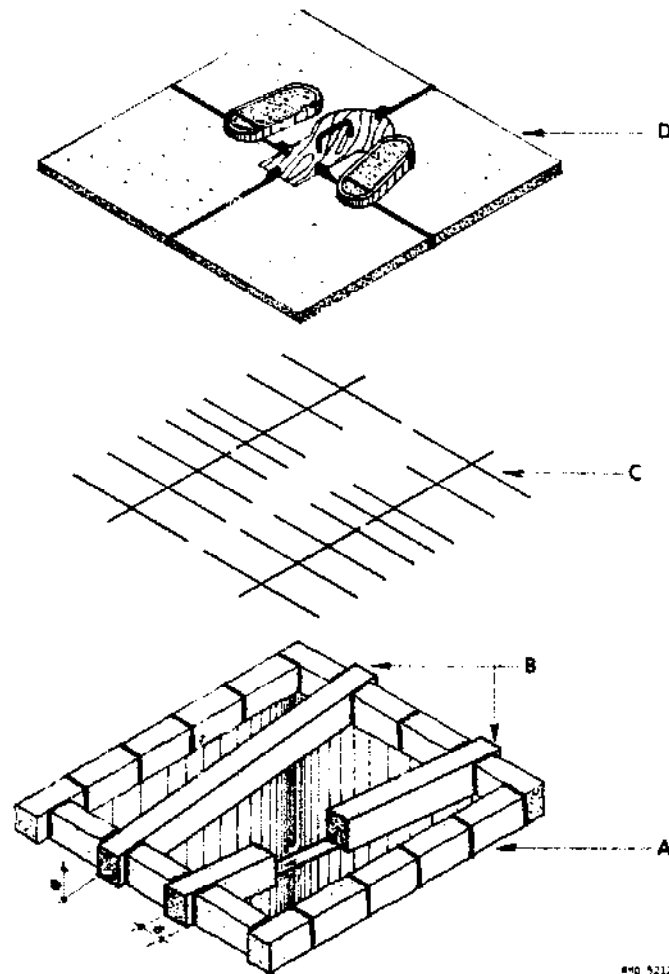


Measurements shown are in centimetres.

- A = Wooden outside form, showing reinforcing steel for one part ready for pouring
- B = Three parts of floor ready for installation
- C = Metal dividers separating floor for pouring
- D = Foot-rest and hole forms

from ants or other insects. Also, there is a chance that excreta may soil the upper portion of the pit wall. Yet this distance should not be too large; otherwise there is a likelihood that the back part of the floor will be soiled. The minimum distance between the rear edge of the opening and the superstructure wall should be 10 cm (4 in.)—preferably 15 cm (6 in.)—and the maximum, 18 cm (7 in.).

FIG. 32. FOUR-PART PRIVY SLAB WITH BASE AND REINFORCEMENT



Measurements shown are in centimetres.

- A = Brick base
- B = Reinforced concrete beams to support four-part floor
- C = Plan of floor reinforcing
- D = Floor showing forms for foot-rests and hole as well as metal dividers separating floor into its four parts

This floor can be easily carried to the point of installation since it is divided into four parts and the slab is very thin. More labour is required for construction and installation, but materials are fewer.

The mound

The function of the mound is to protect the pit and base from surface run-off which otherwise might enter and destroy the pit. It should be built up to the level of the floor and be very well tamped. It should extend 50 cm (20 in.) beyond the base on all sides. In exceptional cases in flood plains and tidal areas, the mound may be built up considerably above the ground for protection against tides and flood waters. It will normally be built with the earth excavated from the pit or surrounding area, and

FIG. 34. COMPLETED PRIVY, SHOWING PALM THATCH WALL AND ROOF COVERING

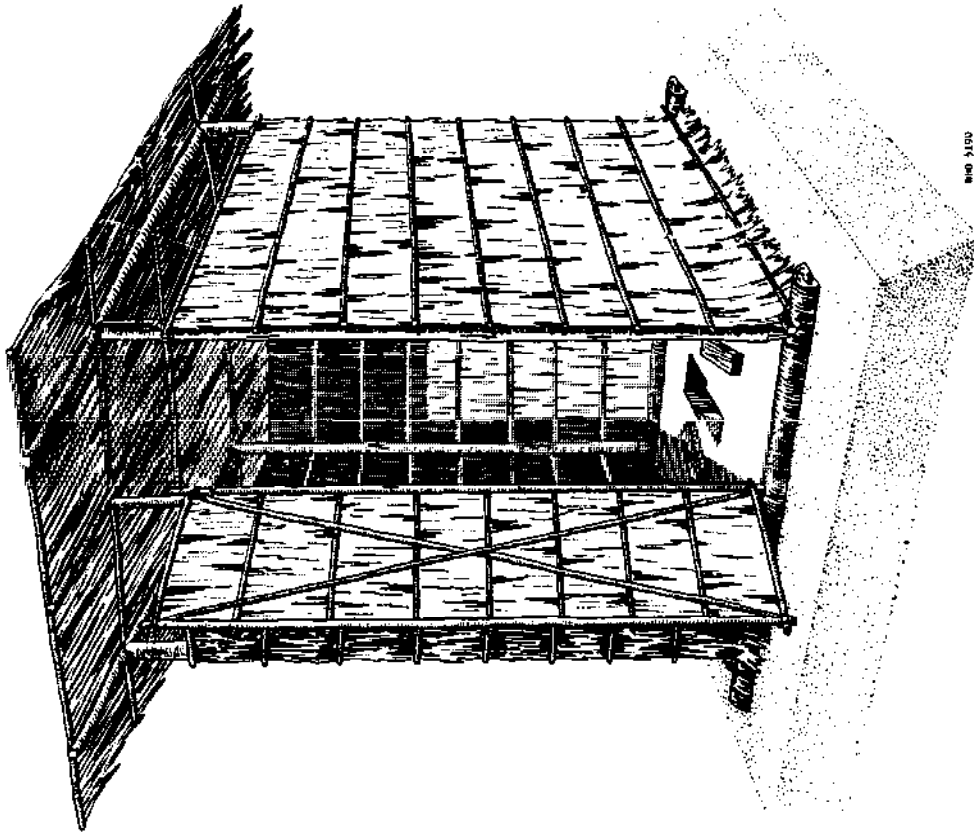
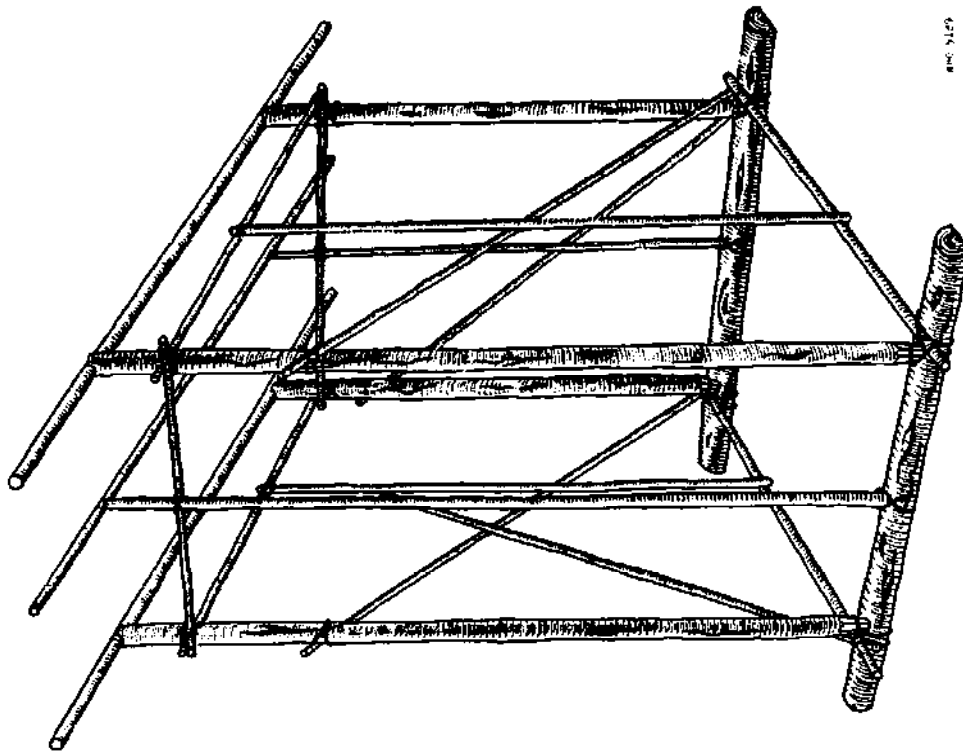


FIG. 33. SKELETON FOR PORTABLE SUPERSTRUCTURE FROM ROUGH-CUT TREE LIMBS AND LOGS



EXCRETA DISPOSAL FOR RURAL AREAS

FIG. 35. WATTLE HOUSE WITH PALM THATCH ROOF

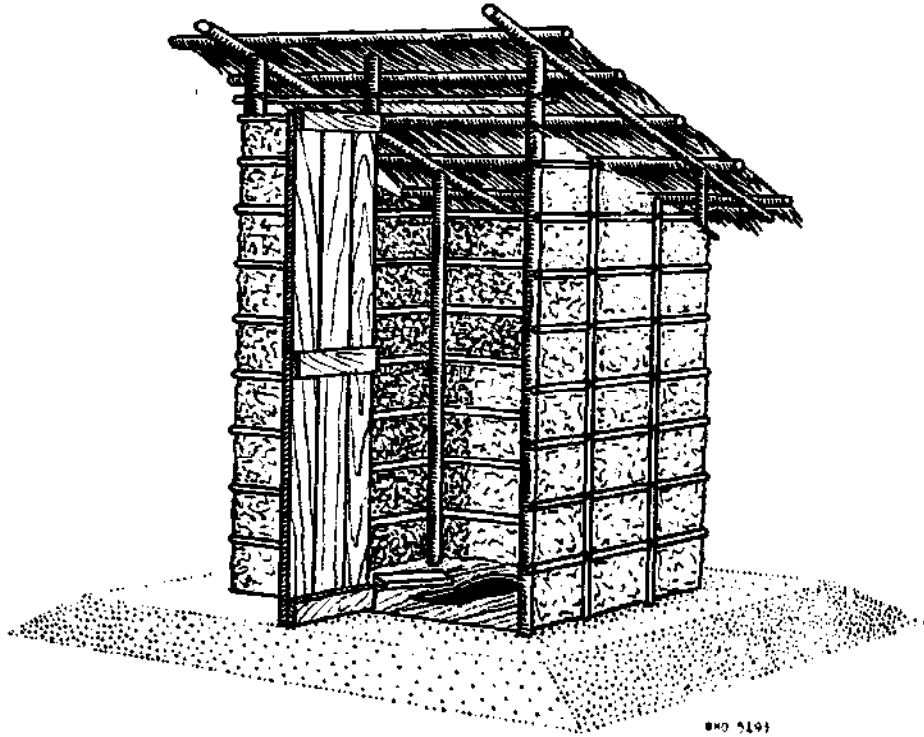
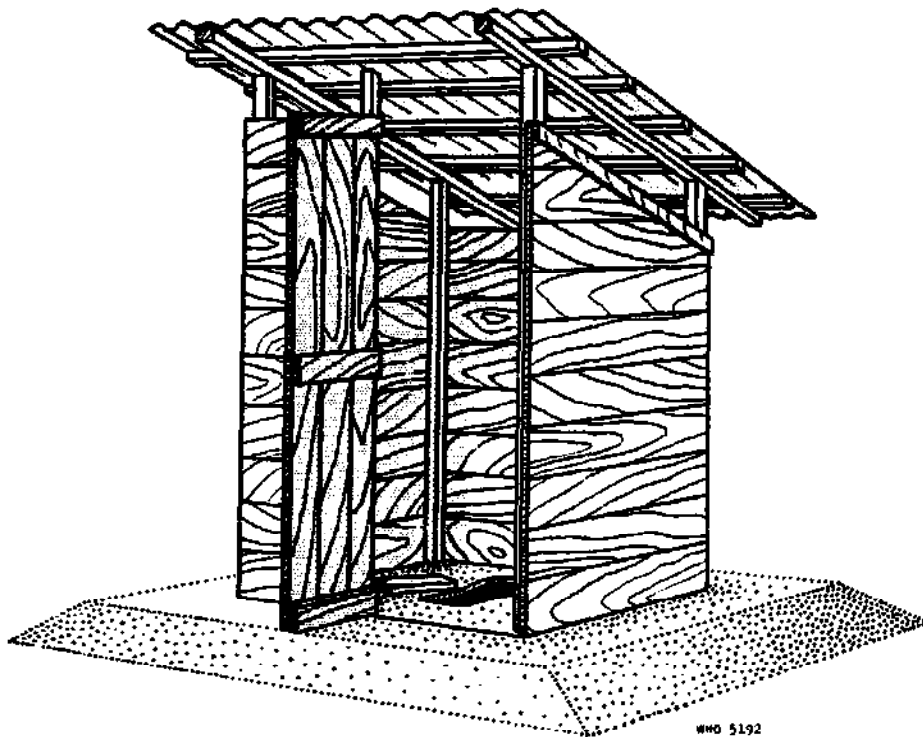


FIG. 36. HOUSE OF CUT LUMBER WITH CORRUGATED METAL OR ASBESTOS CEMENT ROOF



may be consolidated with a stone facing to prevent it from being washed away by heavy rains. In front of the entrance door, it may be preferable to supplement the mound with a masonry or brick-built step. This helps to keep the latrine floor clean.

In the Philippines, where the dwelling is often built above the ground on piles, the latrine floor is also elevated ; and a drop-pipe leads the excreta downward to the covered pit below. This is called the " antipole " system.

The house or superstructure

The house affords privacy and protects the user and the installation from the weather. F.g. 33-38 show various types of house and a typical wooden house frame for use in rural areas. From the sanitary viewpoint, the house is less important than the pit or the floor. For this reason, when latrine programmes are undertaken on a campaign basis, the house is often left for the people to erect in the manner which is most satisfactory to them, only general advice being offered by the health inspector. Standardized superstructures are desirable, however, from many standpoints, among which economy of construction and durability are most important.

A properly built superstructure should conform to certain rules, the most significant of which are :

1. **Size.** It should preferably fit the dimensions of the floor or slab and should never be too large, lest people be tempted to defaecate on any part of the floor at times when the area around the opening has been soiled by previous users. The height of the roof over the slab near the entrance door should be 2 m (6.5 ft) or more.

2. **Ventilation of superstructure.** It is desirable to provide openings 10-15 cm (4-6 in.) wide at the top of the house's walls to facilitate constant ventilation.

3. **Lighting.** Natural light should be available wherever possible. However, the superstructure should provide sufficient shade over an uncovered seat or hole in order not to attract flies.

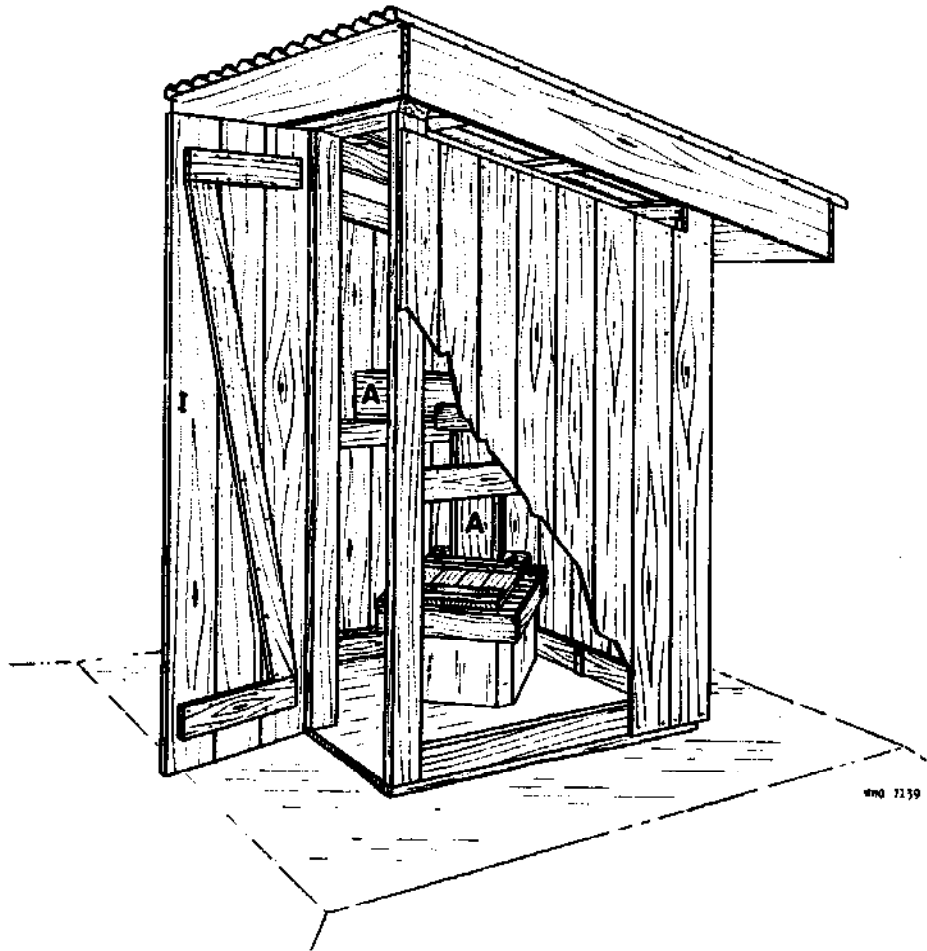
4. **Cleanliness.** A superstructure which is left dirty and in a constant state of disrepair will soon be abandoned and unused as a latrine. It is therefore extremely important that the house be kept clean, at all times, both inside and outside, and that no poultry or animals be housed in it. White or coloured washings of the superstructure should be encouraged, and the vegetation immediately surrounding it should be trimmed. The roof should cover the house completely and have a large overhang to protect the mound and the walls from rain and roof drainage. One of the duties of the health department staff, especially the sanitarians and health educators, is to provide constant advice to the family regarding the cleanliness and the proper use of the latrine.

When it is expected that a latrine will not last long because of small pit capacity, the slab and superstructure should be so designed as to facilitate their removal to a new pit when the existing pit is filled.

Materials used in the construction of the superstructure include, among others, the following :

- (a) wood—cut lumber, may be expensive in some areas ;
- (b) asbestos cement sheets—expensive in most places but durable and portable ;
- (c) metal—expensive but serves for long period ;
- (d) palm or grass thatch—easily available in many places, cheap, and quite durable (When it is placed on a properly constructed frame, this house can be moved.) ;

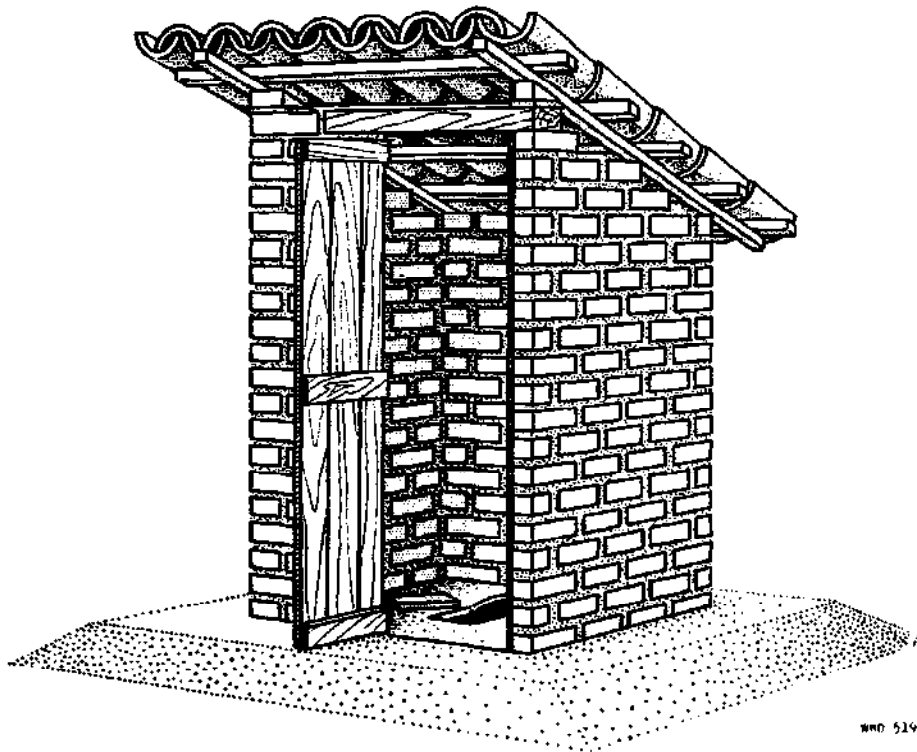
FIG. 37. TYPE OF SUPERSTRUCTURE RECOMMENDED BY US PUBLIC HEALTH SERVICE



Adapted, by permission, from United States Public Health Service (1933) *The sanitary privy*, Washington, D.C. (Revised type No. IV of *Publ. Hlth Rep. (Wash.)*, Suppl. 108).

A = Vent pipe with lateral outlet

FIG. 38. HOUSE OF BRICK WITH TILE ROOF



WHD 5191

(e) brick—mud dried, adobe, burned—permanent but not easily portable ;

(f) mud—if placed on proper form and protected from rains, makes a durable house ; not easily moved ;

(g) protective fence—in some areas where there is little rainfall a fence or screen is built around the privy for privacy in place of a house.

Pit ventilation

The provision of a pit or seat vent may be considered under certain circumstances. In temperate climates or during cool seasons, there is often an appreciable difference in temperature between the air in the pit and the outside air. This temperature difference provokes condensation on the under side of the seat (or hole) cover. It is also believed that a vent induces a draught of air which helps to keep the pit materials dry and small in bulk (completion of aerobic stage of decomposition).

In tropical areas, however, evidence seems to indicate that venting serves no useful purposes. The temperature difference mentioned above is negligible, and the openings are uncovered in most cases. (See Fig. 37 for a typical vent installation.)

Location of Pit Privy

The general rules given on page 32 apply to the pit privy. It may be added here, however, that pit privies should preferably be built at some distance, about 6 m (20 ft) or more, away from a dwelling.

Cost

The cost of pit latrines varies considerably from country to country, depending on the design and local costs of labour and materials. Several figures have been quoted in the existing literature on sanitation, but only a few representative examples are given below since absolute cost figures do not mean much. In order to appreciate their real meaning and value, it is necessary to have information on the local *per caput* income. For countries of South-East Asia and the Western Pacific, it has been recommended that the maximum cost of an earth-pit latrine, including all labour and materials, should not be more than the average monthly income of a manual labourer. This rule might well apply to rural areas everywhere. It is extremely desirable that the cost be reduced to the lowest possible amount consistent with the criteria of health protection, structural safety, and acceptability.

In countries of South-East Asia, the earth-pit privy cost, in 1955, between 30 and 125 Indian rupees (US \$6.30 to \$26.25), including labour and material for the pit, squatting plate, and superstructure. A lower cost of US \$2.30 has been obtained on a WHO-assisted project in Thailand for a latrine with water-seal slab (see p. 87). This cost, however, does not include labour for the pit and superstructure. In Nigeria in 1940, a pit latrine was developed with a pit 91 cm (36 in.) in diameter and 1.83 m

TABLE VI. AVERAGE LABOUR COSTS PER UNIT IN TIME AND CRUZEIROS FOR 1600 PRIVIES BUILT IN THE AMAZON VALLEY, BRAZIL

	Man-days	% of total labour	Cost in cruzeiros *	% of total cost
Slab	0.42	5.9	8.68	8.0
Pit	1.60	22.5	21.04	19.2
Base	1.10	15.5	21.57	19.7
Mound	0.78	11.0	11.52	10.5
House	3.21	45.1	46.61	42.6
	7.11	100.0	109.42	100.0

* US \$1.00 = 20 cruzeiros at the time of this construction.

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**TABLE VII. ANALYSIS OF ALL COSTS FOR 1000 PRIVIES
IN AMAZON VALLEY, BRAZIL: AVERAGE COST PER UNIT IN CRUZEIROS***

	Material	Labour	Super- vision	Local transport	Misc. undis- tributed	Totals	% of total cost
Slab	21.31	8.68	6.07	2.41		29.47	12.1
Pit	2.94	21.04	4.64	0.07		28.69	11.7
Base	5.94	21.57	8.63	2.82		38.96	15.9
Mound	1.58	11.52	3.64	0.07		16.81	6.9
House	44.04	46.61	10.63	2.77		104.05	42.5
Miscellaneous					26.61	26.61	10.9
Totals	66.81	109.42	33.61	3.14	26.61	244.59	
% of total cost	27.3	44.7	13.8	3.3	10.9		100.0

* \$1.00 = 20 cruzeiros at the time of this construction.

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(6 ft) deep and with a dried mud cover supported on sticks. The contract price for such a latrine was 1/- (US \$0.25). In Brazil between 1945 and 1952, the average cost of pit and bored-hole privies was found to be 244.59 cruzeiros (US \$12.23) per unit. These latrines (two-thirds of which were pit privies) had reinforced concrete, squat-type floors, soil-cement bases, tamped earth mounds, and either wooden or palm-thatch houses. The analysis of labour costs and of total costs is shown in Tables VI and VII.

Advantages and Disadvantages

These have been discussed on page 40. Suffice it to say here that, out of the heterogeneous mass of latrine designs produced over the world, the sanitary pit privy emerges as the most practical and universally applicable type.

Construction

Materials

The types of material which may be used to construct various parts of the pit privy have been mentioned above. It is extremely important, in designing privies for rural areas, to plan for the maximum use of local materials. It has been stated earlier that the ultimate objective in any privy project is to get the people of the community to solve their own excreta disposal problem in a sanitary way. The people should therefore be shown a method and means that they can adopt. If the privy units

are difficult to build and full of expensive, imported material, the people cannot be expected to take over by themselves in the future. It should be recommended also, of course, that only good materials be employed. In some cases this may be almost paradoxical, but it is obvious that an installation which begins to fall apart soon after it is constructed is useless. Good materials mean those which will build a sound unit.

In selecting the materials some consideration should be given to the importance of the various parts of the privy ; and, if there is a possibility of employing materials brought in from the outside, such materials should be used on the most important parts. The floor is probably the most vital single part of the unit ; if it can be constructed of reinforced concrete, many subsequent problems are thereby solved. In the first place, concrete makes an impermeable surface that facilitates cleaning ; secondly, if well constructed it will last indefinitely, which is extremely useful for the future when the privy must be moved over a new pit. A good floor is perhaps the biggest stumbling block in getting families to build sound units by themselves. In many countries, especially in Central and South America, there is no further need for intensive privy promotion and construction work in rural areas ; yet health departments continue to fabricate concrete floor slabs, and either to sell them at reduced prices or to give them to the families, who build their own units under the supervision and guidance of the sanitarian. It should therefore be noted that materials can play a valuable role in the rural sanitation programme, and that they should be chosen with care, due consideration being given not only to the initial, but also to the future cost and use.

Mass production

Mass production methods are extremely useful in the construction of sanitary privies whether these are built a few at a time or in great numbers. It is well for the health department to decide on a limited number of types and then to prepare standard plans not only for the unit, but also for its various parts. This procedure has the advantages of :

- (a) economy of construction in time and materials ;
- (b) setting the design, i.e., limiting to a considerable extent the variations which inexperienced staff are apt to introduce into the construction if plans are not made in detail ;
- (c) facilitating procurement of materials ;
- (d) facilitating tremendously the training of workmen to construct the units.

It follows, of course, that where a better selection of materials is possible more use can be made of production in series. In areas where each unit must be constructed of native materials collected locally, there is less

opportunity to apply mass production methods ; but even here some standardization is possible.

The most common and easily mass-produced part of the unit is the concrete floor slab. Forms can be constructed at a central point according to detailed plans to assure uniformity and then be sent to the point of manufacture of the slabs. Here, with a crew of four or five men and ten forms, floors for several hundred privies can be produced in a short time. With proper care, each form can be used hundreds of times. The secret of long form-life lies in careful packing for shipment, keeping them well soaked with oil at all times, and careful handling when in use. A metal form has a fairly high initial cost, but it will last almost indefinitely if properly cared for. In places where transportation facilities permit, floors have been manufactured at a central point and distributed over long distances. This is rather uncommon, and breakage has been found to be high.

After most of the floors have been constructed, one form can be kept at each health centre or wherever an inspector has his headquarters. With the necessary materials, he can usually keep up with the demand for slabs without any special help from his supervisor or any formally organized construction project.

Cribbing of various materials for pits and bored holes has been pre-fabricated in the same way as floors. Houses or parts of houses also lend themselves to production in series.

In many areas, concrete slabs are cast on the spot. This method also has its advantages, which are as follows :

1. There is an opportunity to educate villagers by demonstration.
2. Local voluntary labour and aggregates may be used to reduce unit cost.
3. There are savings in the transportation cost of heavy slabs (about 300 lb. each).
4. There are fewer breakages due to transport.
5. Little technical knowledge is required.

The choice between the two methods must be made by those in the field, and will depend on the type of project, the family's contribution in terms of materials and labour, and other factors.

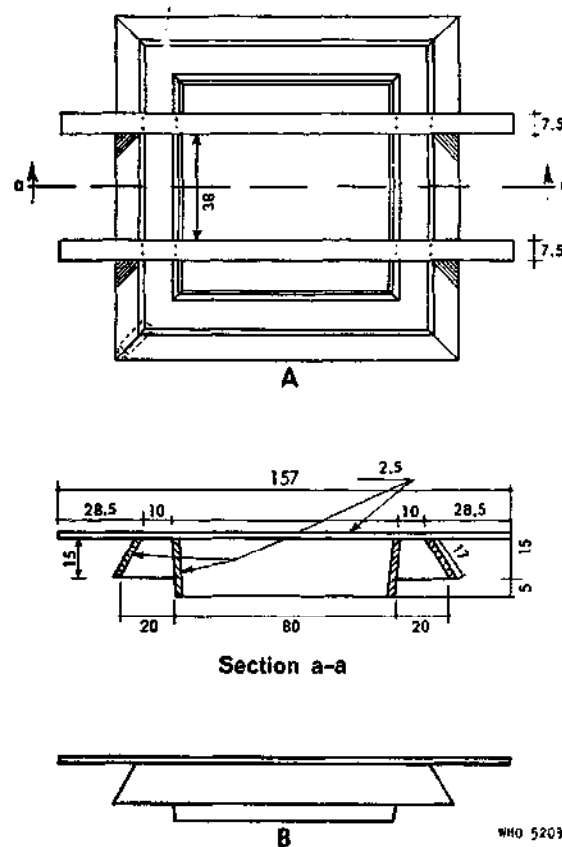
Use of jigs and forms

In any fabrication process, whether simple or complicated, standardization is always desirable to make each part of each unit exactly the same. Building privies is no exception ; and, in order to ensure reasonable similarity, jigs and forms are employed. In digging pits, for example,

it is well to make a simple form marking the limits of the pit where excavation should start. Then, to guide the digger, another form can be made to fit exactly inside the pit, thus assuring that the latter is reasonably close to the size intended.

After the pit is completed, a form can be used to make the base (see Fig. 39). It fits the pit exactly (and facilitates the construction of the base) because the size has been defined by the previous form.

FIG. 39. WOODEN FORM FOR CONCRETE OR SOIL-CEMENT BASE TO USE ON 80-CM-(31-IN.-) SQUARE PIT



Measurements shown are in centimetres.

A = Plan B = Front view, placed on pit

The engineer will find it well worth his time to study carefully the design of the unit to be built and to break it down into its components, using forms and jigs wherever possible to control the work in the field. If, for example, the pits are not started with guides, they will vary from 5 cm (2 in.) to 10 cm (4 in.) or more in either direction, in which case the base and floor may not fit.

These devices are useful to the inspector when he is working alone. He can accomplish more in his supervisory work because the forms guide and control the work to a great extent.

The labour force

It will be found advantageous to spend a little time training a labour force when parts or all of the units are to be constructed in any number. In a reasonably short time men can be trained to do good work and to be consistent in their labours. Their success, of course, is directly dependent on the instruction and on the control measures utilized. A small crew for mixing concrete in floor construction, for example, can be made to understand some simple rules for controlling quality. If they have carefully calibrated cans or boxes for measuring the aggregates and are well drilled in concrete mixing and placing methods, they will produce good products with a minimum of supervision.

It is always advisable to appoint one man in a group as its foreman. A little extra pay will usually bring out supervisory ability. This same procedure applies to the fabrication of a part or of the entire unit. Very often it will pay the health department to hire a person who has had some experience as a construction foreman and to train him in privy construction. Working under the technical supervision of a sanitarian, such a man can often do a great deal of work. With this kind of assistance the sanitarian has time for the important job of contacting and winning the support of the families. This type of organization applies to any kind of construction project; it is especially useful in the execution of privy projects when the health department is contributing money and material.

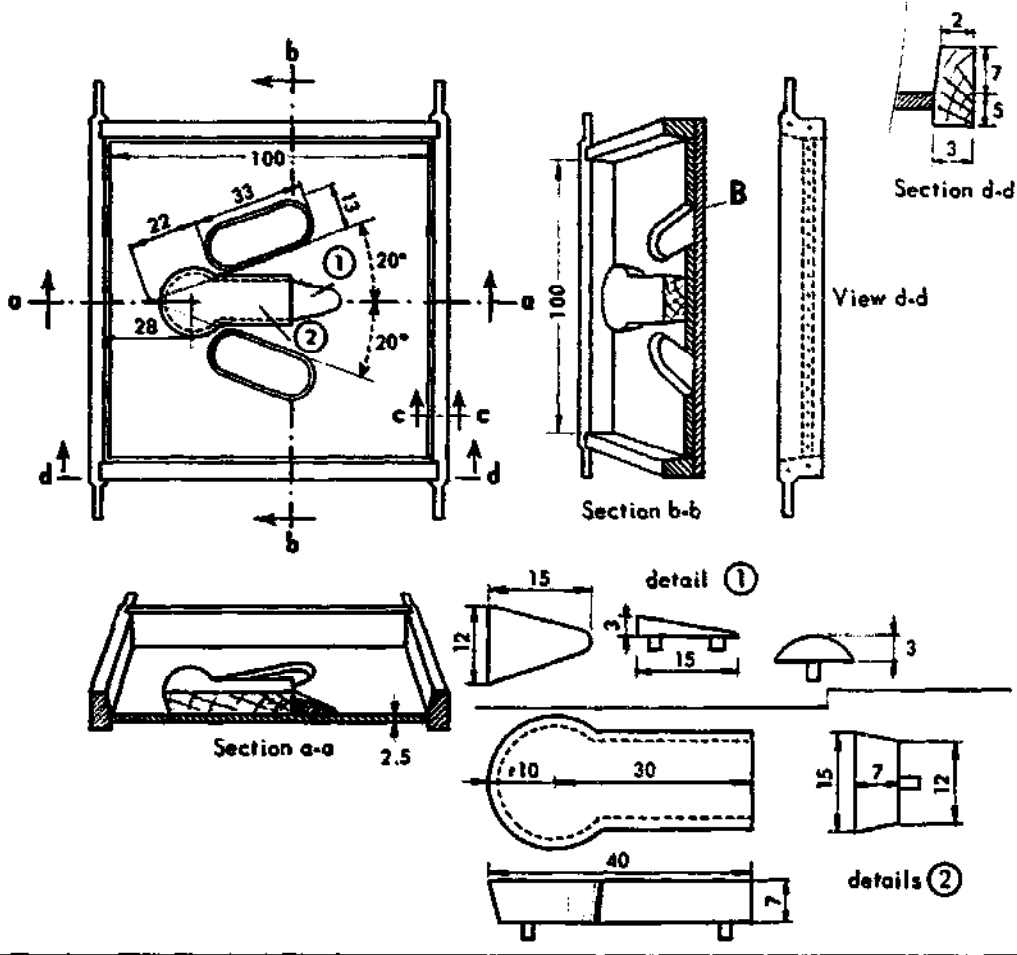
Construction procedures

Procedures used for the digging of pits and the construction of latrine floors and superstructure vary a great deal from one country to another. No attempt will be made to describe them all or to indicate which method is considered best. As pointed out before, the design of latrine features must take into consideration local skills. The following technical information, however, may prove useful in most instances.

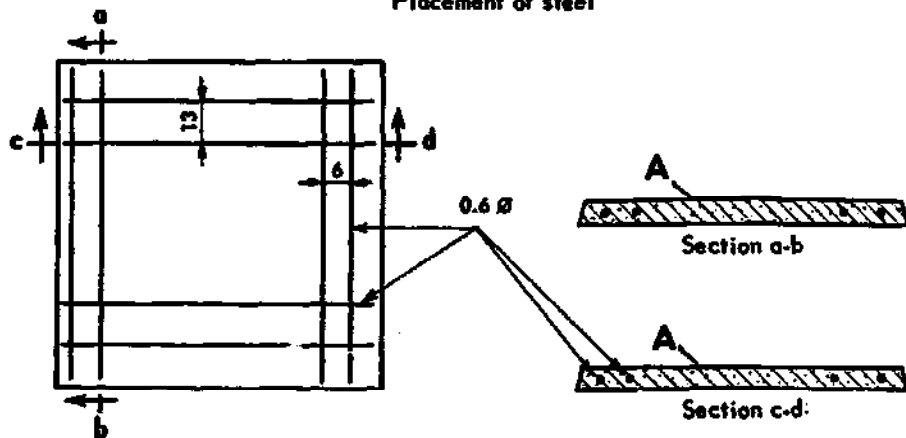
Fig. 19 shows a method of constructing wood in floors out of green logs and wooden planks or wooden poles. Fig. 39 illustrates a simple wooden form for building a concrete or soil-cement base. Typical wooden and steel forms for concrete slabs are shown in Fig. 40 and 41. Wooden forms can be built anywhere to suit the particular slab design and dimensions desired.

Concrete made of one part cement, two parts sand, four parts broken stone (not over 2 cm (0.75 in.) in diameter), and just enough water to

FIG. 40. WOOD FORM FOR PRIVY SLABS 100 CM (39 IN.) SQUARE



Placement of steel



WHO 5205

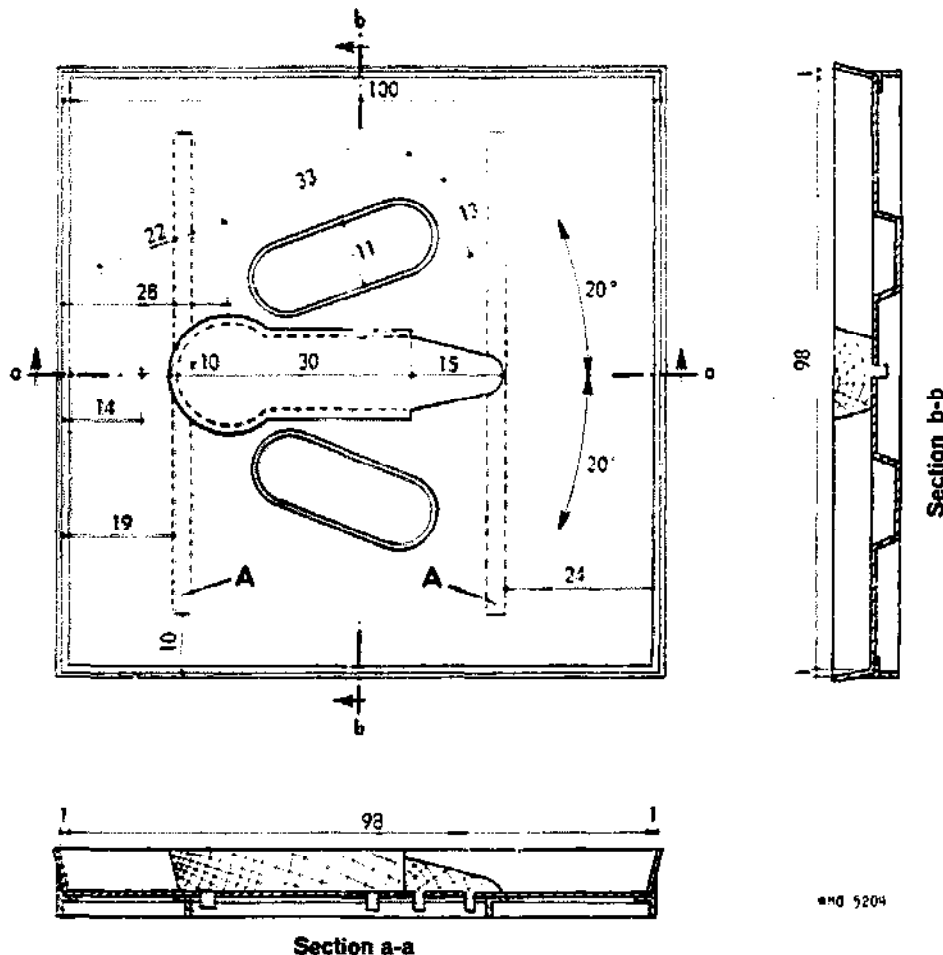
Measurements shown are in centimetres.

- A = Slightly concave slab upside down
- B = Board to support form for foot-rest only

produce a stiff but workable mixture should be used. The concrete may be mixed by hand or by machine. The sand and gravel used should be clean and free from dirt and other excessively fine matter. Reinforcement may be made of hog-wire, 6.35-mm (1/4-in.) steel, or bamboo¹⁷ (after satisfactory field trials).

Concrete should be carefully poured in the form and should be well tamped or spaded, as this operation will make it flow well around the reinforcing bars. The fresh concrete should be covered with a damp mat or straw, which should be sprinkled with water and kept constantly in a moist condition for seven days. This is very important to prevent the concrete from losing part of its water by e. a. poration and, hence, its strength. In mass production operations the slab is removed from the form after one or two days and is immediately immersed in water for five to six days. The slab may also be cast on the ground, or rather on a layer of sand

FIG. 41. STEEL FORM FOR CONCRETE PRIVY SLABS 100 CM (39 IN.) SQUARE



Measurements shown are in centimetres.

A = Angles welded to bottom

spread flat over the ground. This eliminates the need for heavy forms. The slab's surface may then be trowelled to a smooth finish from its upper edges towards the hole.

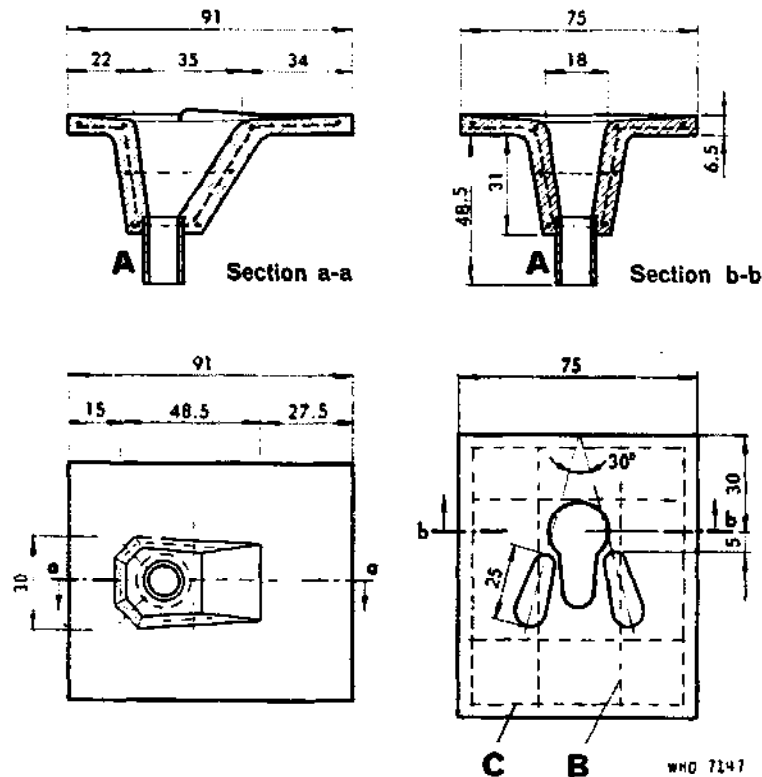
When sand and cement only are available, a mixture of one part cement to three parts sand can be used with brick and reinforcing bars, as shown in Fig. 25 B.

THE AQUA PRIVY

Description

The aqua privy consists of a tank filled with water into which plunges a chute or drop-pipe hanging from the latrine floor (see Fig. 42-44). The faeces and urine fall through the drop-pipe into the tank, where they undergo anaerobic decomposition as in a septic tank. The digested sludge, which is reduced to about a quarter of the volume of the excreta deposited, accumulates in the tank and must be removed at intervals.

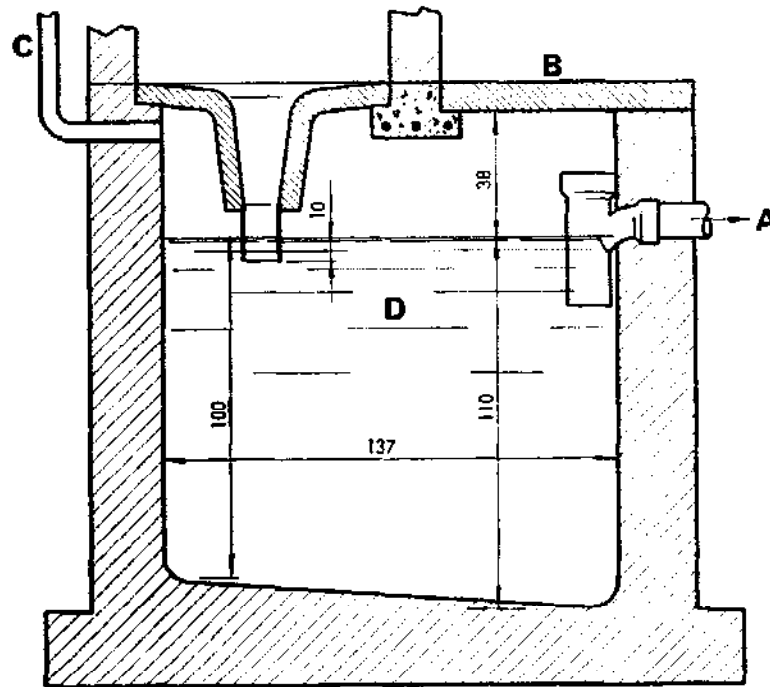
FIG. 42. SQUATTING PLATE FOR AQUA PRIVY



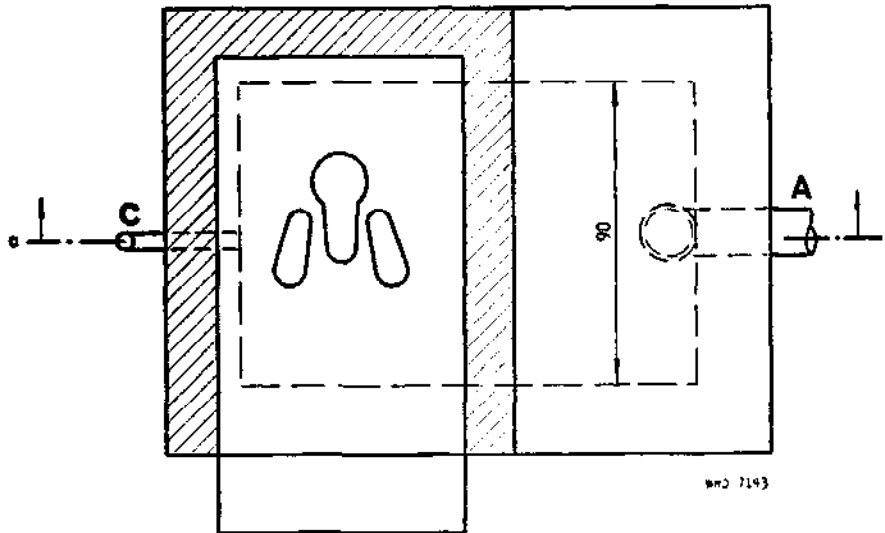
Reproduced from Macdonald, O. J. S. (1952) *Small sewage disposal systems*, p. 138, by kind permission of Messrs. H. K. Lewis London.

- A = Glazed earthenware pipe cut to 22 cm (9 in.) length
- B = Reinforcement, 0.9 cm (3/8 in.) rod
- C = Reinforcement, 0.6 cm (1/4 in.) rod

FIG. 43. FAMILY-TYPE AQUA PRIVY



Section a-a

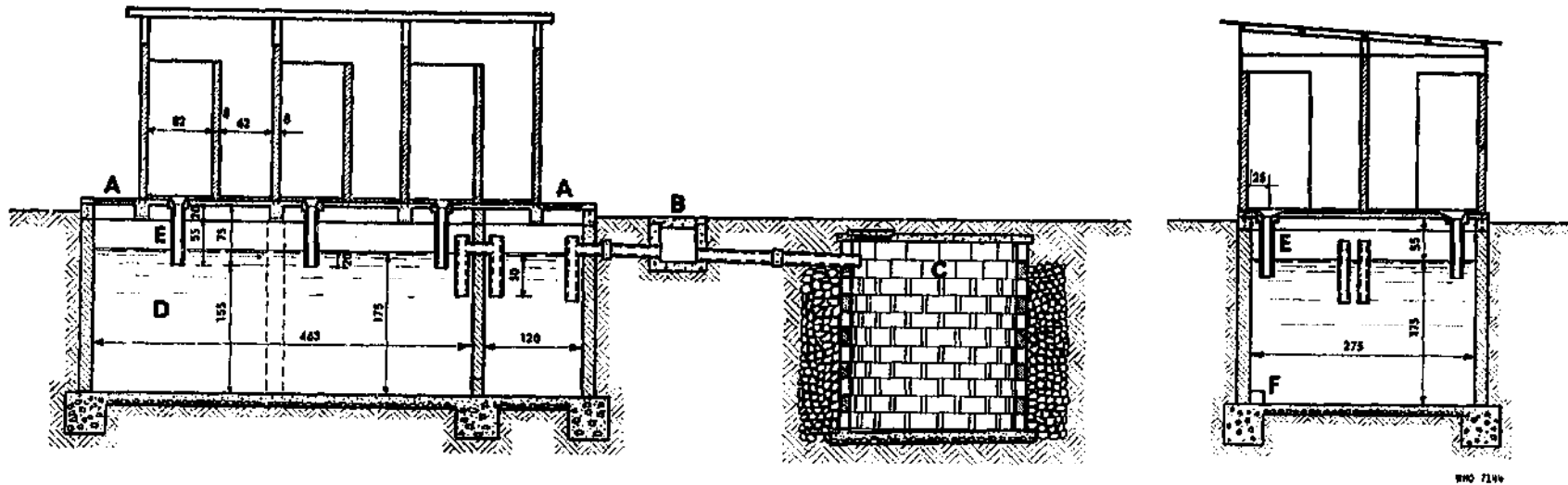


Adapted from Macdonald, O. J. S. (1952) *Small sewage disposal systems*, p. 140, by kind permission of Messrs H. K. Lewis, London.

Measurements shown are in centimetres.

- A = Outlet to soakage trench or soakage pit
- B = Removable, reinforced concrete cover slab
- C = 2.5-cm- (1-in.-) diameter pipe ventilator
- D = Capacity of tank: 1340 litres (295 Imp. gal.)

FIG. 44. PUBLIC AQUA PRIVY BUILT BY UNRWA* IN REFUGEE CAMPS



WHO 7194

Measurements shown are in centimetres.

- A = Inspection manholes, 40 × 40 cm (16 × 16 in.)
- B = Inspection box, 40 × 40 cm (16 × 16 in.)
- C = Soakage pit or soakage trench
- D = Capacity of tank: 22.3 m³ (4900 Imp. gal.)
- E = Drop pipe 10.5 cm (4 in.) in diameter
- F = Opening 15 × 15 cm (6 × 6 in.) in partition wall
- G = For shape of hole, see Fig. 45

* United Nations Relief and Works Agency for Palestine Refugees in the Near East.

Design and Function of Its Parts

The tank

The function of the tank is to receive, store, and digest the excreta, to keep them away from flies and other vermin, and to render them innocuous. The shape of the tank depends on local construction facilities and materials; it may be round, square, or rectangular. Concrete tanks built in place are usually square or rectangular since forms for those shapes are easier to construct. Round tanks may be made of plain concrete sewer pipes 90 cm (36 in.) or 120 cm (48 in.) in diameter placed vertically in an earth pit and sealed at the bottom with concrete.

The size of the tank varies with the number of persons for whom it is designed and with the time interval allowed between sludge removal operations. From information gathered and analysed by Macdonald,²⁹ it appears that the capacity of a family-size aqua privy should preferably be not less than one cubic metre (35 cu. ft), allowing for 6 years or more between cleaning operations. Other data indicate, however, that a smaller tank may also operate efficiently if the precaution is taken to add water to it daily, but that such a tank requires more frequent removal of sludge and undigested debris thrown into the tank. For public latrines of this type, experience dictates a design figure of 115 l (4 cu. ft) per person for the maximum number of persons to be served.

With such sizes, tanks of aqua privies need not be very deep. This is a decided advantage from the viewpoint of construction, especially in areas where ground water or rock level is high. The usual practice is to provide a water depth of 1.0-1.5 m (39-60 in.), 1 m being considered a minimum.

For proper operation of this type of latrine it is important that the tank be water-tight. Should there be any leakage, the water level in the tank will fall below the lower opening of the drop-pipe, and as a result, flies and mosquitos will have access to the tank, odorous gases of decomposition will escape directly into the superstructure, and, finally pollution of the soil and ground water will occur.

Materials commonly used for the construction of the tank include: (a) plain or reinforced concrete, or (b) brick or stone masonry with plaster cover. Concrete is admittedly the best material to ensure water-tightness; in addition, it is permanent and relatively easy to work with. In areas where bricks and stones are abundant, they may be cheaper to use; but they require a coat of rich cement plaster to make them water-tight.

The floor or slab

The floor or slab of aqua privies is usually of the squat type and is provided with a short length of pipe as shown in Fig. 42 and 43. Depending upon its design, it may or may not include a bowl. The earlier type of

septic privy was provided with a riser and seat but had no chute. As a result, the water and scum in the tank were accessible to flies and mosquitos, which bred in it; septic odours were also noticeable. The use of this type of privy is being progressively abandoned in certain better developed countries in favour of better, water-carried, sewage disposal systems.

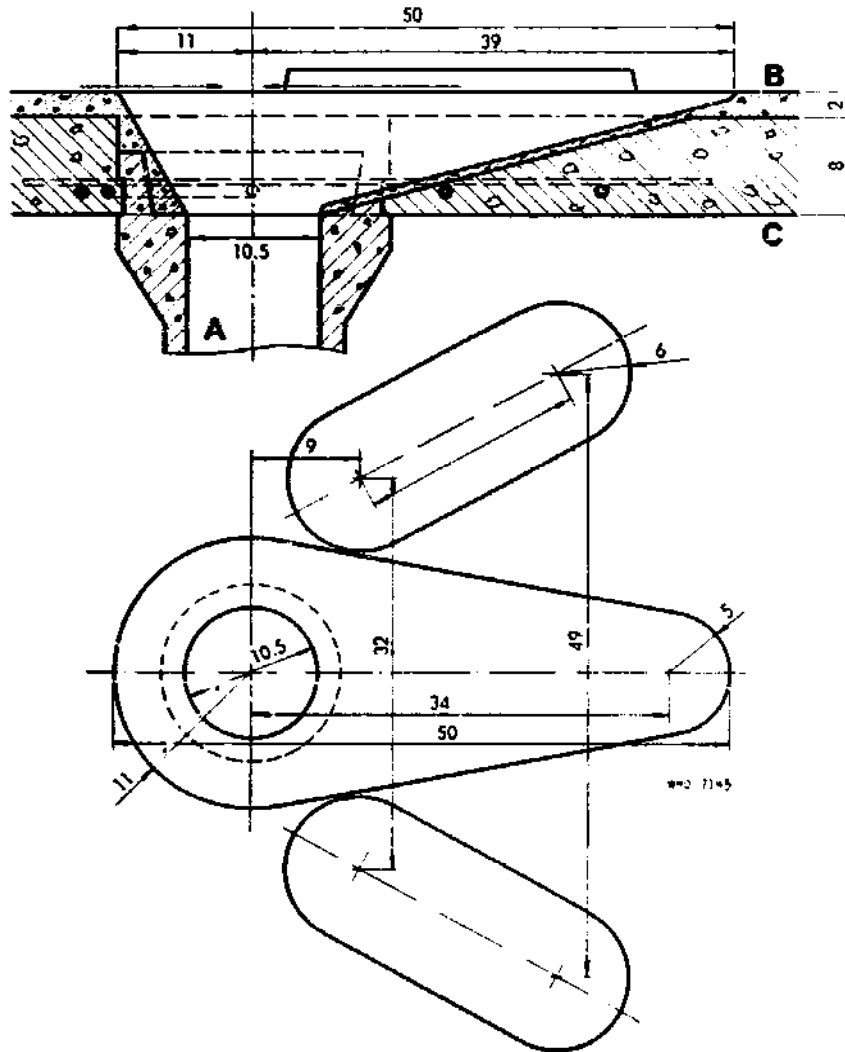
The floor or slab may be made of concrete, wood, or other material. Since the aqua privy is permanent in nature, the floor is usually made of a durable material such as concrete. This material lends itself well to mass production methods, as previously noted in connexion with the construction of pit-privy floors and slabs (pp. 52 and 71). Typical slab designs for aqua privies are shown in Fig. 42 and 45. The size and thickness of the concrete slabs are governed by the same considerations as those already mentioned for pit-privy slabs. The slab surface is provided with a small slope from the edges towards the hole or bowl to ensure drainage into the tank of the water used for cleaning and flushing the slabs, in addition to the water normally used in certain parts of the world for ablution or cleansing purposes.

The bowl is usually made of cement and is pre-cast with the slab, while the chute or drop-pipe is made of earthenware or vitrified clay pipe. Cement pipes may also be used, but will not last as long as the other types mentioned since the lower extremity will tend to disintegrate along the line of contact with the liquid in the tank. The size of the pipe varies from 10 cm (4 in.) to 20 cm (8 in.) in diameter, depending on the anticipated use and maintenance of the privy. If the privy is properly used, the smaller size will be satisfactory; but, in places where stones, mud balls, or sticks are likely to be used for personal cleansing, the larger size will tend to reduce blockage of the pipe. The smaller pipe size will prevent the water from splashing and will normally be free of crust-forming scum when the latrine is in constant use. Pipes larger than 20 cm (8 in.) expose too much of the water surface, over which mosquitos may lay their eggs; in addition, there is an increased nuisance of splashing water.

As to the depth of submergence of the drop-pipe, practice varies a great deal. On this point also Macdonald²⁹ has made a study of the practice followed in many countries and has experimented with 15-cm (6-in.) and 10-cm (4-in.) diameter pipes set with a 15-cm (6-in.) and 10-cm (4-in.) submergence or water seal. He concluded that "the best results were obtained with a 4-inch pipe having a seal of 4 inches, as a narrow pipe and a short seal increases the effectiveness of flushing". A 10-15-cm (4-6-in.) submergence should be sufficient in most cases provided there is reasonable assurance that the tank is absolutely water-tight and that the liquid level will not drop.

In these latrines, perhaps more than in pit privies, there is a great need for foot-rests, the reason being that the floors of aqua privies are likely to be wet from splashing of cleansing and ablution water. As in

FIG. 45. BOWL FOR PUBLIC AQUA PRIVY *



* See also Fig. 44.

Measurements shown are in centimetres.

- A = Drop pipe
- B = Rich sand-cement mixture
- C = Reinforced concrete floor

the case of pit privies (p. 57), foot-rests should be properly designed to ensure prompt and easy drainage of such water towards the hole.

The house or superstructure

The function and design of the house or superstructure for aqua privies are identical to those for pit privies, as discussed above (p. 65).

Tank ventilation

In aqua privies, where the decomposition of excreta is entirely anaerobic in nature, it is necessary to provide for the escape of the large volume of

gas which is normally produced by fermentation. For this purpose a vent pipe should be installed, as shown in Fig. 43. Its opening in the tank should be just below the slab and away from the scum which might choke it. Its outside opening should be above the roof of the superstructure and away from doors and windows of neighbouring houses, if odours are to be avoided. A 7.5-cm (3-in.) pipe will be satisfactory under most circumstances.

The disposal of effluent

For each litre of water added to the water-tight tank of an aqua privy, a corresponding amount of "sewage" must be evacuated and disposed of as effluent. The latter is septic in character and is loaded with finely divided faecal matter in suspension and in the process of decomposition.

It may also carry harmful bacteria and the ova of parasitic worms. Furthermore, because of the small size of the tank, the possibility of water's short-circuiting from the chute to the outlet pipe is obvious. For these reasons, the effluent, though small in volume, should never be permitted to run freely over the ground or in open ditches; nor should it be used for irrigation of garden crops eaten raw.

The average amount of water to be evacuated from an aqua privy has been estimated at about 4.5 l (1 Imp. gal.) per person per day.²⁹ However, a capacity of 9 l (2 Imp. gal.) is recommended for the design of the disposal system. This figure will vary with the degree of availability of water for cleaning purposes and should be corrected by field observations. For example, when an aqua privy is provided with a water tap inside the superstructure, the tank may be expected to receive much more water than is mentioned above and even to be less efficient in its operation. An effluent disposal system designed for a rate of 9 l per person per day will soon be overloaded under such circumstances and will cease to function.

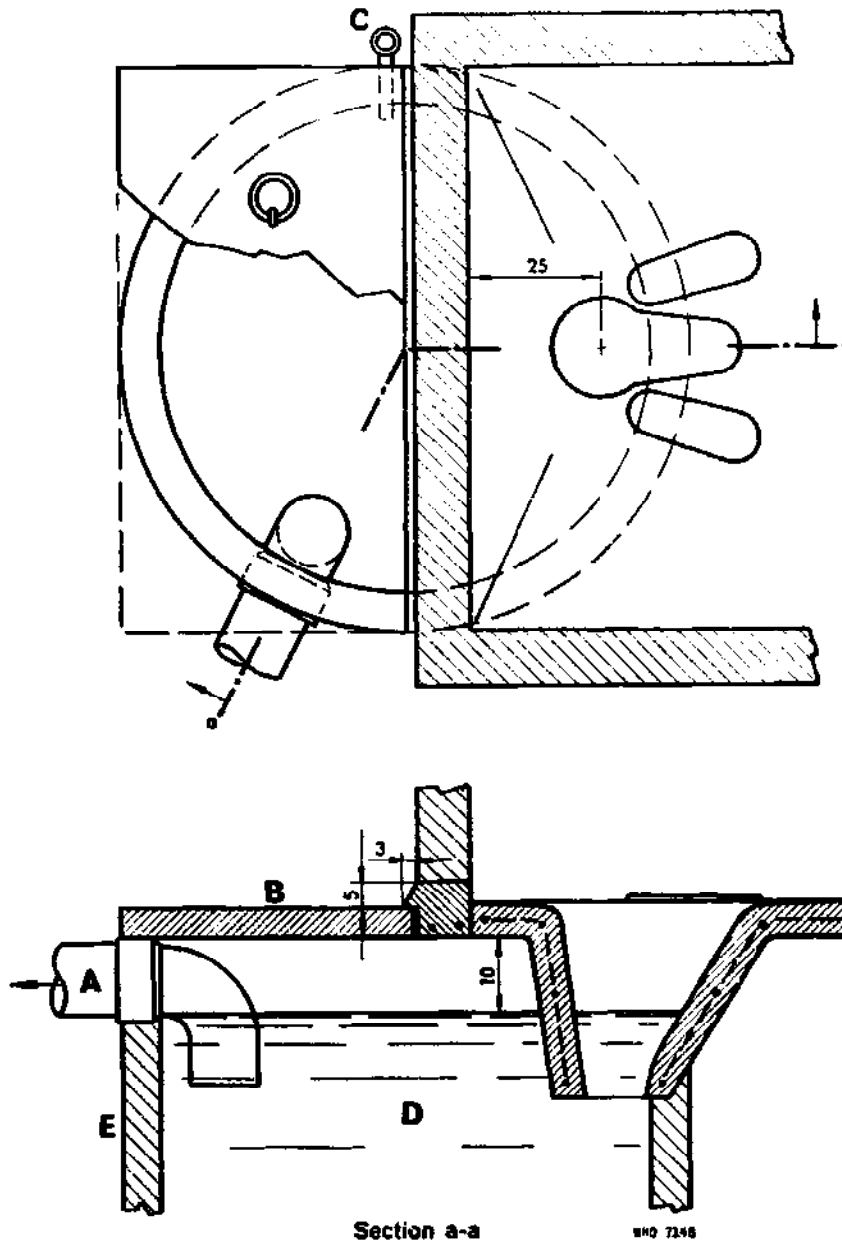
The effluent is carried away through a 10-cm (4-in.) pipe inserted at the proper level into the side of the tank. In order to prevent the scum from entering the disposal pipe, the outlet is fitted with a tee or an elbow, as shown in Fig. 43 and 46. For small installations the disposal of effluent is usually done by seepage pits or subsurface irrigation.

These methods of disposal are discussed later (p. 138 et seq.).

Location of Aqua Privy

A properly operated aqua privy is a clean and odourless installation which may be safely placed close to a dwelling. If proper operation and use cannot be guaranteed, the distance from the dwelling should be increased. Other factors influencing the location of privies in general have been previously discussed (p. 32).

FIG. 46. FAMILY-TYPE AQUA PRIVY USING 90-CM- OR 120-CM- (3-FT- OR 4-FT-) DIAMETER CONCRETE SEWER PIPE FOR THE TANK



Measurements shown are in centimetres.

- A = Outlet to soakage trench or soakage pit
- B = Removable, reinforced concrete cover slab
- C = 2.5-cm- (1-in.-) diameter pipe ventilation
- D = Tank capacity varies with diameter and length of sewer pipe used
- E = 90-cm- or 120-cm- (3-ft- or 4-ft-) diameter concrete sewer pipe, 90 cm (3 ft) long or more, sealed with concrete at lower end

Operation and Maintenance

The first operation in starting an aqua privy is filling the tank with water up to the invert level of the effluent pipe. Some digested sludge, bailed out from another privy, may be added in order to seed the water with the right types of bacteria and micro-organisms to carry out the decomposition process. This is not absolutely necessary; but, if the tank is not seeded, some time (6-8 weeks) is required to reach an efficient level of operation. Once established, satisfactory action will maintain itself thereafter, provided the privy is in daily use. In areas where anal cleansing with water is not practised, the tank will still receive the small amount of water necessary for its proper functioning through a daily cleaning and flushing of the slab and bowl with two or three buckets of water—i.e., approximately 25-40 l (5-8 Imp. gal.).

As in the case of the wet-pit privy, the human waste deposited in the tank will, when digested, be considerably reduced in volume. After several years' operation (6-8 years, approximately), the digested sludge in a family-size installation will occupy 40%-50% of the tank's water capacity and should then be bailed out. Sticks, stones, mud balls, coconut husks, and similar cleansing agents will not disintegrate and will cause the tank to fill more rapidly, which requires more frequent cleaning. Provision should therefore be made in the design of an aqua privy for periodic sludge removal through a manhole. Such a manhole may be located either inside or outside the superstructure. It should provide for easy access to the sludge and to the outlet tee and the ventilation opening, both of which may need to be cleaned of the scum or other solids accidentally lodged in them. The manhole should be tightly fitted to prevent the ingress of flies and mosquitos. It should also be easily accessible, and not be buried under an earth cover and forgotten.

The sludge bailed out will, of course, contain some undigested matter which is still offensive. This should be buried in shallow trenches 40 cm (16 in.) deep.

One difficulty often experienced with poorly maintained aqua privies is that the drop-pipe gets choked with fresh faeces upon which flies lay their eggs. Maggots then hatch and migrate all over the house's interior walls and ceiling and create a considerable nuisance to the users. An attempt has been made to alleviate this trouble, apparently with success, by providing an arrangement for lifting the chute 20 cm (8 in.) before and during flushing. By this procedure the seal is broken for a short period. Another method is to use a plain stick to push the faeces down the chute.

Cost

As previously mentioned, the aqua privy is receiving increasing attention in Asian and African countries. If, as recommended, the maximum cost

of a latrine should not be more than the average monthly income of a rural labourer, the aqua privy could not reasonably be considered acceptable or economical in the rural areas of these countries. It is true that this type of latrine has not seen extensive application in the rural villages of South-East Asia and Africa, chiefly because of its high original cost; it has rather been used in urban or suburban areas, often as a public convenience, and on large plantations and estates.

Few reliable data are available on costs of aqua privies in various countries. In Ceylon, Macdonald²⁹ found in 1952 that the average costs of aqua privies built with permanent materials and including the superstructure were £22 (US \$61.60) for the single unit shown in Fig. 43, and £39 (US \$109.20) for a double unit. The construction of aqua privy parts by mass production methods would undoubtedly reduce these costs.

Advantages and Disadvantages

From the foregoing considerations, the advantages and disadvantages of the aqua privy can be summarized as follows:

Advantages :

1. If properly used and maintained, the aqua privy satisfies the seven criteria, set forth on p. 39 relating to health hazards and aesthetic considerations.
2. The aqua privy is a permanent type of installation which is relatively simple and inexpensive.
3. It can be placed near a dwelling.
4. It will withstand abuse.

Disadvantages :

1. Its rather high initial cost may prevent its extensive use in rural areas in certain parts of the world.
2. It may not be successful in rural areas where there are no organized sanitation and health education services.
3. It requires water (although a small volume only will suffice) for its operation.
4. It requires operation and maintenance on a daily basis.
5. It cannot be used in cold climates.

Among the various types of latrine the aqua privy ranks high, with the pit privy, as a desirable excreta disposal system in areas where the water supply is limited.

Construction

Materials

As in the case of the pit privy, locally available materials should be used to the greatest possible extent in the construction of the aqua privy. However, the aqua privy is a permanent installation which should preferably be built of durable materials. Also, the vital part of an aqua privy is its tank, which must be water-tight. This implies that cement must be used for concrete walls, or for joints in stone masonry or brickwork, and for the all-important plaster coat. Cement is not available in every rural area, and often its cost is prohibitive. This consideration alone may preclude the use of the aqua privy in some instances, and the solution of the excreta disposal problem will then be found in the use of the pit privy with a water-seal slab, or another type of installation suitable to local conditions and meeting local acceptance.

Concrete is to be preferred for the construction of the aqua-privy floor, although wood may also be used. For the house, any locally available material may be used, to suit the owner's taste.

Mass production

The small, family-size, aqua privy lends itself well to construction by mass production methods. The use of large-diameter concrete sewer-pipes, where possible, eliminates the need for forms, which involve lumber and skilled labour, and may result in an appreciable saving of money and construction time (see Fig. 46). The slab, or floor parts, may also be standardized (see p. 71).

Construction procedures

The training and use of a small crew drawn from local craftsmen for building aqua privy tanks are a decided advantage even in areas where pre-casting of parts is done at a central plant.

The essential steps in the construction of the tank are as follows :

1. Dig a pit to fit the size of the tank and place therein a 10-cm (4-in.) layer of gravel, which should be well tamped to make a firm foundation.
2. Pour at one stretch the bottom concrete, at least 10 cm (4 in.) thick, together with 20 cm (8 in.) of bottom wall, using a 1 : 2 : 4 cement-sand-gravel mix with not more than 23 l (5 Imp. gal.) of water per bag of cement.
3. Continue the wall, inserting the outlet tee and vent pipe connexions at the proper levels. Then plaster the inside surface of the tank with a 1.25-cm (0.5-in.) coat of a rich 1 : 3 cement-sand mixture, paying particular care to the joints in the concrete walls.

4. After the concrete has set, test the tank for water-tightness by filling with water for 24 hours.
5. Lay the floor, and complete the superstructure.
6. Dig the seepage pit or disposal trenches as designed.

The construction of concrete slabs has been described above (p. 73). The only difference to be noted here is that aqua privy slabs are always cast in an inverted position to facilitate the casting of the bowl and the proper placing of the drop-pipe.

THE WATER-SEAL LATRINE

Description

The water-seal latrine, also called the pour-flush unit, consists of an ordinary concrete slab into which a specially made bowl is incorporated, as shown in Fig. 47. Usual practices call for a seal 1.25-3.75 cm (0.5-1.5 in.) deep. Such a slab may be installed directly over or at a close distance to, a pit, bore-hole, or septic tank. In the case of the septic tank, the bowl is connected to the tank by a short length of pipe. One to three litres (or quarts) of water are sufficient to flush the contents into the pit. Because of the water seal, flies cannot gain access to the contents of the pit, and odours cannot escape.

Design and Construction

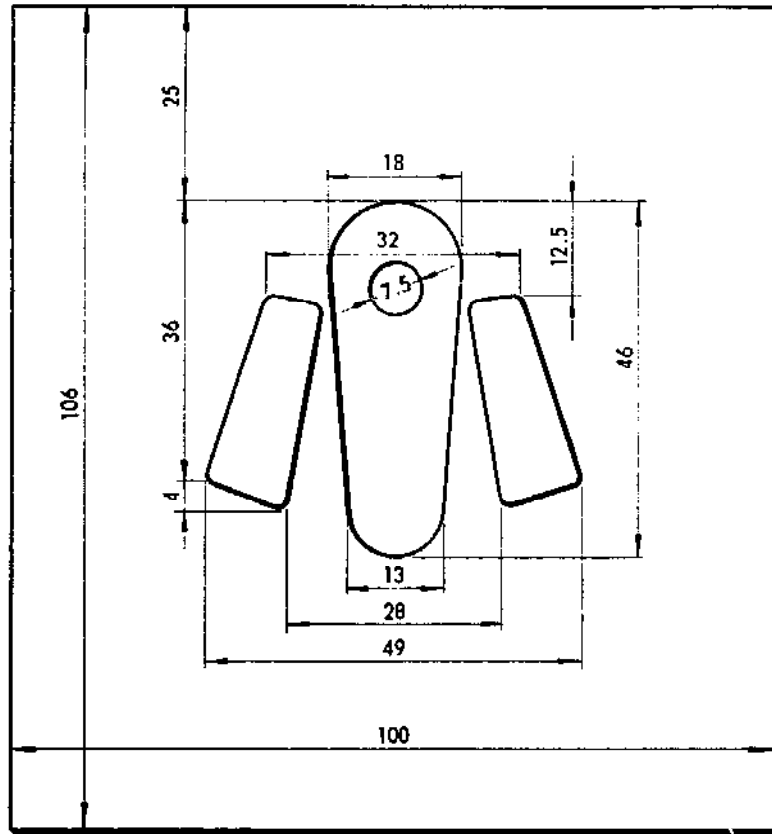
The squatting plate

Various methods have been developed to cast the slab and bowl (see Fig. 48 and 49). Sometimes the trap assumes a P-shape or an S-shape, depending upon the location of the slab with respect to the pit.

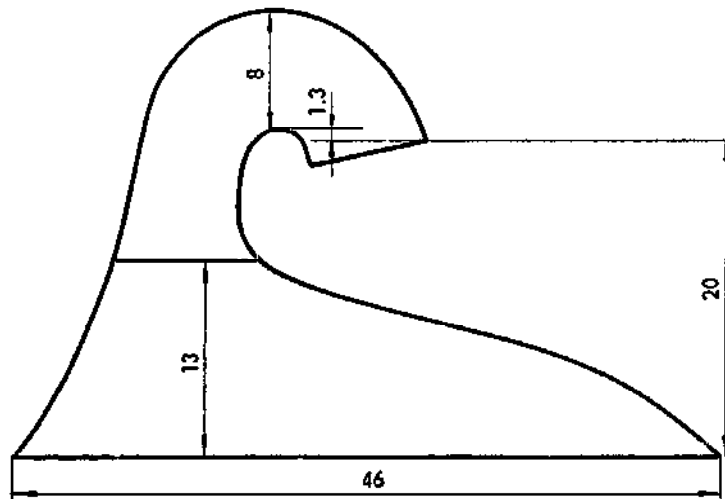
The following description⁴² is drawn from experience at Chiangmai, Thailand, where latrine bowls were formed from cement mortar and incorporated in concrete slabs. The Chiangmai technique, which is applicable everywhere, was found to be more practicable and to result in lower costs than most of the previous methods of casting. The dimensions given are intended merely as a guide, since the size and shape of latrine bowls and slabs are subject to local variations. In particular, the inclusion of raised foot-rests is a debatable point (see p. 57).

The general method of manufacture is as follows. A form is prepared in the shape of the interior of the bowl and trap; the form is plastered with a mixture of Portland cement and sand; and the bowl is left to harden and cure at the point of manufacture. The finished bowl is then transported

FIG. 47. WATER-SEAL LATRINE



A



B

WHO 6253

Measurements shown are in centimetres.

A = Plan

B = Form for casting water-seal bowl

to the latrine site ; the latrine slab is cast, with the bowl forming an integral part of it ; and the finished slab, after hardening, is lifted into place over the latrine pit.

A longitudinal profile of the form for the interior of the bowl is shown in Fig. 47 B. Each form consists of two parts, the main portion being made of a rich cement mortar (two parts Portland cement to one part sand), or of solid wood, carefully finished and oiled ; the other part of the form—for the interior of the trap—is made of clay. In Chiangmai, the wooden form costs the equivalent of US \$3.40 and is much preferred to concrete, both because of its superior durability and because of the greater ease with which it allows the bowl to be removed.

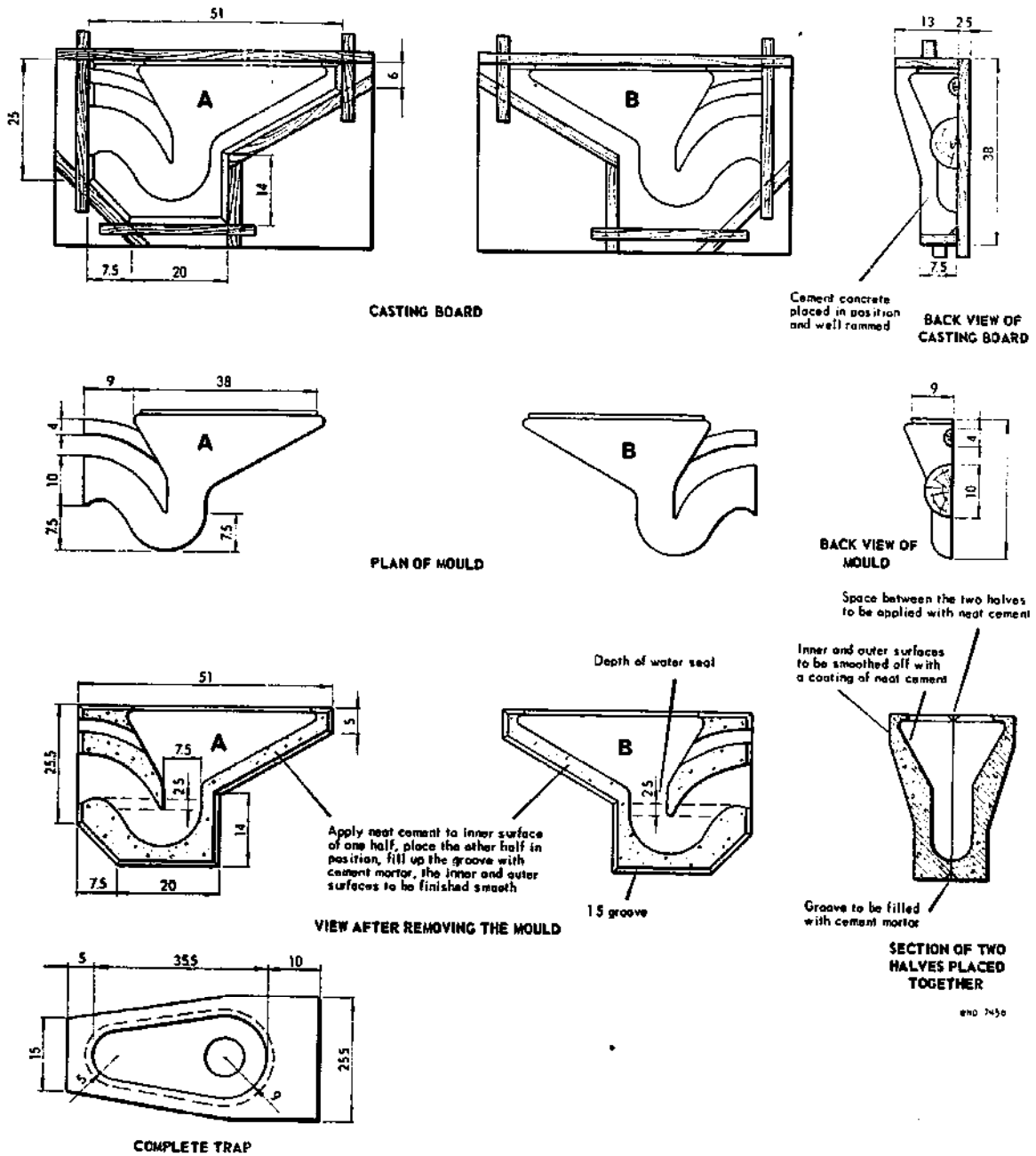
The clay to be used in making the form for the interior of the trap is kept covered with water until needed. When it has been brought to a workable consistency by the addition of ash, it is moulded into a U-shaped roll in a curved pipe-mould. An essential part of the form is a shelf, which is used to support one end of the U-shaped roll of clay ; the other end of the clay roll rests upon the main part of the bowl form. The shelf is located 20 cm (8 in.) above the base of the main form. When the U-shaped roll is set in place, it is carefully smoothed to the main form with a small trowel, so that no irregularity is left on the interior surface of the finished bowl. The whole assembly is then oiled.

A thin cement-sand slurry is pressed over the form by hand, and dry cement is dusted on to provide the bowl with a dense, smooth interior surface. Finally, a stiff mortar, consisting of one part Portland cement to three parts sand, is pressed on by hand and trowelled smooth to a uniform thickness of 1.25 cm (0.5 in.). The bowl is left in place for 24 hours or longer, and is then removed from the form, taking the clay core with it. The operation of preparing the form and making one bowl requires about 25 minutes. After the bowl has hardened, the clay core is dug out of the trap with a small trowel, the entire surface is washed with a cement-water slurry, and the finished bowl is set aside and kept wet for about one week to cure. One 50-kg (110-lb.) bag of Portland cement, costing about US \$1.50, is sufficient for 27 to 30 bowls.

One advantage of the Chiangmai bowl is that the trap discharges forward, beneath the mid-section of the bowl. Experience with traps that discharge towards the rear has shown that the back wall of the pit is liable to be washed away. Such a danger is minimized when the discharge is near the centre of the pit.

The details of the slab used at Chiangmai are shown in Fig. 47 A. The size of the slab must be adapted to the dimensions of the pit. Whether or not a special foundation is needed to support the slab edges depends upon the nature of the soil. The finished bowl is transported to the site of the latrine and is cast into the squatting slab. A hole is dug, and the bowl is inserted so that its rim is level and 5 cm (2 in.) above the surface of the ground.

FIG. 48. METHOD OF CASTING WATER-SEAL SLAB IN CEYLON



Measurements shown are in centimetres.

Details of casting

The casting boards A and B with the moulds fixed should be placed in position and cement concrete 1 : 2 : 2 (0.6 cm or 0.25 in. gravel) should be deposited into position and well rammed.

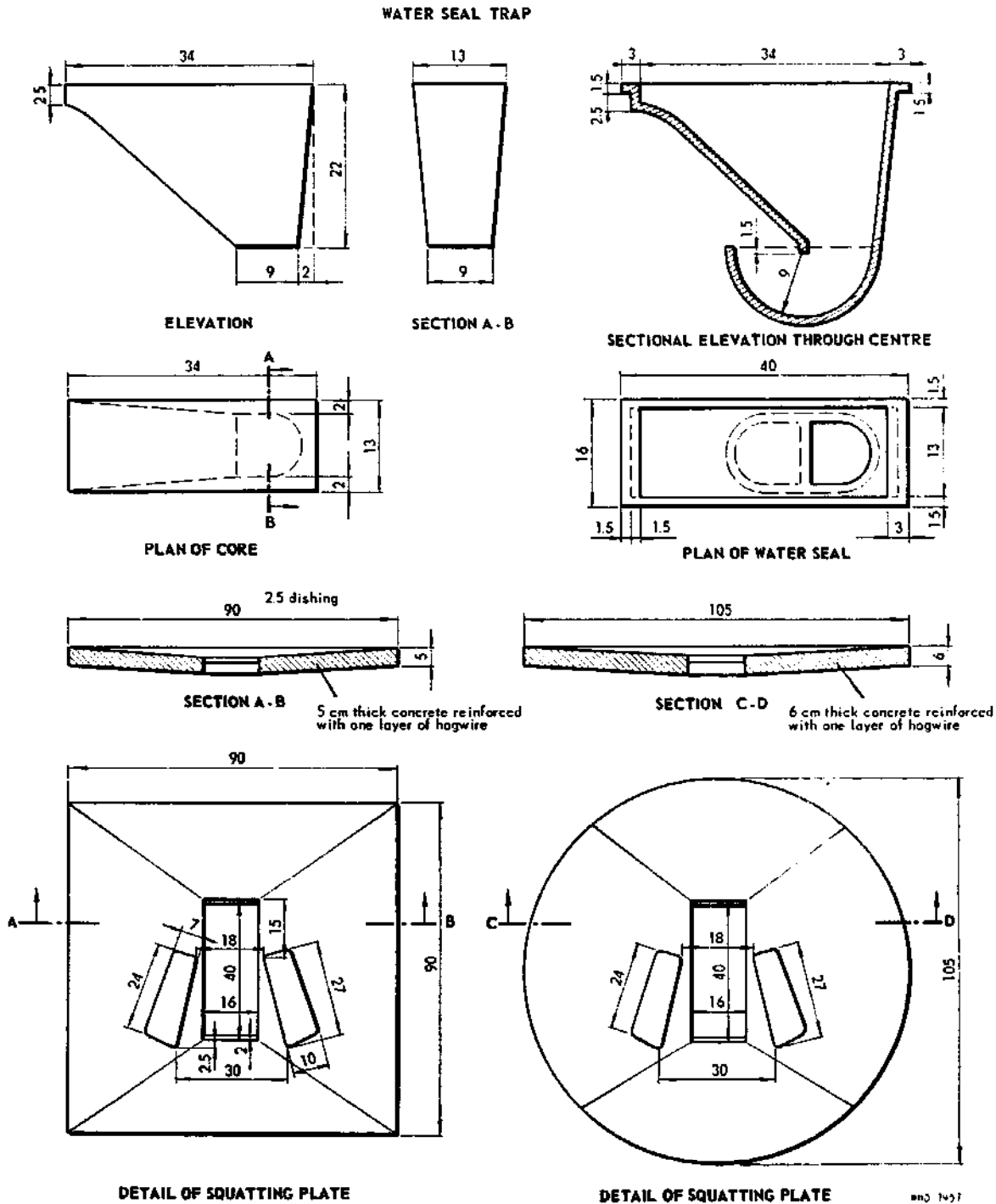
Twenty-four hours should be allowed for setting.

Remove the two halves and apply neat cement to the edge of one half and place the other half in position and fill up the groove with cement mortar.

The inner surface should be smoothed off with a coating of neat cement.

After completion, the trap should be cured in water for a period of at least one week.

FIG. 49. WATER-SEAL TRAP AND SQUATTING PLATE



Measurements shown are in centimetres.

Siphons made of a cement-sand mixture (1 part cement to 1 part sand). Upper portions and lips 1 cm ($\frac{1}{8}$ in.) thick; lower portion, 0.9 cm ($\frac{7}{8}$ in.) thick. Finished weight about 26 kg (12 lb.). Cast inverted in one operation by plastering over core and expendable clay mould (for trap).

Loose soil is packed around the bowl, and a wooden frame, 5 cm (2 in.) high, is set in place, with its upper edge level and 2.5 cm (1 in.) above the rim of the bowl. The ground inside the frame is then smoothed and tamped, so that it slopes downwards from the frame towards the bowl; thus a uniform thickness is preserved in the finished slab. Some kind of reinforcing material—chicken-wire, for example—is then laid, and 5 cm (2 in.) of concrete, made with one part cement, two parts sand, and four parts broken stone (not over 2 cm (0.75 in.) in diameter), is poured on and trowelled to a smooth finish from the upper edge of the form to the edge of the bowl. The slab must have an even finish to ensure easy drainage into the bowl. If foot-rests are required, separate small wooden forms may be used. It should be noted that casting on the bare ground eliminates the need for the heavy and expensive base-boards and ribs which are commonly used. After the slab has hardened, the pit is prepared, and the squatting plate is lifted by hand and set in place over the pit.

The cost of such a slab, based on 1955 prices, has been calculated in Chiangmai as follows:

<i>Item</i>	<i>US \$*</i>
Bowl.	0.25
Slab:	
cement (1/3 bag).	0.50
labour **	0.23
reinforcement	0.23
sand and gravel	0.14
Total	<u>\$1.35</u>

* Exchange rate of 22 bahts to the dollar

** Daily wage of US \$0.68

This estimate includes the overhead costs for casting bowls at a central plant, but not, of course, the cost of digging the pit or building the superstructure. According to Chiangmai experience, when a householder supplies the labour for these last two items, his total expenditure on materials for the squatting plate and the superstructure amounts to approximately US \$2.30, that is, about one-sixth of the monthly income of the lowest paid worker.

The disposal system

When the squatting plate is placed over the disposal pit, the latter is designed and built in the same manner as for ordinary pit privies (see p. 42). If the squatting plate is installed inside the dwelling, the pit is dug outside and assumes the shape and design of a leaching cesspool (see p. 123), or of a bore-hole. In this case, the distance between the cesspool or bore-hole and the squatting plate should be as close as the building foundation permits; otherwise, the drainpipe becomes too long and tends

to clog within a short time because of the small volume of water used to flush the faeces from the bowl (see Fig. 50). The drain pipe is usually 10 cm or 15 cm (4 in. or 6 in.) in diameter and made of cast iron or ordinary cement sewer pipe laid with a steep slope (not less than 5%). Because of the added expense and difficulty in laying this pipe, it is often preferable to place the squatting plate directly over the pit or bore-hole.

Another system makes use of a septic tank in lieu of a pit or bore-hole in areas where the ground water is high and interferes with the proper functioning of deep pits. This system is, of course, very expensive for ordinary rural areas and communities. It should be noted that, in addition, a subsoil disposal field is required in such systems for the effluent of the septic tank.

Location

If properly operated, latrines equipped with the water-seal-type slab fulfil all sanitary requirements and may be placed inside the dwelling itself. Some engineering factors governing the location of the disposal system often prevent such an ideal arrangement. However, even then it is possible to locate such latrines very close to the houses which they serve, a condition which ensures its daily use in bad as well as good weather.

Advantages and Disadvantages

These may be summarized as follows :

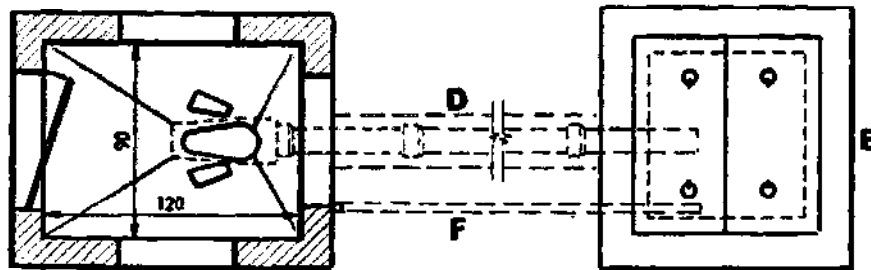
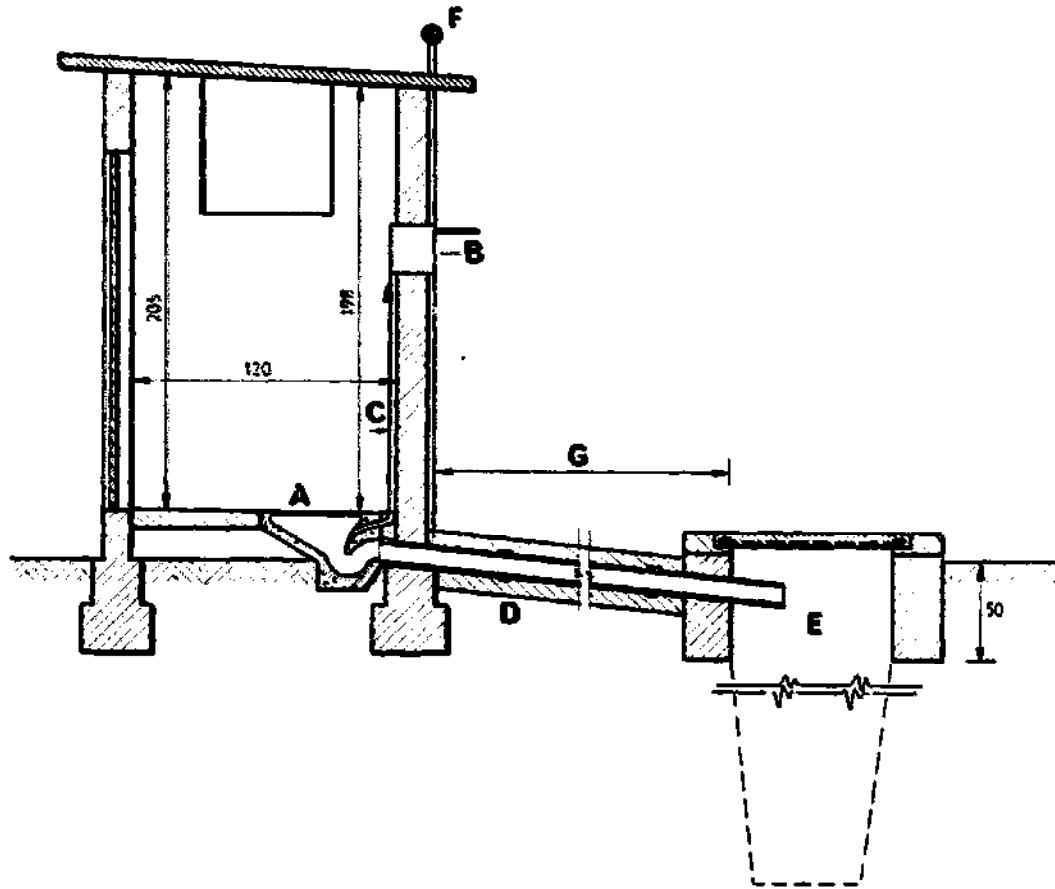
Advantages :

1. The water-seal (pour-flush) latrine, when properly operated and maintained, satisfies all sanitary and aesthetic criteria (see p. 39).
2. It can be installed near or inside the dwelling.
3. It minimizes contact with flies and vermin.
4. The odour nuisance is kept to a minimum.
5. It is entirely safe for children.
6. With improved construction techniques, it is simple to build and cheap for use in rural areas.

Disadvantages :

1. It can be used only in areas where water is obtainable (a small volume will suffice) the year round.
2. It requires a period of intensive education in its proper use and cleaning and continued follow-up by sanitation authorities.

FIG. 50. WATER-SEAL LATRINE USED IN CEYLON



WHO 7438

Measurements shown are in centimetres

- A = Water-seal bowl with S trap
- B = Water tank, filled by hand and provided with plug cock and overflow pipe
- C = Water pipe leading from tank to bowl for flushing purposes
- D = Drain pipe embedded in concrete leading to seepage pit
- E = Seepage pit
- F = Ventilation pipe for pit
- G = Distance between bowl and pit should be as short as possible

3. It costs slightly more than ordinary pit privies, but less than aqua privies.

4. In many rural areas of the world, it would require a change in customary use of cleaning materials.

5. It is not readily applicable in areas with impermeable soils.

6. It cannot be used in freezing climates.

In countries of South-East Asia, latrines with water-seal slabs have been used for more than twenty-five years, and appear to have been readily accepted by the rural people of the region, as they fit in well with their customs and religious patterns. Experience shows, however, that the water-seal latrine should be used only in family installations, that it is not suitable for use in public conveniences.²⁹

THE BORED-HOLE LATRINE

Description

The bored-hole latrine is only a variation of the pit privy, from which it differs by the much smaller cross-sectional area of its pit. The latrine floor, or slab, and the superstructure are the same for both types of installation. The bored-hole latrine, which was developed 30 years ago in the Dutch East Indies,⁴⁶ is now extensively used in countries of Africa, the Middle East, South-East Asia, the Western Pacific, and South America.

Design and Function of Its Parts

The bored hole

This consists of a circular hole usually 40 cm (16 in.) in diameter bored vertically into the ground by means of an earth auger, or borer, to a depth of 4-8 m (13-26 ft), most commonly 6 m (20 ft) (see Fig. 51 and 52). Holes of 30 cm (12 in.) and 35 cm (14 in.) have also been used extensively, and are easier to bore than is the larger, 40-cm (16-in.) size; but experience shows that their capacities are much too small. In fact, the volume of the 40-cm- (16-in.-) diameter hole is considerably smaller than that of the pit privy of same depth, the ratio being 1 to 6.5 in favour of a pit 90 cm (3 ft) square. The same pit privy, 90 cm (3 ft) square, is 11.5 times larger than a 30-cm- (12-in.-) diameter bored hole of the same depth.

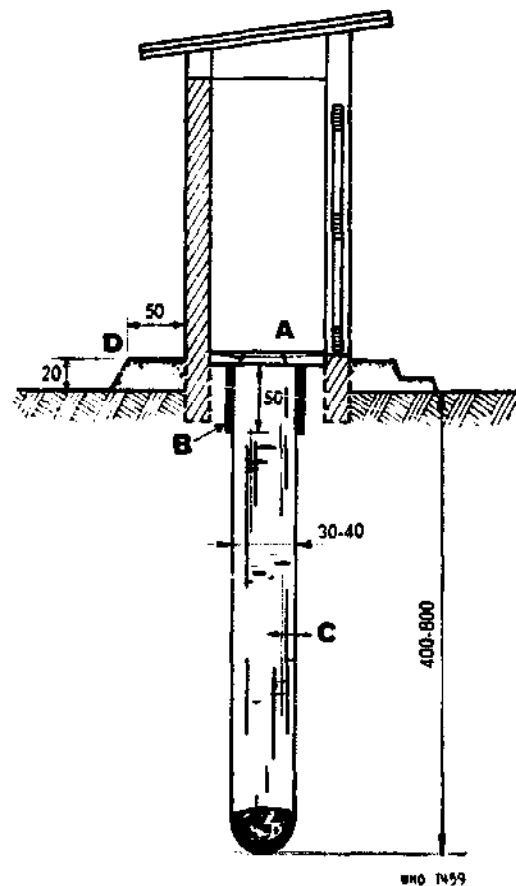
Because of its small capacity, the bored-hole latrine dug into dry ground and used only by a family of 5 or 6 persons does not last more than 1½-2 years in most instances, and less where bulky cleansing materials

are used. The solution in such a case is to build two holes a short distance apart and to use one at a time. When the first hole is filled, it is covered with 50 cm (20 in.) of well-tamped earth, and the slab and superstructure are skidded over the other hole. After about one year, the well-digested material in the first hole is removed, making the hole available for the next move. The life of a bored hole (like that of the pit privy) is appreciably increased when it penetrates 1-2 m (3-6 ft) into ground water, for reasons already discussed under "life of a pit" (p. 43). Chiefly because of its small capacity, the bored-hole latrine is a family type of installation and cannot be used as a public convenience.

The greatest engineering difficulty encountered in the design and construction of bored-hole latrines is the collapse or caving of the pit walls. Caving is rather frequent with this type of latrine, especially in sandy or alluvial soils, and is sometimes so severe as to obstruct the hole completely. In some instances, holes have been bored into dry and firm ground requiring no casing and have caved in during the next rainy season when the ground water rose and flooded the pit. To avoid such occurrences, casings or linings should be provided to support the walls of the pits. Much care must be taken, when planning bored-hole latrine installations, to study ground formations and the fluctuations of ground-water levels in the area under consideration.

Because of the small dimensions of the bored hole, the upper section of the pit is likely to be soiled by both excreta and urine. This may result in offensive conditions, and flies may be attracted and breed in the earth below the squatting plate. To alleviate this situation, it is good practice to line the upper 30-60 cm (12-24 in.) of the bored hole with a tight, impervious lining (e.g., concrete, baked clay).

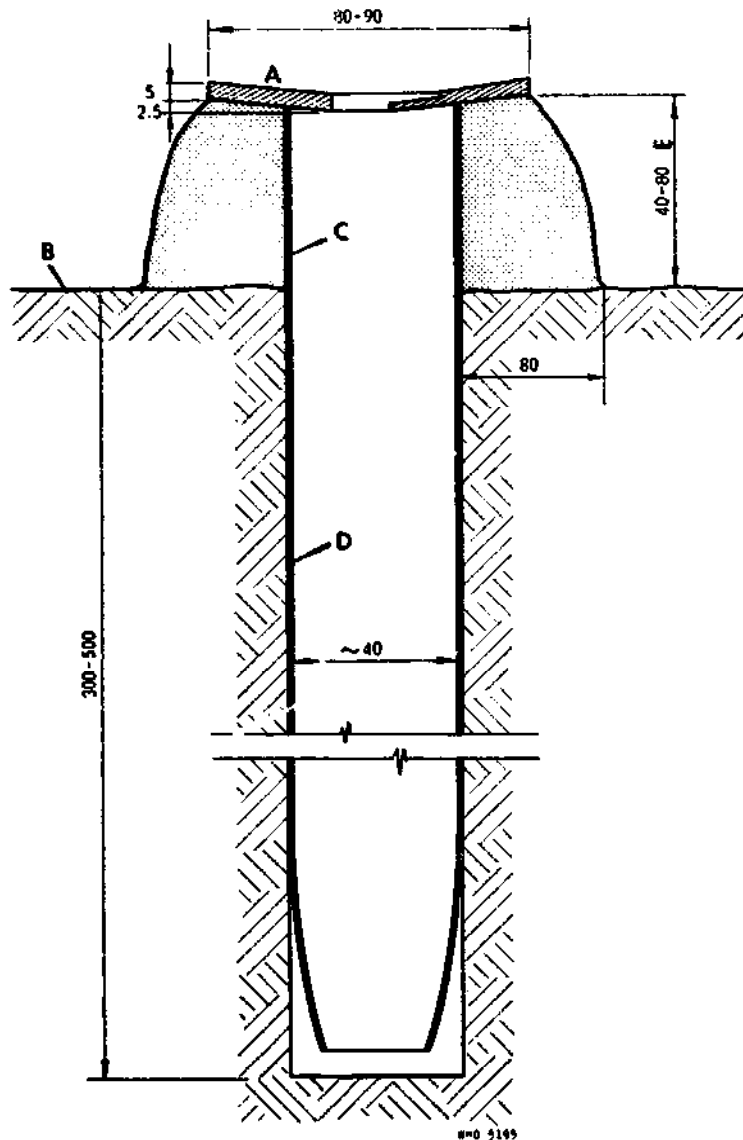
FIG. 51. TYPICAL BORED-HOLE LATRINE



Measurements shown are in centimetres.

- A = Squatting slab. Note sides sloping towards hole
- B = Impervious clay-tile lining
- C = Woven-bamboo lining
- D = Earth mound, well tamped

FIG. 52. BORED-HOLE LATRINE IN ALLUVIAL SOILS, SUITABLE FOR FLOOD PLAINS AND TIDAL AREAS*



* Built in East Pakistan. Measurements shown are in centimetres.

- A = Round slab with slope to centre, as shown in Fig. 27
- B = Original ground
- C = Bamboo lining required in mound
- D = Bamboo lining full length if required
- E = Tamped earth mound

The floor or slab

The floor of a bored-hole latrine is identical in size and shape to that of the pit privy (see p. 52). When the floor is built of concrete, it needs little or no reinforcement because of the small unsupported span (40 cm, or 16 in.) of the bored hole latrine slab. The thickness of the concrete

slab may be safely reduced to 5 cm (2 in.) on the slab edge and to 4 cm (1.5 in.) at the centre. It is desirable to use hog-wire or similar reinforcement, chiefly for the purpose of preventing cracks caused by temperature differences and by shocks during transportation. The floor is usually raised 15-20 cm (6-8 in.) above normal ground level, but a specially built base is generally not necessary.

The mound

A mound of earth should be built around the floor to protect it against run-off. The mound should be at least 50 cm (20 in.) wide and well tamped. In flood plains and tidal areas, the floor should be elevated above the highest water level, and the mound solidly built. As shown in Fig. 51, it may be built of moist earth, well-tamped in small layers of 15 cm (6 in.); but where necessary, the mound should be revetted with flat stones. As in the case of the pit privy (p. 65), it is preferable to supplement the earth mound in front of the entrance door with a masonry or brick step to help prevent dirt from being tracked into the privy on the user's feet.

The superstructure and the ventilation

The superstructure is identical to that recommended for pit privies (p. 65). While the house should be ventilated in order to minimize the odour nuisance, the ventilation of bored holes is generally considered to be unnecessary. It may be noted that, thus far, the bored-hole latrine has been used almost exclusively in the tropics, where temperature differences between the air in the pit and the outside air are slight; as a result, any draught of air through a vent pipe would be negligible.

Location of Bored-Hole Latrine

The basic considerations regarding the placement of latrines in general with respect to sources of water supply and dwellings have been previously discussed (see p. 32). In the case of the bored-hole latrine, the danger of pollution of the ground water is obvious since it is generally desirable that the bored hole penetrate it deeply for more efficient and durable operation. However, the rules governing the location of bored-hole latrines are the same as those for the pit privy.

Advantages and Disadvantages

The advantages and disadvantages of bored-hole latrines are in many respects similar to those of pit privies. Given proper construction and location, they satisfy most of the requirements set forth under "criteria for selection" (p. 39).

In particular, the bored-hole latrine is cheap and easy to construct in ordinary soils. In a WHO-aided rural sanitation project in East Pakistan, the cost of a bored-hole latrine in 1955 was found to be Rs. 11/15 (US \$3.58), plus Rs. 6/- (US \$1.80) for a woven bamboo lining. In Egypt, the estimated price in 1952 was US \$5.60.

Penetration of the ground water may be either an advantage or a disadvantage, as previously noted. In addition, the formation of a thick scum above the water level in the hole may seriously impair the operation and life span of the latrine. In such situations, and especially in areas like the Nile delta in Egypt, where heavy fluctuations of the ground water bring the water table within a few feet of the ground level, the bore-hole fills up quickly since the solids deposited float over the scum. By breaking the scum layer with a pole (a procedure which is admittedly impractical in many instances), the efficiency of the latrine may be restored. However, recent investigations have shown that proper location is more important than a great distance between a latrine of any type, including the bored-hole latrine, and the source of water supply.

The bored-hole latrine has been classified among other less desirable types of excreta disposal installations for the following reasons :

1. It requires special equipment for its construction.
2. If it does not penetrate ground water over approximately one-third of its depth, its life span is extremely short (see discussion on "life of a pit", p. 43), a most serious consideration in the success or failure of an excreta disposal programme.
3. In many countries it is difficult to secure cheap but strong and durable materials for supporting the walls of the bored hole against caving.

Construction

Materials

For the construction of linings, or casings, the following materials are most commonly used : wooden strips, bamboo, split cane, and baked clay. In addition, it is often possible to find in rural areas some kind of material which may be woven or made by the rural artisans themselves for use in the construction of casings. In large areas of Asia, bamboo is plentiful and used for this purpose. It has the great advantage of lasting for years under water without a preservative (although tar is used in Indonesia for this purpose). However, untarred bamboo and other wooden linings in dry pits or above the water line in wet pits are sometimes attacked by insects, although it is possible that they may last as long as the latrine itself (in the case of dry pits, at least). In areas where pottery is made,

cheap linings can be manufactured for bored-hole latrines in the form of perforated clay pipes. In the Americas, split cane has been used with success in the same manner as bamboo.

Whatever the material used, it must be remembered that the purpose of a lining is only to prevent caving. The perforations, or holes, in the lining should be as large as the soil permits, in order to allow for prompt leaching of liquid waste and dissolved solids out of the pit into the ground. In areas where the ground-water level is high, or which are subject to flooding, the latrine floor is elevated above the surrounding ground in the manner shown in Fig. 52. In such a case, the portion of the lining which passes through the elevated mound and penetrates the first 50 cm (20 in.) below the normal ground level should preferably be impervious and built of strong material, such as concrete.

Boring the hole

Equipment

One 40-cm (16-in.) earth auger, one auger shaft, one handle, one tripod, one pulley block, and one auger guide.

There are many types of auger which can be purchased on the market for different purposes. Fig. 53 and 54 show various types of auger and equipment which are suitable for bored-hole construction. A good latrine-boring auger for ordinary soils (not containing boulders, rock, or hardpan) might fulfil the following specifications :

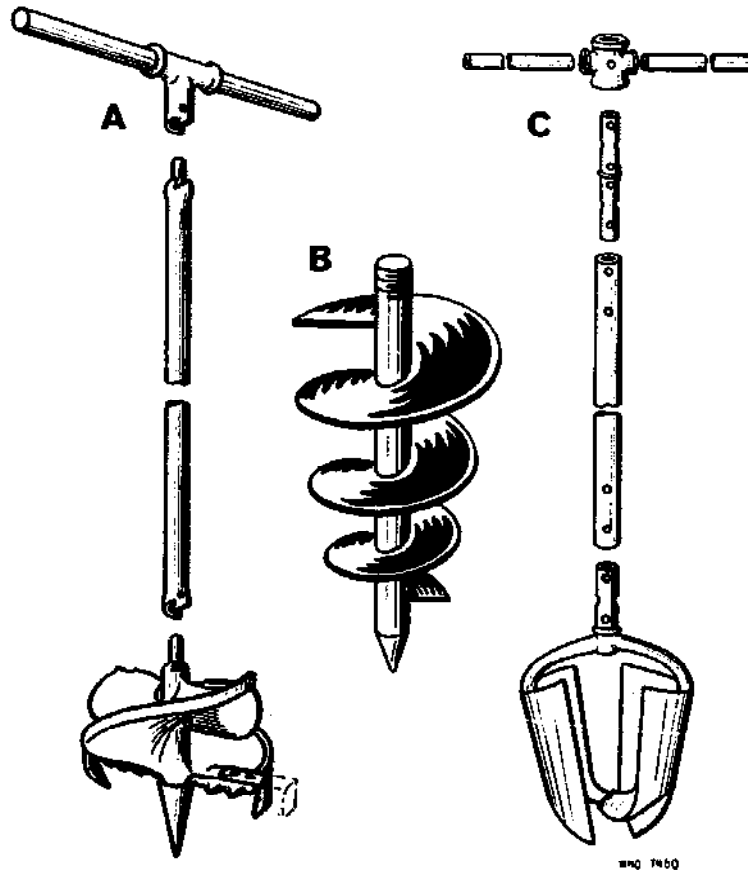
Double-bladed, hand-operated earth auger, with a nominal diameter of 40 cm (16 in.), capable of boring through moderately difficult soils to a depth of 6 m (20 ft). The blades to be high carbon steel, 5 mm ($\frac{3}{16}$ in.) thick, with the points strapped to prevent the blades from springing apart. The yoke and plug to be malleable iron cast as one piece, the plug having an external diameter of 37.5 mm ($1\frac{1}{2}$ in.) to fit into a standard $1\frac{1}{2}$ in. diameter iron pipe.* The plug to be cast with holes, each 10 mm ($\frac{3}{8}$ in.) in diameter through the body of the plug at right angles to its axis, with bolts to fit. In use, the operating shaft, consisting of standard $1\frac{1}{2}$ -in. iron pipe, fits over the plug and is secured by the bolts through corresponding holes in the pipe shaft. The auger to be furnished completely assembled, pipe shaft excluded.

An additional remark which may be made about double-bladed auger design is that the edges of the blades should not be so far apart as to leave large open spaces through which silting sand and soft mud may fall out when the auger is being raised. Earth augers of the disc, helical, or worm types may be used in boring through clay and softer soils without stones.

* In many countries where the metric system of measurement is used, this would be replaced by a 40-mm-diameter pipe, and the other specifications would be altered accordingly.

The auger shaft may be either round or square to fit the yoke of the auger selected. To fit the auger for which the above specifications are given, ordinary 1½-in.-diameter iron pipe will be used. This equipment will include: (a) one length, 6.70 m (22 ft), of standard 1½-in. iron pipe

FIG. 53. AUGERS FOR BORING HOLES



- A = "Lang" earth borer. Note edge cutter which can slide up to 3.2 cm (1.5 in.) to increase diameter of hole
 B = Worm-type earth auger
 C = "Iwan" earth auger

perforated across its barrel every 60 cm (2 ft) with 10-mm (3/8-in.) holes; (b) one 10-mm (3/8-in.) bolt or steel pin 9 cm (3½ in.) long; (c) one coupler (which may be required) for connecting two separate lengths of 1½-in. pipe, preferably an inside or plug-type coupler, with holes 10 mm (3/8 in.) in diameter, at right angles to the axis of the coupler, with bolts to fit.

The handle will include a pipe cross, 50×30 mm (2×1¼ in.) fitted to slide along the 1½-in. round shaft, tapped to take two handle branches, each consisting of a standard 30-mm (1¼-in.) diameter iron pipe 75 cm

(30 in.) long, threaded to fit the cross. The cross is to be drilled with one hole 10 mm (3/8 in.) in diameter through the centre at right angles to both branches, with a bolt to fit. In operation, the handle is slid along the operating shaft, and is pinned through successive corresponding holes in the shaft.

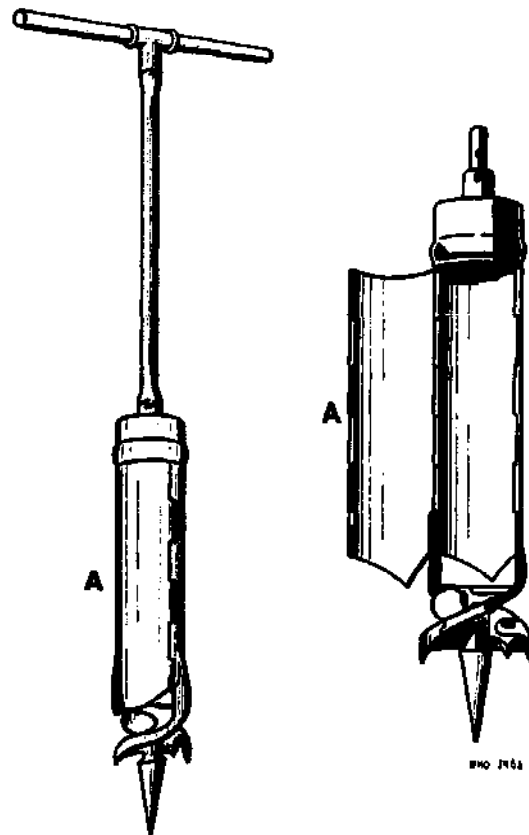
The tripod may also be made of 1½-in.-diameter iron pipe or of wood or bamboo poles, as shown in Fig. 55. The pulley block, single sheave, for 20-mm (3/4-in.) rope will usually be sufficient. One auger guide as shown in Fig. 55 and 56 will also be required.

Procedure

The procedure to be used with the equipment described above is fairly standard all over the world. The following suggestions are offered by Mr J. C. Carter, of the International Health Division of the Rockefeller Foundation :⁷

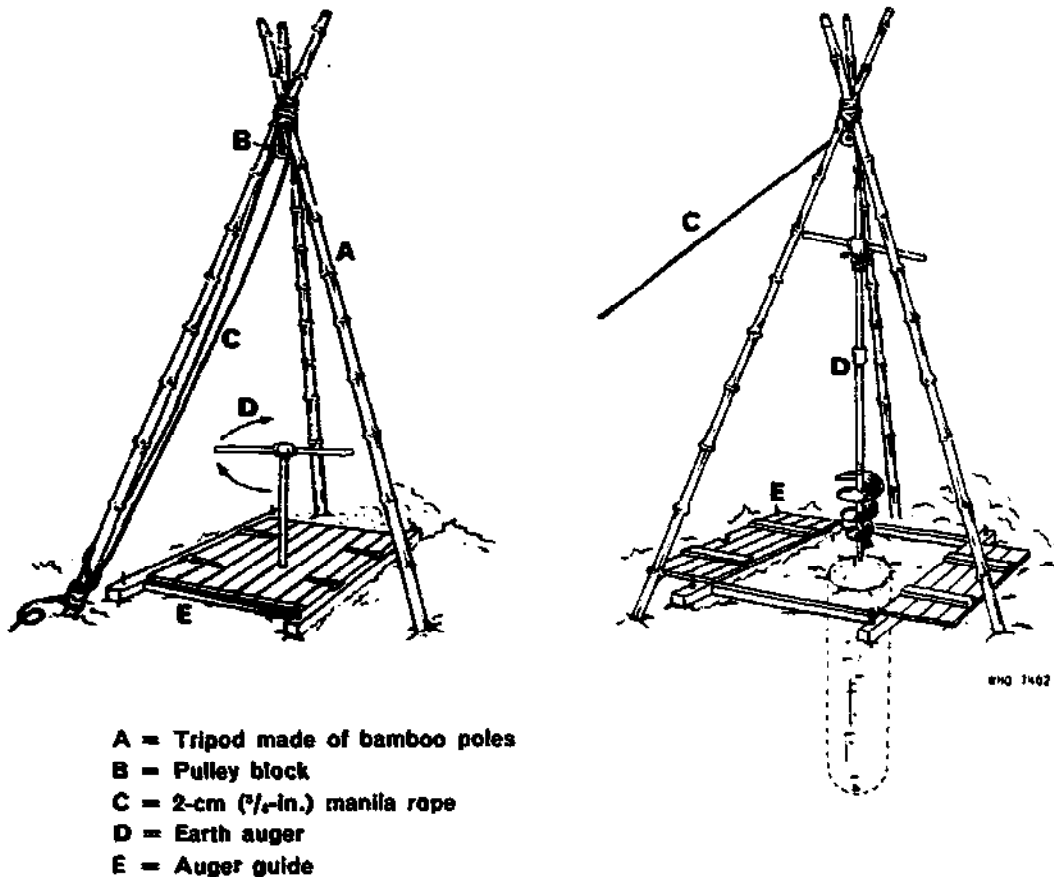
“(a) Set up the tripod over the spot where it is desired to bore the hole and attach the pulley block in place. (b) Directly under the pulley block, excavate a hole about 6 inches [15 cm] deep and of the same diameter as that of the auger. (c) Place the auger, equipped with shaft and turning handles, in the hole which has been excavated and adjust the turning handles to the desired height on the shaft. Lock the turning handles in place by the use of the set screw in the cross tee, or by the use of a steel pin if a round shaft is used. (d) Thread the hoisting rope through the pulley block and attach one end to the auger, or to the auger shaft. (e) Turn the auger in a clockwise direction until it is filled. Care must be exercised to ensure that the shaft is kept in a vertical position while turning until the hole is deep enough to put the auger guide into use. (f) When the auger is filled, lift it out of the hole by hauling on the hoisting rope, swing it to one side and empty it. Then let the auger swing back over the hole, lower it, and proceed as before. (g) When the hole has reached a depth of about 3 feet, place the auger guide in position and fix it in place by the use of an iron or wood peg at each corner. With the auger guide in place no further difficulty should be experienced in boring a vertical hole. (h) After the desired depth has been reached remove the auger from the hole and set the tripod aside. Insert the lining (if one is required) . . .”

FIG. 54. COMBINATION AUGER AND SAND BALER FOR BORING HOLES IN SOFT SOILS



A = Sand baler

FIG. 55. TYPICAL INSTALLATION FOR BORING



- A = Tripod made of bamboo poles
- B = Pulley block
- C = 2-cm (3/4-in.) manila rope
- D = Earth auger
- E = Auger guide

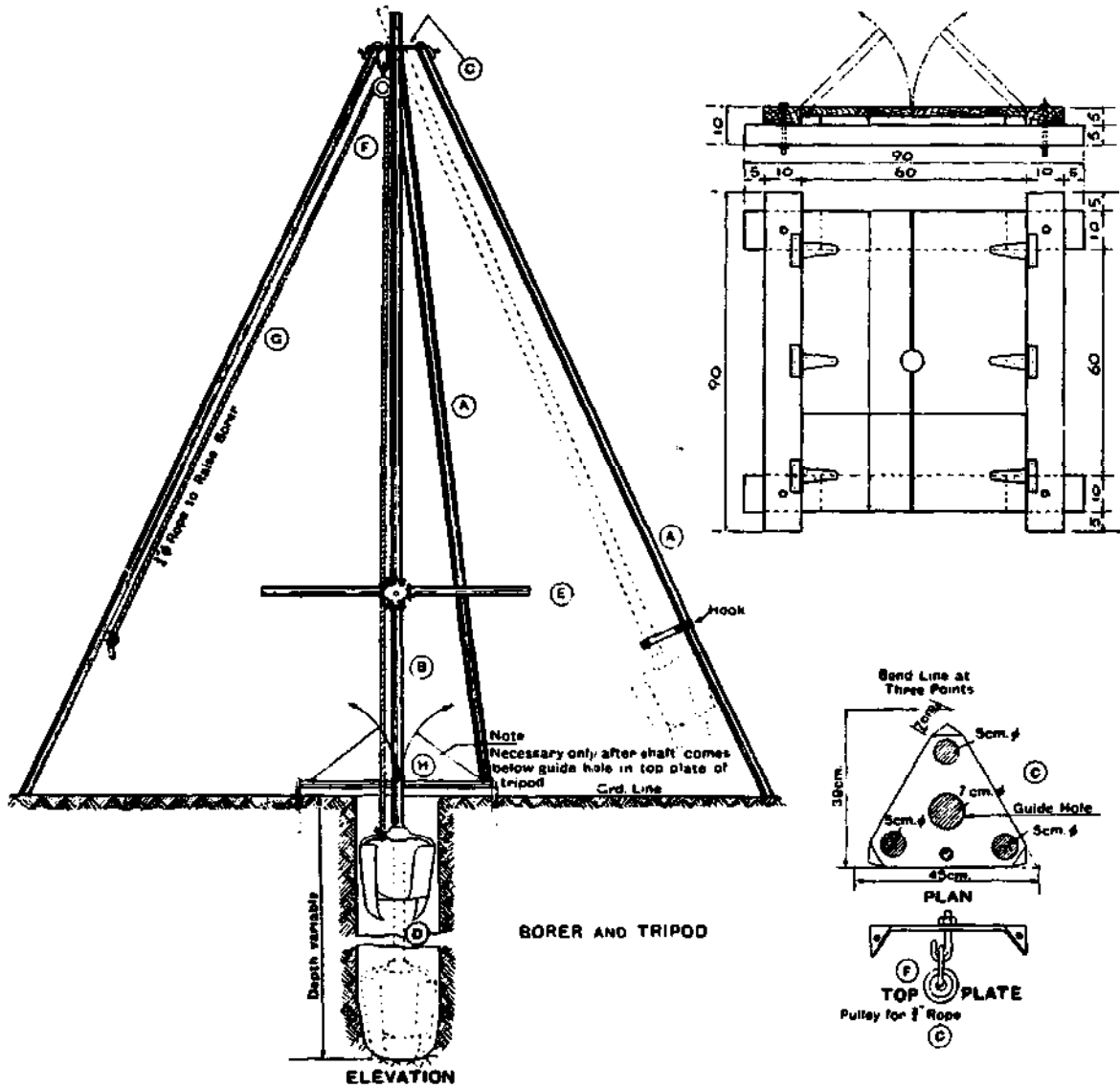
THE BUCKET LATRINE

Description

This system of excreta disposal is also referred to as box-and-can privy, conservancy system, pail latrine, or earth closet in English-speaking countries, and as *tinettes* in French-speaking areas. In principle, it consists of a bucket in which excreta are deposited and which is removed for emptying and cleaning at frequent intervals (see Fig. 57). In the earth closet and *tinette* types of bucket latrines, a mechanical device is available from which dry earth, sawdust, or ash is released by the user to cover the excreta.

These types of latrine are in use in rural towns and urban areas without sewers in many countries of Africa, South-East Asia, and the Western Pacific. They were also used extensively in the past in Europe and the Americas but have almost completely disappeared in favour of better and more sanitary types of excreta disposal installations, especially the pit privy and the water-borne systems.

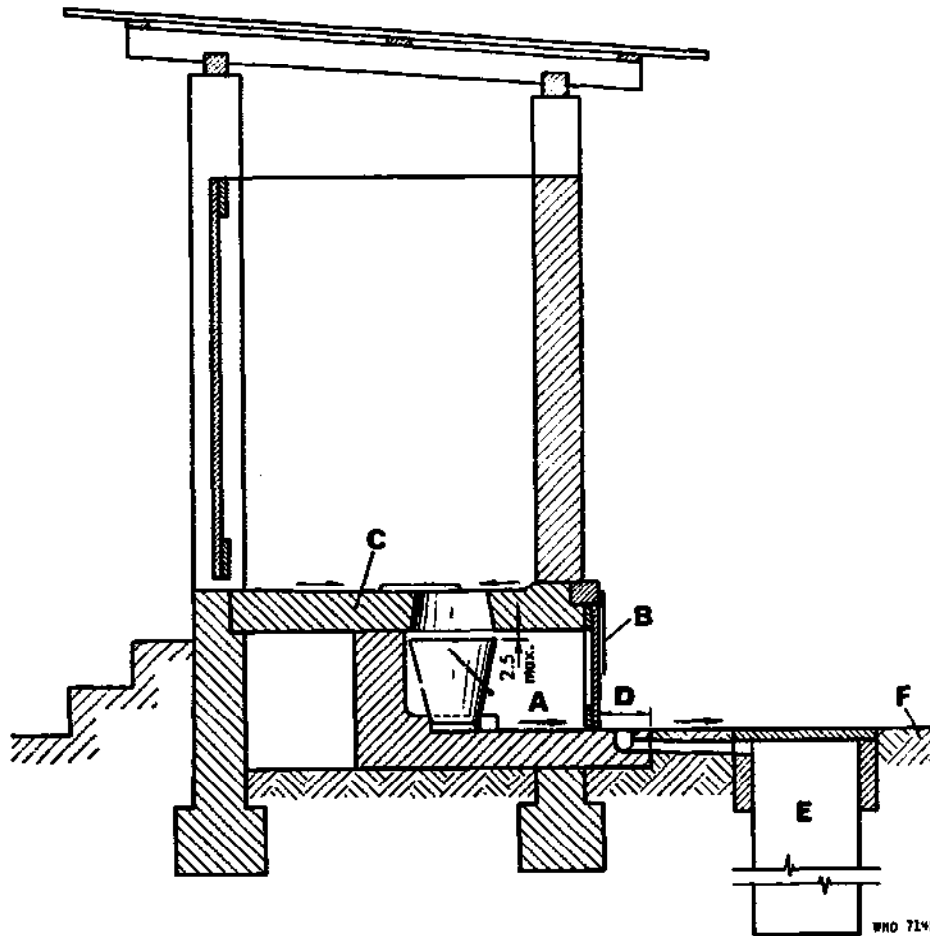
FIG. 56. DETAILS OF TRIPOD CONSTRUCTION AND AUGER GUIDE



Reproduced from Carter, J. C. (1938) *Bull. Hyg. (Lond.)*, 13, 596, 597, by kind permission of the Bureau of Hygiene and Tropical Medicine.

- A = Iron pipes for tripod
- B = Iron pipe for auger shaft
- C = Plate
- D = Auger
- E = Cross-T and handles
- F = Pulley block
- G = Rope
- H = Auger guide

FIG. 57. THE BUCKET LATRINE



The measurement shown is in centimetres.

A = Collection chamber built of impervious material; note bucket
 B = Fly-proof door
 C = Elevated floor or slab

D = Paved surface and drain
 E = Soakage pit or trench
 F = Original ground-level

Design and Function of Its Parts

The bucket or receptacle

The bucket or receptacle is usually made of seamless galvanized iron, rubber, or white enamel. It is about 38 cm (15 in.) in diameter at the top and 30 cm (12 in.) deep and has adequate handles for lifting and carrying. In some cases it should be provided with a removable, tight-fitting lid held in place by clamps. It is the practice to make two buckets, painted different colours, available for each latrine hole or seat so that a clean pail may be placed in the latrine when the other pail is taken away for emptying.

The collection chamber and the superstructure

The bucket is placed in a collection chamber (or box) situated below the squatting plate (or seat). The chamber may be built of brick or concrete, with rounded corners and is so shaped as to help centre the pail. Most chambers open to the rear of the latrine, into the service lane used for collection. Where seats are used, the space beneath constitutes the box, and the pails may be removed through the hinged latrine seats. In any case, it is important from the sanitary standpoint that the collection chamber be fly- and animal-proof. Good practice also calls for ventilation of the chamber by means of a pipe vent carried to roof level of the superstructure. The vertical distance between the bottom surface of the floor slab and the rim of the bucket should not be greater than 2.5 cm (1 in.).

The superstructure itself is built in the same manner as for an ordinary pit privy, except that the floor is raised above the collecting chamber and the ground level. In some countries the floor is designed in such a manner as to separate solid faeces from urine and ablution water, which tend to fill up the buckets quickly and to keep their contents in a semi-liquid state. Urine and other liquid wastes are directed by troughs either to an impervious catchpit, which is emptied periodically, or to a soakage trench.

Collection and Conveyance of Buckets

Collections are usually made daily, although in some places they are made only weekly or bi-weekly. The collected pail should be sealed with a fly-tight lid and replaced by a clean and disinfected one of different colour (to facilitate routine sanitary inspection). It is sometimes emptied into a tank carried by a vehicle, and then taken away to be washed. The practice of emptying buckets into a tank or wagon and immediately returning them to the latrines must be unreservedly condemned. The time of collection, whether night or day, may be decided by the community concerned.

The method of transportation varies greatly among countries, from the coolies' "basket" system in the Far East to push-carts or bull-carts and to motor vehicles elsewhere. Care is seldom taken to avoid spilling the contents of the buckets during collection and transportation to the disposal grounds.

In Asian countries, the amount of night-soil (faeces and urine) collected per pail per day is roughly 4.5 l (1 Imp. gal.); in Ceylon, where faeces only are collected, the collection amounts to 1.4 l (0.3 Imp. gal.) per pail per day.

At the disposal site, the buckets are emptied, thoroughly washed, and disinfected with a phenol or creosol type of disinfectant before being stored away and re-used. The wash water is disposed of underground by means of soakage pits, and should not be permitted to run freely in

open ditches or used, without adequate control by local health authorities, for farm irrigation. It goes without saying that the disposal sites should be located as far away as possible from human habitations and all sources of drinking water.

The collection system is best carried out by the community administration and under the direct supervision of the health authorities. A fee is usually paid by the family for this service, and is sufficient to cover the costs of operation and replacement of the equipment.

Methods of Night-Soil Disposal

The methods of disposal of night-soil were reviewed at the previously mentioned WHO seminar on sewage disposal for South-East Asian and Western Pacific countries. The following is based on the report on that seminar.^a

Night-soil collected by the conservancy system may be disposed of by a number of methods, varying widely in efficiency, in sanitation, and in cost.

Various methods used

(a) The use of water transport, where available, to convey night-soil to its ultimate disposal point in a sufficiently large body of diluent water is acceptable from a public health standpoint. This is, however, relatively expensive and may become entirely inoperative during even moderate storms.

(b) Burial in earth pits or trenches, which has the advantage of being extremely simple, is rather common. It requires a considerable amount of hand labour.

(c) Incineration of night-soil along with other types of refuse fulfils sanitary requirements but is expensive.

(d) Detention in specially designed tanks is practised in some Asian countries in which it has long been the custom to use human excreta to fertilize growing crops. If the detention period is sufficient to permit the "die-away" of pathogens, public health criteria for using this material are met. The cost of this operation depends on the cost of storage and transport and the selling price of the material.

(e) In some countries, raw or partially decomposed night-soil is used for agricultural purposes. This practice, however, is universally condemned on public health grounds.

^a *Report on Seminar on Sewage Disposal (Rural and Urban)*, Kandy, Ceylon, 1955 (Report issued by the WHO Regional Office for South-East Asia, New Delhi)

(f) Disposal directly into sewers is practised in a number of urban areas throughout Asia. This is an accepted method of sanitary disposal if "depots" are properly constructed, maintained, and operated. It is a relatively inexpensive method but has the disadvantages of producing odours, placing shock loads on treatment plants, and sometimes creating septic conditions within sewers which produce deterioration of the sewers and sewer structures.

(g) The anaerobic digestion of night-soil in closed tanks is a relatively new disposal technique. Digestion plants may be designed and located so as to be used later as a part of proposed conventional water-borne sewage-treatment plants.

(h) Finally, experiments have been carried out, in Japan, on developing methods of heating night-soil for sterilization. One method that has been tried is using the strong heat from municipal refuse incinerators.

Details of several methods

1. Trenching—method (b)

Costs of the pit or trenching technique include the cost of suitable land located at a reasonable distance from the collection points and the costs of labour and transportation.

Sanitary considerations associated with this technique include subsoil conditions, the possible utilization of ground water for water supplies, gross contamination of surface waters, and depredations of domestic or wild animals.

A common method of trenching at the present time is to use a trench 60 cm (24 in.) deep, filled with 45 cm (18 in.) of night-soil and covered with 15 cm (6 in.) of earth. This amount of coverage is considered inadequate for two reasons: (1) according to parasitologists, hookworms can work their way through 10-13 cm (4-5 in.) of soil; and (2) during monsoon weather, the bulking of the faecal matter can cause oozing through the cover. It is therefore essential that the trench should contain only 30 cm (12 in.) of night-soil, with a 45-cm (18-in.), tamped earth-cover, 15 cm (6 in.) of which is a mound of earth above ground level.

The bottom of the trench should be above the highest water-table and preferably above the layer of soil likely to be moistened by capillary action. In areas of excessive rainfall a deeper trench should be provided, if possible. Grass may be grown to assist digestion and prevent erosion, so long as there are no cattle.

The service life of trenching areas will vary from about two months (the time necessary for digestion) to two years (the time for which they are used in present normal practice). It is believed that further work on this problem may result in a reduction of this two-year service life. Service life, utilization, and land values are inter-related; and, if a reduction in

the trenching time were effected, less land would be required, and the area might be utilized in a better way.

2. Disposal into sewers—method (*f*)

Satisfactory depots for the disposal of night-soil into sewers should be located at convenient points away from very populous areas. The buildings should be fly-proof and always kept clean and sanitary. The public should not be allowed to enter the premises to obtain water or to wash clothes. An abundant water-supply under pressure is most important, and a storage tank of adequate capacity should be installed. Without water the night-soil would be inadequately flushed, the screenings exceedingly difficult to handle, and the condition of the pails, trucks, and depots a serious public health hazard. The receiving hopper should be made of concrete with rounded corners and should be installed with a bar screen, through which the night-soil may be flushed. A trap should be installed between the dumping hopper and the sewer main. In all water pipings, care must be taken to see that there are no cross-connexions or possibilities of back-siphonage.

The seminar participants did not endorse the collection of night-soil in lieu of the extension of sewers. They felt, however, that, where the practice had to be continued, collected night-soil could be disposed of into the sewer if proper precautions were taken to prevent damage to the sewer or interference with treatment processes.

3. Digestion plants—method (*g*)

The disposal of night-soil by digestion is being practised in Japan, where, in different areas, about 20 plants, to serve populations ranging from 3500 to 100 000, are under construction or in operation.

This process essentially involves the same digestion process of sewage sludge as occurs in conventional sewage-treatment plants; the digestion plants are usually designed so that they can become component parts of complete treatment plants when water-borne sewage schemes become possible.

The night-soil is carried to the plant by hand or by motor transport and is discharged through a screen chamber into the digestion tank. The containers are cleaned, and the wash-water goes into the digester. Digester gases are collected, stored, and used for maintaining the temperature of the digester contents at 30°C (86°F) for about 30 days. Digested sludge is withdrawn to drying beds, and dried sludge used as fertilizer. Supernatant liquors are diluted and treated by biofiltration. Screenings are usually incinerated.

A review of the operation of one group of seven digester installations indicated that they had capacities ranging from about 28 l to 39 l (1.0 cu. ft to 1.38 cu. ft) person served.

Operational and cost data are unfortunately not yet available for this method of night-soil disposal.

Comments on the Bucket Latrine System

In theory, a properly designed and operated bucket latrine system will fulfil all sanitary requirements. In actual practice this is far from being the case, and satisfactory conservancy systems anywhere in the world are rather rare exceptions. Experience gathered in every country shows that the bucket latrine system, though cheap in initial cost, is in fact the most expensive type of installation to operate and maintain. In addition, it has obvious health hazards for the community and for the scavengers, in particular ; by its very nature, it inevitably leads to difficulties of a social nature because of the stigma attached to the scavengers who engage in this filthy type of work. In fact, in most countries of the world it is becoming increasingly difficult to recruit labour for scavenging. In rural areas it may still be possible to secure the co-operation of interested farmers for this job.

It has been noted that the use of dry earth, sawdust, or ash is often ignored even in areas where the latrine still bears the names of "dry earth closet" and *tinette*. As a result, the contents of the buckets are highly odorous and attractive to flies, which lay their eggs in them at the first opportunity. The door of the collection chamber and the squatting hole or seat are seldom fly-tight and closed. In spite of active supervision, the contents of buckets are often spilled carelessly near the latrines or along the road to the disposal site. The bucket lids are rarely kept in place ; and it has been reported that, in a major town, the buckets are left exposed for hours without covers on sidewalks pending collection ! The system, which depends on the separation of urine and faeces, is seldom built and maintained properly, as a result of which the urine simply runs over soaked ground and through unsightly pools. Conditions at the disposal sites are often intolerable due to spillage, lack of an abundant supply of water, intense fly-breeding, odours, and rodent infestation.

Owing to the enormous difficulties in operating this system in a sanitary manner, the bucket latrine usually violates most, or all, of the sanitary requirements set forth on page 39.

The cost of operation of the conservancy system is, in most instances, staggering, although not often so recognized by town councils. In countries of South-East Asia, present costs range from Rs. 20/- to Rs. 70/- (US \$4.21 to \$14.70) per pail per year for poor to "good" conservancy systems. In Hong Kong the cost is H K \$56 (US \$9.82). These are only direct operating costs of collection and disposal and do not include latrine structure, maintenance and replacement of pails and other transportation equipment, or gratuities to scavengers, which are additional costs borne by the family.

A rural community of 1500 persons, for example, having a conservancy system of 320 pails may be spending up to US \$3200 per year for a never-ending insanitary excreta disposal system, without realizing that this annual cost could finance an immediate capital expenditure of US \$41 600. This is calculated on the reasonably safe assumption that the community would reimburse this capital by equal instalments of \$3200 a year for twenty years, the interest rate being 4.5%. It is strongly recommended that communities which possess conservancy systems should undertake a thorough sanitary and financial study of the operation of these systems with a view to changing them to better and more economical types of excreta disposal installation.

The only thing which may be said in favour of the bucket-latrine system is that it offers a means for collecting night-soil, which, in some areas, is ultimately used as soil fertilizer. There is, however, another type of latrine—the compost privy—which is better adapted to this purpose and which is described later.

THE "FEUILLÉES" OR TRENCH LATRINE

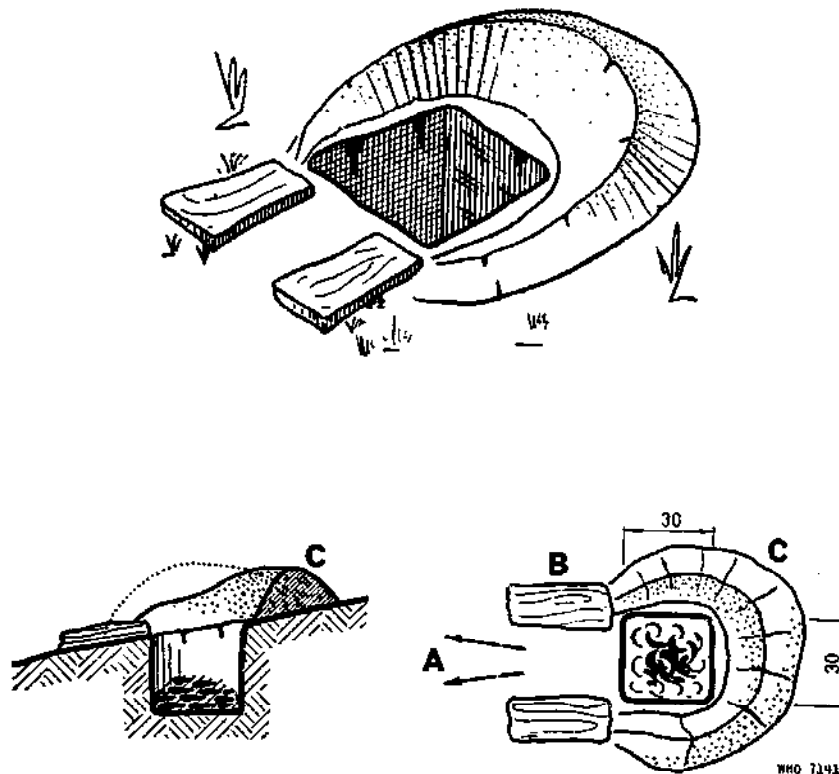
Description

In French-speaking countries, the term *feuillées* applies to very small and shallow pits dug into the top layer of the ground. The pit is usually square, about 30×30 cm (12×12 in.) in cross-section, and 40 cm (16 in.) deep. The excavated earth is piled loosely around the hole (Fig. 58). Each user is expected to throw a scoopful of loose earth over the faeces deposited. The urine normally falls outside the pit and drains away. It is estimated that a pit of this size will receive 100-150 droppings, after which it is thoroughly covered with an equal volume of earth. Under tropical conditions, the decomposition of faeces is completed in about eight weeks, and the resulting humus may be dug out and utilized to fertilize garden crops. A new hole is dug at a minimum distance of one metre (39 in.) away from the first pit and is used in the same manner.

The trench latrine operates under the same principle as the *feuillées*, i.e., the excreta are deposited in the top layer of the soil, in which the aerobic saprophytic bacteria are most numerous and active and reduce the offensive material in the shortest possible time (see p. 25 "decomposition of excreta"). The trench is often dug to a depth of 60 cm (24 in.), which is acceptable from the biological standpoint, with a length of about 1-3 m (3-10 ft).

While the trench latrine is designed for temporary use only in such places as military bivouacs, scout camps, temporary building or mining

FIG. 58. A "FEUILLÉE"



Measurements shown are in centimetres.

- A = Flow of urine over the ground or in a furrow
- B = Flat stones forming foot-rests
- C = Loose earth used for covering faeces

sites and similar locations, *feuillées* are used as a permanent measure in rural and suburban areas, and even in urban areas of large towns, especially in Africa. The Bureau Central d'Etudes pour les Equipements d'Outre-Mer, Paris, France, in a publication dated February 1955,¹⁶ describes one type of *feuillées* applicable to soft ground (into which they are dug) and another type applicable to hard soil (over which they may be installed). An improved type has also been designed by this French government office and is described by Médecin-Général Sanner³¹ as follows:

"The system includes [Fig. 58]:

- "(a) a pit 0.60 × 0.40 × 0.40 m (24 × 16 × 16 in.);
- "(b) above the pit a Turkish-type squatting plate provided with two foot-rests, two handles, one hole, and one gutter to divert urine towards a small pit or a drain;
- "(c) a rough superstructure;
- "(d) an open box or pitcher full of loose earth.

"When the pit is full, it is covered with an iron sheet held in place with four stakes (against animals, rain run-off, and soil pollution with worm larvae); and the squatting

plate and superstructure are moved over another hole. After six to eight weeks, the iron sheet may be removed, the faeces having been transformed into humus and pathogens having been destroyed. Squatting plates of this type may be built of wood, metal, or concrete. They could be mass-produced and given away to poor communities following proper health education of the people as to their use." [Trans.]

Advantages and Disadvantages

Feuillées and trench latrines offer serious disadvantages and health hazards for villagers and rural communities as a whole. The improved type of *feuillées* described above might constitute a considerable sanitary improvement and might be used in rural areas if the people could reasonably be expected to observe faithfully the few steps involved in the latrine's construction and operation, especially the step which prescribes the covering of the full pit with an iron sheet for a period of two months. General experience with respect to hole covers in latrines, the maintenance and operation of the bucket latrine system, and the possible alternative uses of sheet metal in villages leads one to believe that, despite routine inspection and supervision, the full pits would not be kept covered in the majority of instances.

The most significant hazards caused by these latrines are :

(a) the inevitable pollution of the soil surrounding the *feuillées* or the trench latrine, since there is virtually no protection against the access of worm (especially hookworm) larvae to the ground surface ;

(b) the breeding of flies in enormous numbers, and the access of flies and animals to uncovered or lightly covered faeces in the pits ;

(c) the danger of pollution of both surface and ground water ;

(d) the easy access to and scattering of the material by rodents and other animals.

To these may be added the odour nuisance and, from the aesthetic point of view, the unsightly conditions generally attached to these types of latrine. On the credit side, it may perhaps be said that they are easy and cheap to build and fit in well with the primitive habits of village folk in many areas. However, in countries where they are used, the cost of sickness and debility and the losses of productive power and of life-capital through premature death generally are a heavy burden not only on the people concerned, but also on whole regions and their governments. Often the actual value of these losses cannot be assessed. In one instance at least, the *feuillées* system has shown how expensive it can be : in a large city in Africa comprising densely populated suburbs where the *feuillées* had been adopted, chemicals (DDT, diazinon, etc.) were sprayed regularly from the air, at a heavy cost to the health authorities, in an attempt to reduce the enormous fly infestation over the whole city.

Both the *feuillées* and the trench latrine occupy a place among excreta disposal installations as temporary devices to be used by moving groups of individuals for a few days at a time.

THE OVERHUNG LATRINE

The overhung latrine consists of a superstructure and a latrine floor built on top of wooden piles above water along the banks of rivers, sea beaches, or coastal flats. This type of latrine, which is found occasionally around seaports and fishing villages in every continent, is very common in large coastal areas of Asian countries. The severity of the health problems raised by this system of excreta disposal was recognized by the participants in the WHO-sponsored seminar on sewage disposal, in the report^a on which the following views were expressed :

Throughout Asia many people are forced to inhabit land areas that are frequently or periodically covered with water. The coastal fishing villages where, it is claimed, some adults have never set foot on solid ground would be typical examples. For people living in raised huts with cat-walks for streets, the problem of the disposal of human excreta has rarely been given thought or attention. In the case of brackish rivers or tidal flats, drinking-water is difficult to obtain ; most of the inhabitants rely on rain-water or carry well-water from some distance by small boats. The health hazards under such conditions are difficult to evaluate, especially in the light of the existing knowledge of the epidemiology of certain environmental diseases.

Under such circumstances a carefully located " overhung " or " drop " latrine might be the only measure which could be applied. Such a latrine might be acceptable, provided the following general conditions are met :

- (1) the receiving water is of sufficient year-round salinity to prevent human consumption ;
- (2) the latrine is installed over such water depth that the bed is never exposed during low tide or the dry season ;
- (3) every effort is made to select a site that will provide for carrying floating solids away from the village and will furnish dilution ;
- (4) there is a stream flow of 14 l (0.5 cu. ft) per second per family for adequate dilution ;
- (5) the walkway, piers, squatting openings, and superstructure are made structurally safe for adults and children.

^a *Report on Seminar on Sewage Disposal (Rural and Urban)*, Kandy, Ceylon, 1955 (Report issued by the WHO Regional Office for South-East Asia, New Delhi)

There was reluctance on the part of the seminar participants to give support to this technique, however. This reluctance was based on:

- (a) the relatively long survival rates of pathogenic organisms in fresh and brackish tropical waters;
- (b) the universal habit of prolonged contact with water in bathing and fishing; and
- (c) the possibility that the practice of using this type of latrine would become established upstream, where it would empty into smaller and fresh-water courses.

Such latrines should be considered only in places where the conventional terrestrial type cannot be built. (It is recognized, however, that reluctance to accept the overhung type of latrine, when properly situated and constructed and discharging into a stream or harbour of sufficient flow, is not entirely consistent with the accepted practice of urban sewage disposal by dilution.)

It should be stressed that the practice of drinking from any surface stream in the populated areas of Asia is not safe at present, and that surface waters are expected to become progressively more contaminated as cities and towns become more highly developed and populated.

THE COMPOST PRIVY

Use of Night-Soil as Fertilizer

The use of night-soil as soil fertilizer has been studied by several scientists, in particular by Gotaas¹⁸ and Scott³³ in recent publications. Scott states that in many countries of the Western Pacific "faecal-borne diseases are very definitely related to agricultural practices in that night-soil is used as fertilizer". Both authors point to the important relationship between sanitation and agriculture in all parts of the world and review modern composting methods which are capable of producing a safe and valuable fertilizer from mixtures of human and village wastes. Many investigations cited by these authors have shown that pathogenic bacteria and worm eggs are unable to survive temperature conditions and biological antagonisms prevailing during composting processes. In rural areas where from time immemorial excreta have been used by the farmer, it is recommended that health authorities work hand in hand with those concerned with agricultural development in order to solve the problems involved in the safe utilization of human wastes.

As has been previously noted, one problem which has not yet found a satisfactory solution is the collection and transport (i.e., handling) of

night-soil from the latrine to the composting site. The health hazards involved in these operations are considerable, not only for the scavenger group, but also for the whole community; and they cannot be ignored by either health or agricultural authorities. Because of these hazards, modern composting procedures, which would make possible the recovery of the vast amounts of plant nutrients contained in human faeces and urine cannot yet be applied everywhere.

In urban areas of many countries, pit privies, vault and aqua privies, and septic tanks are periodically emptied by mechanical means, generally by use of a closed metal tank, carried by a truck, into which the liquid and semi-liquid faeces are pumped. The truck may even carry the water necessary for liquefying the solid contents of the latrines. Such an operation is, of course, expensive in initial cost and not readily applicable to every rural area of the world.

The collection and transportation methods involved in the so-called conservancy or bucket-latrines system cannot be recommended, for reasons already discussed. There is a great need for further research and field experiments to discover an economical and adequate solution to this sanitation problem. It is very likely that, when such a solution is found, human wastes from over a billion rural inhabitants will be returned to the soil to fertilize it for the benefit of mankind.

Description and Operation of the Compost Privy

A reasonably safe way for a villager to prepare excreta for use as fertilizer is for him to compost it in a privy pit. After the required period of composting, the pit can be emptied, thus eliminating the handling of the raw excreta.

The privy pit, slab, location, and other features would be no different from those described above (pp. 42-68) for the pit privy. However, the compost privy should be provided with the largest possible capacity so that it will not fill too fast. For this reason it may be necessary to enlarge the cross-section of the pit. This may be done by using a large, four-part, concrete slab as shown in Fig. 28, or by giving the pit an oblong shape, in which case part of the vault extends outside of the superstructure and is covered with a tight-fitting and durable cover. A pit 80 cm (32 in.) wide, 1.80 m (6 ft) long, and 2.50 m (8 ft) or more in depth may be used for the compost privy.

The method is a modification of the Bangalore composting process¹⁸ and is based on anaerobic decomposition of organic wastes which are left undisturbed during a period of at least six months to ensure destruction of pathogens and ova of helminths. The procedure would be as follows:

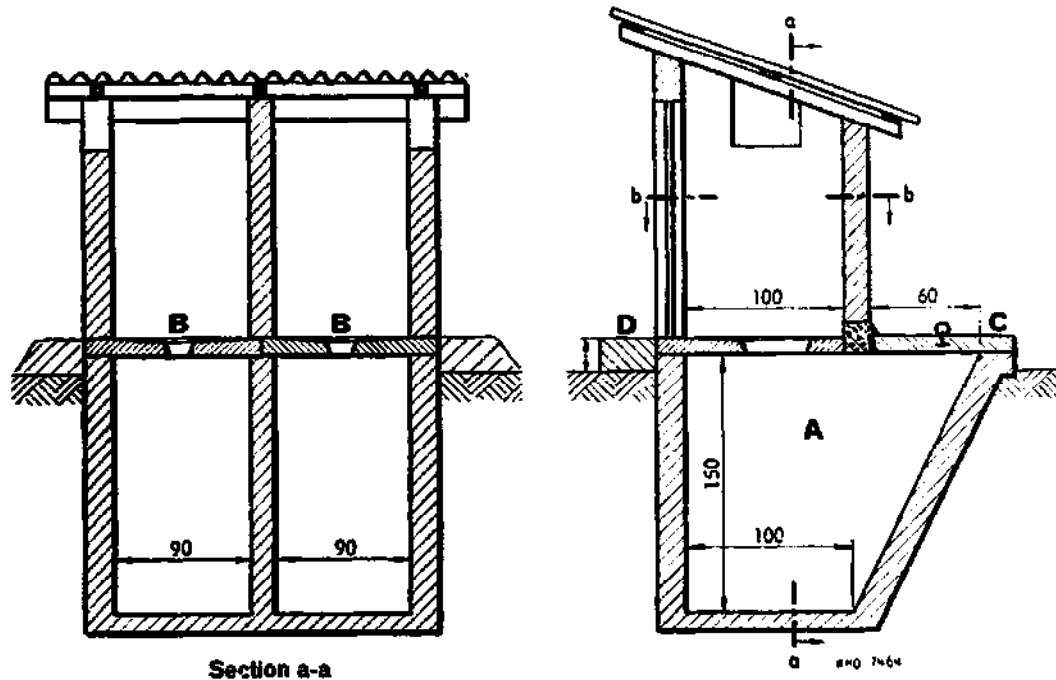
1. Dig a pit of required size, the bottom of which should always be above ground-water level.
2. Before the slab is placed, cover the bottom 50 cm (20 in.) of the pit with grass cuttings, fine leaves, garbage, paper, etc. ; but allow no rubbish such as metal cans, glass bottles, or similar materials to be deposited therein.
3. Place slab, and complete superstructure, keeping in mind that they will both be moved periodically to another site.
4. In addition to depositing human excrement, throw the daily garbage into the pit, along with cow, horse, sheep, chicken, and pig manure, as well as urine-soaked earth or straw. The latter materials are important, as urine is rich in nitrogen, an essential plant nutrient.
5. About once a week throw a few kilograms of grass clippings and fine-texture leaves into the pit. After some experimentation, one can arrive at a pit mixture which will provide a good fertilizer.
6. When the pit's contents reach a level 50 cm (20 in.) below ground, a new pit is dug 1.50-2 m (5-6.5 ft) away (more if desired), and the superstructure and slab are moved over it. The first pit is levelled, finally, with 15 cm (6 in.) of grass clippings and leaves, and the top 35 cm (14 in.) with well-tamped earth.
7. When the second pit is filled as indicated above, the first pit is uncovered and the compost removed. It should be stable, and will provide a good fertilizer which can be applied immediately to the fields or stored.

The volume of the pit depends on the needs for fertilizer and the number of people using the privy. The proportion of night-soil that can be added to refuse for satisfactory composting should be about 1 to 5 by volume.¹⁸ From the data given above (pp. 43-48), it will be noted that a family of five will produce, on the average, one cubic metre (35 cu. ft) of partly digested excreta in about four years. On this basis, one-fifth of a pit of one cubic metre (35 cu. ft) capacity would be filled with excreta in approximately 9-10 months, which would be a good composting cycle for such a pit. (The other four-fifths of the contents would consist of refuse and other wastes thrown in as explained above.)

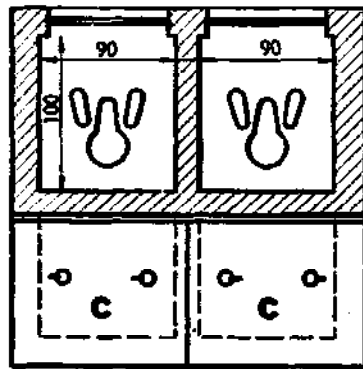
Before applying or recommending this method in a rural area where it is not familiar, it is desirable to try it first on a pilot scale under adequate control in order to determine the proper operating schedule and materials suitable and available in the area under consideration. The collaboration of agricultural officials and of local leaders among the farmers of the area is necessary.

To obviate moving the superstructure and slab back and forth over two separate pits, the system may be amended by building what may be

FIG. 59. DOUBLE-VAULT LATRINE



Measurements shown are in centimetres



Section b-b

- A = Two vaults
- B = Squatting slabs
- C = Removable covers
- D = Step and earth mound

called a "double-vault" latrine (see Fig. 59). This latrine consists of a large vault divided into two compartments, each of which is topped by a slab and a hole. The superstructure is likewise partitioned into two houses with separate entrances. In practice, the vaults are filled and emptied alternately in the same manner as described above for the compost privy. They should be large enough to allow sufficient time for the materials to compost thoroughly before their removal. The vaults need not be water-tight but should be built well above the ground-water

table. The difficulty with the double-vault privy is that often both compartments are used simultaneously, thus defeating their purpose. Constant inspection and advice by health and agriculture staff are necessary.

Advantages and Disadvantages

Proper composting in privy pits is rather complicated and may well be, in the beginning, beyond the comprehension of most rural families. Close supervision by health and agriculture officials and systematic education and follow-up are required during the first two or more years of application. Furthermore, privy pit composting is not free of hazards and requires attention. Proper placement is essential to prevent pollution of ground water supplies and the entrance of water into the pit.

Under proper conditions of operation, this method will satisfy most sanitary requirements laid down on page 39. It is, of course, somewhat more expensive than the ordinary pit privy since it involves the construction of two or more pits. One further disadvantage is the loss of a portion of the liquids (especially urine), which seep away into the ground, carrying with them nitrogenous matter held in solution. However, it offers a reasonable means of conserving most of the fertilizing value of excreta with a minimum of health risks.

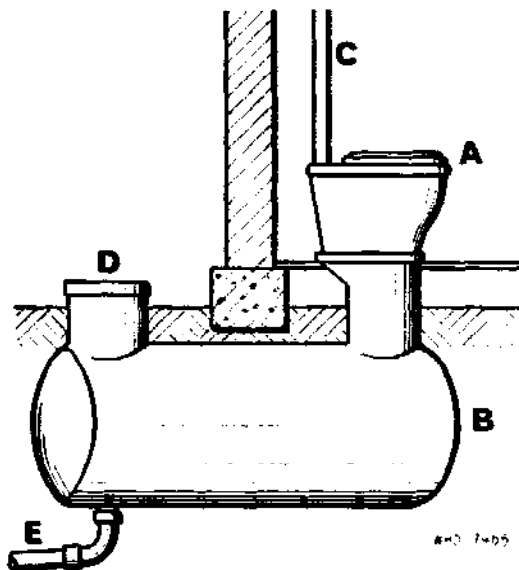
THE CHEMICAL TOILET

Description

The chemical closet consists of a metal tank containing a solution of caustic soda. A seat with cover is placed directly over the tank, which is ventilated by a flue rising through the house roof (see Fig. 60). The tank is made of a special steel alloy capable of withstanding corrosion and has a capacity of about 500 l (110 Imp. gal.) for each seat served by it. A charge of 11.3 kg (25 lb.) of caustic soda dissolved in 50 l (11 Imp. gal.) of water is applied to the tank for each toilet seat. The excreta deposited in the tank are liquefied and sterilized by the chemical, which also destroys all pathogens and worm eggs. To facilitate this action, the tank is usually provided with an agitator which helps to break the solids and to speed their disintegration by the chemical. After several months of operation, the spent chemical and the liquefied matter are drained or removed and are deposited in a leaching cesspool, suitably located.

This toilet is non-odorous and suitable for use inside dwellings, isolated houses, schools, etc. It is also employed in the form of a movable commode of about 40-l (9 Imp. gal.-) capacity on boats, aircraft, motor caravans,

FIG. 60. CHEMICAL CLOSET



- A = Closet seat inside house
 B = Tank containing solution of caustic soda
 C = Ventilation flue
 D = Inspection opening
 E = Drain

and other vehicles. It is obtainable from commercial establishments and is fairly expensive in initial cost and in operation.

Advantages and Disadvantages

With proper operation the chemical toilet is a very satisfactory type of excreta disposal installation which fulfils all sanitary and aesthetic criteria. It has the further advantage that it can be placed inside the dwelling.

The primary disadvantage is its price and the recurring cost of the chemical. It does require attention and will not stand up to abuse. Only toilet paper (and no other rubbish) should be thrown into it. If poorly operated and maintained, which is usually the case when the

chemical is spent and not immediately replaced, there are odours and an increasing amount of floating matter over the liquid contents of the tank. For these reasons, the chemical toilet cannot be used at present in most rural areas of the world.

WATER-CARRIED METHODS OF EXCRETA DISPOSAL FOR RURAL AREAS

SOME PROBLEMS IN THE DISPOSAL OF WATER-BORNE WASTES

General Considerations

Experience has shown that, when running water is available, the water-carried system of excreta collection and disposal is most satisfactory and convenient under both urban and rural conditions. It fulfils all sanitary and aesthetic criteria. In particular, contamination of the soil and of surface water is avoided; potentially dangerous wastes are rendered inaccessible to flies, rodents, and domestic animals; and the mechanical transmission of faecal-borne diseases to man is prevented.

One serious disadvantage, however, is the difficulty of disposing of the large volume of wastes resulting from the addition of water. While in cities the liquid wastes are usually carried away by means of sewers, in most rural areas of the world sewerage systems do not exist, and liquid wastes are conveniently discharged into the ground. Since in such areas ground water is often tapped as a source of domestic water-supply, there is an obvious need for proper location and construction of the excreta disposal system, with a full understanding of the hazards involved (see p. 32).

Such a situation is frequently found in suburban areas, in which case the possibilities of linking up the drainage of these areas with the public sewerage of the near-by town should first be investigated. Individual waste disposal is often more costly and troublesome in the long run than public sewerage. In densely populated rural areas of some countries in Europe and North America, the sewerage problems of communities sufficiently close to each other have been solved through the creation of special "sewer districts" administered in common by the municipal authorities concerned.

In developing rural villages and communities with scattered dwellings, it may be desirable for the local government to take the initiative and responsibility in order to ensure the adoption and construction of the most satisfactory installations, keeping in mind future conditions in the

developed and fully inhabited areas. In some instances, the government may decide to undertake the planning, construction, management, and supervision of the individual sewage disposal systems. This procedure is not recommended for application in rural areas, for reasons already explained. However, satisfactory waste-disposal will be achieved by individual families if the local health authorities are prepared to supply the necessary guidance and the continued attention and supervision after the facilities are installed.

Various methods may be used in rural areas to dispose of liquid wastes. They include disposal by dilution in large bodies of water, the use of cesspools and seepage pits, and the septic-tank systems, which involve settling tanks with single or multiple compartments followed by subsurface irrigation fields, filter trenches or sand or trickling filters. Selection of methods will depend primarily upon the degree of sewage treatment to be provided, upon the location of the system and other local factors, and, finally, upon costs. Local factors which bear upon the selection and design of the disposal installation include, among others, the nature of soil formations, the presence and levels of ground water and the direction of flow, topography, the proximity of sources of water supply, the quantity of sewage, and the area available for the disposal works.

Disposal by Dilution

Where large bodies of surface water, such as the sea, lakes, or large rivers, are available nearby, the liquid wastes from dwellings or communities may be discharged into such waters directly or after septic-tank treatment only. The outfall pipe conveys the sewage to a point well below the lowest water or sea level, preferably near the bottom of the receiving water, in order to ensure adequate dilution of the warmer and lighter sewage, which will normally rise and disperse through the diluent water body.

This system of disposal is designed to take advantage of the natural ability of water for self-purification, which is based primarily on the availability and amount of oxygen in solution in the receiving water. This oxygen reacts with and stabilizes the organic matter in the sewage by oxidation. If there is not enough oxygen in the receiving water or if the volume of this water is too small to supply the quantity of oxygen required, anaerobic decomposition will begin and proceed at such a pace that the normal biological balance of the water may be upset. As a result, the receiving water will become foul and black, and its normal fauna (especially the fish, which require oxygen to survive) will be totally destroyed.

Another hazard created by the disposal of sewage in this manner is the possibility of contamination of the receiving water with pathogenic

bacteria and the eggs and larval forms of harmful helminths, such as those of bilharziasis and liver flukes. In rural areas where such water is used for bathing, washing clothes, irrigation of foods to be eaten raw, and other purposes, the dangers involved are obvious. This explains why liquid wastes from rural dwellings, institutions, or communities should never be discharged into public bodies of water without the permission of local health authorities. Where the objective is simply the avoidance of nuisance, health authorities usually prescribe the desirable ratio of volume of sewage with respect to the amount of receiving water. For natural waters, the amount of sewage should not be more than one-twentieth to one-fortieth of the amount of water flowing.^{12, 13}

The Cesspool

A cesspool is essentially a covered pit which receives raw sewage. It may be of the water-tight or of the leaching type. In some cases, especially in Europe, it is made water-tight and is designed to hold the liquid wastes, which must be removed periodically, about every six months. The leaching cesspool, on the contrary, is dug into pervious soils in order to allow the liquid portion of the waste to seep off into the ground. The solids then accumulate in the pit and gradually seal the pores of the ground.

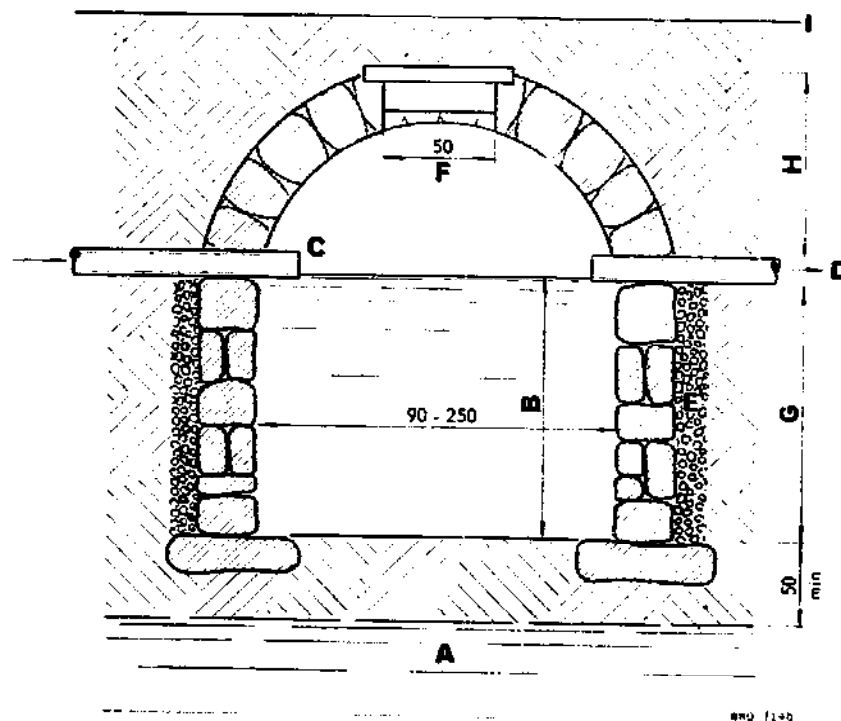
Water-tight cesspools are usually designed for a capacity of 68 l (15 Imp. gal.) per person per month, or 408 l (90 Imp. gal.) per person when they are emptied every six months.²³ Leaching cesspools have diameters of 90 cm (36 in.) or more, and are provided with an open-joint lining below the inlet level (see Fig. 61). The top part of the lining, which is within 60-90 cm (2-3 ft) of ground level, should be impervious and laid with mortar. Covers with inspection manholes are usually provided. After the pores of the ground become clogged and the pit fills, an outlet tee and an overflow pipe lead the supernatant liquid to a seepage pit.

As previously stated (p. 32), a cesspool should be located downhill from a well; in any case, a distance of 15 m (50 ft) will prevent bacterial pollution of the well. To prevent chemical pollution, too, the distance between a well and a cesspool placed directly uphill from it should be not less than 45 m (150 ft). Cesspools of the leaching type should be located at least 6 m (20 ft) away from dwelling foundations. Their construction is not permitted by health authorities in densely inhabited communities where wells are used as sources of drinking-water supply.

The Seepage Pit

The seepage pit receives the effluent from aqua privies, cesspools, and septic tanks and allows it to percolate away into the ground. It is sometimes used for the disposal of laundry, bathroom, and kitchen wastes.

FIG. 61. CESSPOOL LINED WITH LARGE STONES



Measurements shown are in centimetres.

- A = Ground water
- B = Depth 2 m (7 ft) or more to pervious soil
- C = Inlet pipe
- D = Outlet pipe to another cesspool. This pipe serves only when first cesspool is clogged and stops working
- E = 15-cm (6-in.) layer of coarse gravel
- F = Inspection manhole, 50 x 50 cm (20 x 20 in.)
- G = Stones laid without mortar
- H = Stones laid with mortar
- I = Ground level

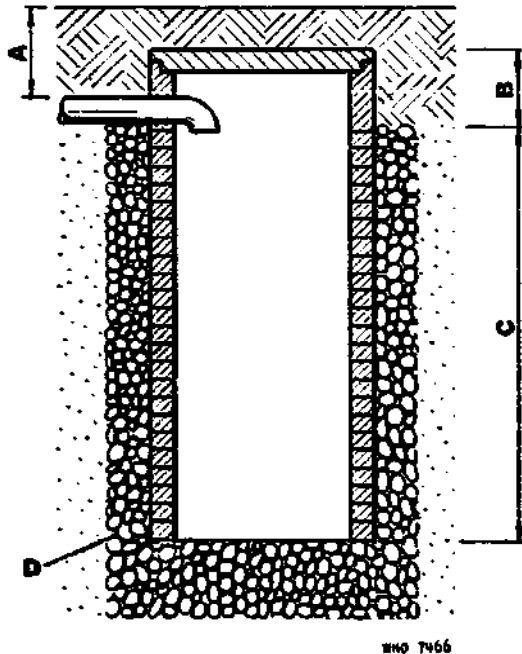
In the latter case, a grease trap may be necessary on the house sewer-line. The seepage pit may also be built at the lower ends of subsurface disposal tile lines in order to catch the septic-tank effluent which may have gone through without percolating away.

As shown in Fig. 62, the seepage pit consists merely of a round hole in the ground dug deep enough to penetrate 1.8 m (6 ft) or more into a porous layer of the earth. Diameters of 1.0-2.5 m (39-100 in.) and depths of 2-5 m (7-16 ft) are common. The side walls are lined with bricks or stones laid without mortar below the level of the inlet pipe. The hole may be filled with stones, in which case a lining is not required. The seepage pit should be closed with a tight cover which will prevent access to mosquitos and flies and to surface water as well.

If the soil through which the pit has been dug is not sufficiently porous, the effluent will slowly accumulate and will ultimately overflow. Even

in porous soils such a situation is common, as the pores of the earth walls become choked by the deposit of the finely divided matter carried by the effluent and by the solids built up by the life activities of zoogloal organisms

FIG. 62. SEEPAGE PIT



- A = Variable depth of soil
- B = Cement joints
- C = Open joints
- D = Rock fill, 15 cm (6 in.) or more

which thrive on the grains of the soil in contact with this effluent. These phenomena, in fact, govern the life span of a seepage pit, which should normally last for several years (perhaps 6-10 years) if the effluent is only slightly turbid as a result of efficient primary treatment of the raw sewage.

When a seepage pit ceases to operate, a new one should be dug several metres away. In order to increase the life span of the disposal system, it is possible to dig two or three seepage pits and to connect them at the top. The distance between any two pits should be at least three times the diameter of the larger pit.

The obvious disadvantage of seepage pits is the danger of pollution of ground water. For this reason they should be carefully located; the general rules governing their location have already been discussed

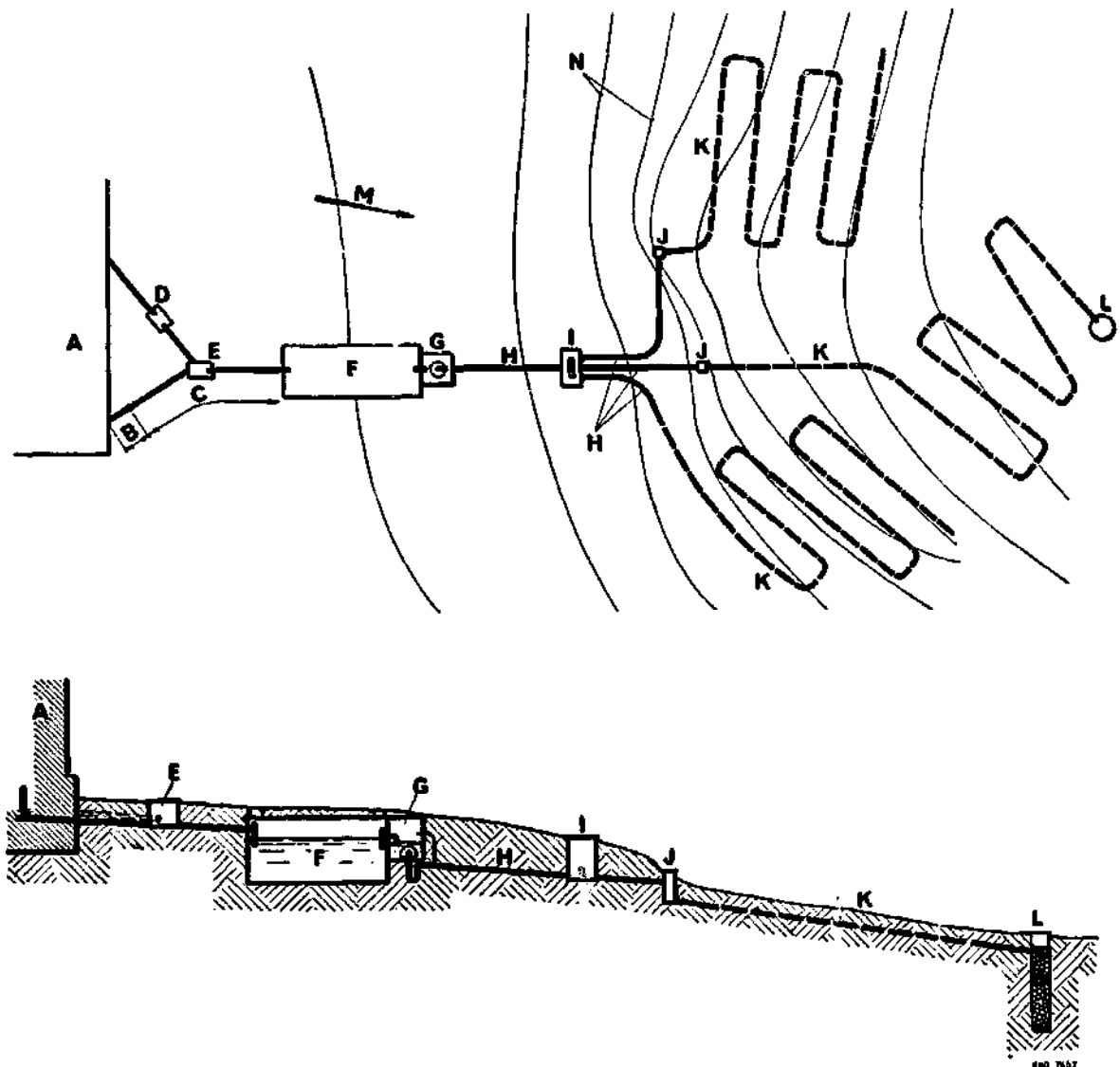
(p. 32). It will be recalled here that seepage pits should preferably be located downhill and, in any case, at least 15 m (50 ft) away from drinking-water sources and wells. As in the case of cesspools, the construction of seepage pits is not usually permitted by health authorities in closely built communities where ground water is used for domestic purposes.

THE SEPTIC TANK

The septic tank is the most useful and satisfactory unit among all water-carried systems of disposal of excreta and other liquid wastes from individual dwellings, small groups of houses, or institutions located in rural areas out of reach of sewer systems. It consists of a covered settling tank into which the raw sewage is led by the building sewer (see Fig. 63-65). The processes which take place inside the septic tank constitute the

“primary treatment” of the raw sewage, and those which occur in the disposal field form the “secondary treatment”. It should be noted that all liquid wastes, including those from bathrooms and kitchens, may be sent to the septic tank without endangering its normal operation. Recent research has shown that, contrary to former belief, sullage wastes can and should be discharged into septic tanks.

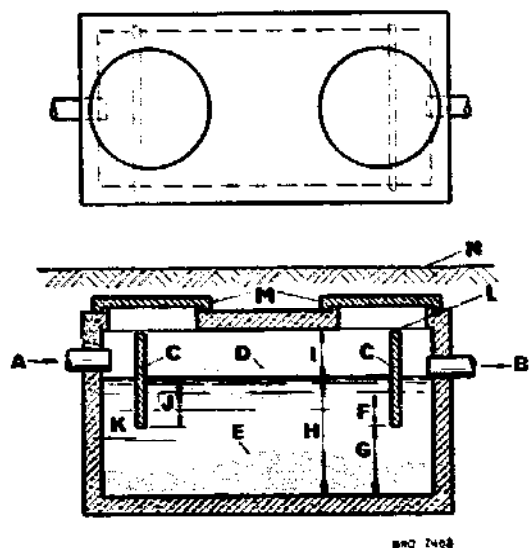
FIG. 63. TYPICAL LAYOUT OF SEPTIC-TANK SYSTEM



A = Private house or public institution
 B = House sewer
 C = Building sewer
 D = Grease interceptor on pipe line from kitchen
 E = Manhole
 F = Septic tank
 G = Dosing chamber and siphon

H = Pipes laid with tight joints
 I = Distribution box
 J = Drop-boxes or terracotta L's
 K = Absorption tile lines
 L = Seepage pit, when required
 M = Slope of ground surface
 N = Topographic contour lines

FIG. 64. TYPICAL HOUSEHOLD SEPTIC TANK



- A = Inlet
- B = Outlet
- C = Baffle
- D = Floating scum
- E = Sludge
- F = Scum-clear space
- G = Sludge-clear space
- H = Depth of water in tank
- I = Clearance
- J = Depth of penetration of baffle
- K = Distance of baffle to wall, 20-30 cm (8-12 in.)
- L = Top of baffle 2.5 cm (1 in.) below roof for ventilation purposes
- M = Tank covers, preferably round
- N = Ground level, less than 30 cm (12 in.) above tank (if less, raise tank covers to ground surface)

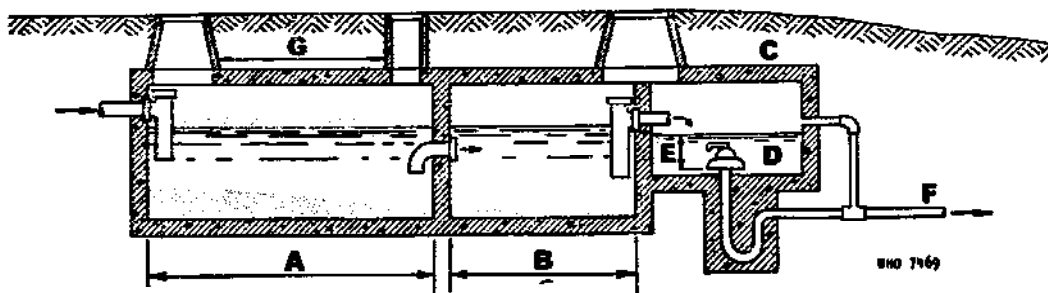
The Biological Processes Involved

Primary-treatment stage

In the tank, the incoming sewage is held quiescent, being retained for a period of one to three days, according to the tank capacity. During this period the heavier solids settle to the bottom as sludge. Most of the lighter solids, including grease and fats, remain in the tank and form a scum over the water surface, while the rest is carried away by the effluent into the final disposal system.

The solids which are retained in a septic tank undergo anaerobic decomposition through the activity of bacteria and fungi. The significant result of this process is a considerable reduction in the volume of sludge,

FIG. 65. SEPTIC TANK WITH TWO COMPARTMENTS AND DOSING CHAMBER



- A = Inlet compartment
- B = Outlet compartment
- C = Dosing chamber
- D = Dosing siphon
- E = Drawing depth of liquid
- F = Discharge pipe
- G = Manhole covers (raised when earth cover greater than 30 cm (12 in.))

which allows the tank to operate for periods of one to four years or more, depending upon circumstances, before it needs to be cleaned. This decomposition involves not only the sludge, but also the dissolved and colloidal organic content of the sewage.

The effluent of a properly designed and efficient septic tank is only slightly turbid, due to finely divided solids in suspension, and has a relatively low biochemical oxygen demand (BOD). However, it is still offensive in character; on standing, it yields little sediment but has a characteristic, putrid odour. In addition, this effluent is potentially dangerous to health, as it may contain pathogenic bacteria, cysts, and worm eggs which have passed unharmed through the tank during the relatively short detention period.

As the sludge decomposes, gas is produced and constantly rises to the surface as bubbles. The gas bubbles carry with them particles of decomposing organic matter which inoculate the incoming sewage with organisms which are necessary for putrefaction. These particles reach the scum which, in time, becomes thick and heavy and partly sinks below the water level. The floating cover of scum may attain such dimensions that its lower surface extends into the main sewage current. This usually coincides with a thick accumulation of dense and compact sludge over the bottom of the tank. As a result, the flow-through section becomes so small that adequate sedimentation of the suspended matter is no longer possible. At that time large amounts of floating matter will be noticed in the effluent. This condition can be prevented by regular cleaning of the tank.

The bubbling of gas through the liquid interferes to a certain extent with the normal sedimentation of sewage solids. This interference may be minimized by the addition of a second compartment to the septic tank. The lighter, suspended solids carried from the first compartment find quieter conditions for settling in the succeeding compartment. This is especially valuable at times of rapid anaerobic decomposition when sludge solids are found in greater quantity in the tank's first compartment. The sludge in the succeeding compartment is usually more homogeneous and flocculent than that in the first compartment, and there is also less scum production. The effluent of such a tank will contain a lower proportion of suspended matter than that from a single-compartment system.

For the efficient development of the biological processes, turbulence should be avoided, and the disturbing effects of surge flows should be reduced to a minimum. Turbulence and surge flows may be so serious in small or overloaded tanks as to cause a complete breakdown of tank operation and of secondary-treatment processes. The space available for clarification in the larger tanks has a certain compensatory or equalizing effect.

In order to ensure and to speed up the establishment of the biological processes at a high level of efficiency, newly constructed septic tanks are usually seeded with a quantity of ripe sludge bailed out from another tank already in operation. This sludge, which is in an advanced state

of decomposition, provides the bacteria and fungi necessary for rapid alkaline fermentation, which succeeds the initial breakdown of the raw organic matter by anaerobic bacteria. The addition of yeast is not effective in starting digestion in a new tank or in rejuvenating a sluggish tank.

Secondary-treatment stage

The secondary treatment of septic-tank effluent is based on the oxidation of organic matter through the activity of aerobic bacteria. These bacteria thrive in the upper layers of the soil and in sand or stone beds whose pores are naturally aerated by oxygen from the air. In subsurface irrigation and in filter beds, the effluent is spread as uniformly as possible over the grains of soil or sand, or over small stones. A biological slime develops in which the aerobic bacteria and micro-organisms are active. It is important that these biological media should not be overloaded or submerged for any great length of time; otherwise, the aerobic bacteria will die and anaerobic conditions will develop. In larger installations, aeration is achieved by intermittent dosing by means of a dosing siphon installed next to the septic tank. In this way, the soil or filter bed recuperates, and air penetrates anew in the interstices of the filtering medium during the intervals between flushes of the siphon. Natural aeration of the soil is facilitated in the case of filter trenches through the drain pipes and, in the case of subsurface irrigation, through a vent pipe or seepage pit installed at the lower end of the disposal field.

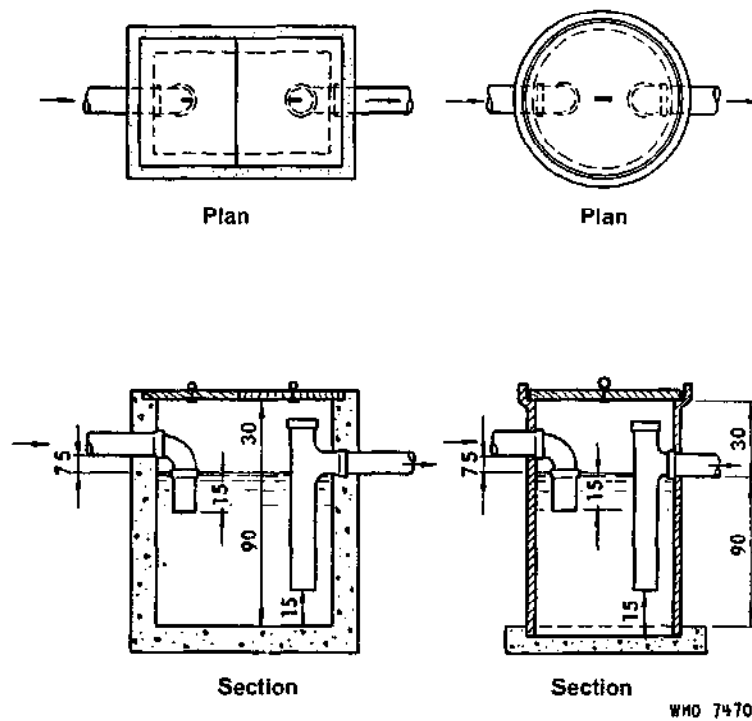
Ventilation of the filtering medium may be arrested if the pores are allowed to become clogged by suspended matter carried by the effluent or by excessive slime growths. In either case, the trouble may be traced to defective or inefficient operation of the septic tank itself, although excessive slime growth may also be due to overloading of the disposal field. In subsurface irrigation in particular, the need for efficient primary treatment and a clear effluent is greatest. Of course, much depends upon the porosity of the soil, fine-grained sand being best from the standpoints of both permeability and ventilation; impervious soils, such as clay, are totally inappropriate. Where ground water is close to the surface, it may not be possible to dispose of the effluent through subsurface irrigation, since the pores of the soil above the water table are clogged with water held by capillary action. Experience shows that tile pipes should not be laid closer than 90 cm (3 ft) to the ground-water level.

Design of the Septic-Tank System

The grease interceptor

Liquid wastes from large kitchens, such as those found in hotels, small hospitals, and similar institutions, are likely to contain much grease, which

FIG. 66. TYPES OF GREASE INTERCEPTOR



Adapted, by permission, from *Manual of septic-tank practice*.²⁷
 Measurements shown are in centimetres.

may pass through the septic tank along with the effluent and may clog the pores of the filtering medium of the disposal field. In such cases, a grease interceptor is installed outside the building just before the building sewer (see Fig. 66). It is designed as a small skimming tank provided with submerged inlet and bottom outlet. Its operation is based on the principle that the incoming liquid waste is warmer than the sewage already in the interceptor and is cooled by it, causing the grease content to congeal and rise to the surface, from which it is skimmed off and disposed of by burial at periodic intervals. For this reason, grease interceptors should be easily accessible for inspection and cleaning.

Grease interceptors are not considered necessary in sewage disposal systems for dwellings and other small installations. Their size depends on the type of building and the volume of sewage to be handled. For a single-family dwelling (when it is desired to install one), the interceptor capacity should be about 110 l (30 US gal.).²⁸ Other interceptors should preferably have a capacity equal to five times the volume of waste water that is liable to be discharged into them at any one time.²⁹ They may be constructed of metal, brick, vitrified or concrete pipe, or concrete. The inlet and outlet should be placed as far apart as possible in order to avoid

a direct flow between them, and the depth below the outlet flow line should not be less than 60 cm (2 ft).

The building sewer

The U.S. Joint Committee on Rural Sanitation³⁸ has the following recommendations to make :

“ The building sewer is that part of the horizontal piping of a building drainage system extending from a point usually 5 feet [1.50 m] outside the inner face of the foundation wall to the public sewer connection or individual sewage disposal unit (septic tank, cesspool, or other type of disposal).

“ The building sewer should be constructed of bell and spigot pipe made of cast iron, vitrified clay, concrete, or other durable material. Portland cement mortar or bituminous compounds should be used for all joints on pipe lines other than cast iron ; lead or other suitable joint material should be used on all cast-iron pipe lines. Where the septic tank or primary unit of the disposal system is located within 25 feet [7.50 m] of the building or dwelling, it is desirable to construct the building sewer of extra heavy cast-iron pipe throughout its entire length because cast-iron lines are less susceptible to clogging and are easier to clean. Vitrified clay or concrete pipe should not be used in sizes smaller than 6 inches [15 cm]. When cast-iron pipe is used in the building sewer it may be the same diameter as that of the building drain, provided that it is not smaller than 4 inches [10 cm] in diameter. Whenever the building sewer is a different size than the building drain the connection therewith should be made with the proper type increasing fittings, assuring a watertight joint and satisfactory construction to eliminate clogging at the connecting point.

“ All joints on the building sewer should be made by using a ring of oakum (jute) and such joint material to provide water tightness. Whenever the building sewer line is laid within root-growing distance of large trees or dense shrubbery and constructed of material other than cast-iron pipe with lead-caulked joints, the joints should be made with a bituminous compound or other root-proofing material. Special copper rings may be used with cement mortar or the cement mortar may be treated with copper sulfate or coarse salt to prevent roots penetrating the joints, entering the pipe line, and eventually clogging the sewer.

“ The most essential features to be observed in construction of the building sewer line are as follows :

“ 1. Minimum size of pipe : 6 inches [15 cm] if sewer is of vitrified clay or concrete, 4 inches [10 cm] if sewer is of cast iron.

“ 2. Minimum grade—1 percent . . . However a fall of [2 percent] is preferable and should be provided wherever feasible.

“ 3. Grade of building sewer for 10 feet [3 m] immediately preceding the tank should not exceed 2 percent approximately . . .

“ 4. Cast-iron pipe with lead or other comparable joint material used when within :

50 feet [15 m] of a well or suction line from a well.

10 feet [3 m] of any drinking water supply line under pressure.

5 feet [1.50 m] of basement foundations, and when laid beneath driveways with less than 3 feet [90 cm] of earth cover.

“ 5. Cleanout at every change in line of 45° or more and at every change in grade in excess of 22½°. Bends of 90° should be avoided wherever possible or such bends made with two 45° ells or a long-sweep quarter curve. (Cleanouts are desirable within 5 feet [1.50 m] of the septic tank where tanks are located more than 20 feet [6 m] from the building. An economical cleanout may be provided by inserting a tee in the line with

the vertical leg extending to ground level and plugged with a brass cap. If the line is deeper than 4 feet [1.20 m], manhole construction should be required for cleanout purposes.)

"6. All joints made watertight and protected from damage by roots wherever necessary."

The tank

A review of the literature shows a multiplicity of designs adopted in various countries for septic tanks. Many of the designs recommended for dwellings and small institutions are cumbersome and complicated unnecessarily by the provision of special features claimed to achieve a better effluent. As a result of extensive research carried out between 1947 and 1953 by the United States Public Health Service,^{3, 39, 40} most of the problems involved in the design of septic tanks have been clarified. The following information includes several of its findings, in addition to data resulting from well-accepted practice in the USA,³⁷ Europe,²³ and elsewhere.²⁹

Size of tank

The principal factors to be considered in deciding on the capacity of a septic tank are :

- (a) the average daily flow of sewage ;
- (b) the retention period, from 1-3 days, usually 24 hours ;
- (c) adequate sludge storage, for desludging every 2-3 years.

The average daily flow of sewage depends on the average water consumption in the area under consideration. In rural areas and small communities the water consumption per person is likely to be lower than in municipalities. As a result, sewage flows of less than 100 l (26 US gal.) per person per day may be expected in most rural areas of the world. However, experience indicates that such low figures cannot be used for the design of small septic tanks, which should be provided with ample capacity since such tanks are seldom cleaned before trouble develops. It is therefore important that their capacity be ample to permit reasonably long periods of trouble-free service and to prevent frequent and progressive damage to the effluent absorption systems due to discharge of sludge by the tanks. For this reason the capacity of residential, single-chambered, septic tanks should not be less than 1900 l (500 US gal.) below water-level.

The liquid capacities of the septic tanks described in Tables VIII and IX are based on a sewage contribution of :

- 190 l (50 US gal.) per person daily in dwellings ;
- 95 l (25 US gal.) per person daily in camps ;
- 64 l (17 US gal.) per person daily in day schools.

TABLE VIII. REQUIRED CAPACITIES * FOR SEPTIC TANKS SERVING INDIVIDUAL DWELLINGS

Maximum number of persons served	Nominal liquid capacity of tank (US gal.)	Recommended dimensions							
		width		length		liquid depth		total depth	
		ft	in.	ft	in.	ft	in.	ft	in.
4	500	3	0	6	0	4	0	5	0
6	600	3	0	7	0	4	0	5	0
8	750	3	6	7	6	4	0	5	0
10	900	3	6	8	6	4	6	5	6
12	1100	4	0	8	6	4	6	5	6
14	1300	4	0	10	0	4	6	5	6
* 16	1500	4	6	10	0	4	6	5	6

* Liquid capacity based on number of persons served in dwelling. The volume based on total depth includes air space above liquid level.

The capacities indicated in Table VIII should in most countries provide sufficient sludge-storage space for a period of two years or more, and an additional volume equal to the sewage flow for 24 hours.

It should be noted, however, that, in a few countries, small garbage grinders are being installed more and more frequently in the kitchens

TABLE IX. REQUIRED CAPACITIES FOR SEPTIC TANKS SERVING CAMPS AND DAY SCHOOLS

Maximum number of persons served		Nominal liquid capacity of tank (US gal.)	Recommended dimensions							
camps	day schools		width	length	liquid depth	total depth				
			ft	in.	ft	in.	ft	in.	ft	in.
40	60	1000	4	0	8	6	4	0	5	0
80	120	2000	5	0	11	0	5	0	6	3
120	180	3000	6	0	13	6	5	0	6	3
160	240	4000	6	0	18	0	5	0	6	3
200	300	5000	7	6	18	0	5	0	6	6
240	360	6000	8	0	20	0	5	0	6	6
280	420	7000	8	6	20	0	5	6	7	0
320	480	8000	8	6	23	0	5	6	7	0

Note: Tanks with capacities in excess of 8000 gallons should be designed for the specific requirements involved; however, in such cases the necessity for a more complete type of treatment should receive consideration.

of dwellings for the purpose of grinding garbage or wastes, which are then discharged into the house sewers. This adds an appreciable load of settleable organic solids to the sewage and to the septic tank. Where such grinders are used, the capacity of the septic tank should be increased by 50% to allow for additional sludge-storage space.

The capacities shown in Table IX are based on a 24-hour flow of sewage without allowance for sludge-storage space, since it is expected that septic tanks serving camps and schools will receive regular inspection and maintenance, including more frequent cleaning than those for residences.

In the case of public institutions, such as rural hotels and hospitals, and groups of houses, such as housing projects, the figures given in Tables VIII and IX may not apply. It will first be necessary to secure the advice of a competent engineer whose duty it will be to determine the probable daily water consumption and sewage flow, both of which are likely to be much higher than the figures cited above. Most recent information indicates that :

1. For flows between 1900 l and 5700 l (500 US gal. and 1500 US gal.) per day, the capacity of the septic tank should be equal to at least 1½ days' sewage flow.

2. For flows between 5700 l and 37 850 l (1500 US gal. and 10 000 US gal.) per day, the minimum effective tank capacity should be 4260 l (1125 US gal.) plus 75% of the daily sewage flow, or :

$$V = 1125 + 0.75 Q, \text{ where}$$

V is the net volume of the tank in US gallons, and Q is the daily sewage flow, also in US gallons,

or :

$$V = 4260 + 0.75 Q, \text{ where}$$

V is the net volume of the tank in litres, and Q is the daily sewage flow in litres.

3. For flows greater than 37 850 l (10 000 US gal.) per day, Imhoff tanks may be more satisfactory than septic tanks for primary treatment.

Multi-compartment tanks

Research by the US Public Health Service^{3, 30, 40} has demonstrated that properly designed, multi-compartment, household septic tanks give a performance as good as, or better than, single-compartment tanks of the same total capacity. This is especially true of the smaller tanks. As pointed out previously, the effects of fluctuations of flow and of surge flows are disastrous to the efficiency of the primary-treatment processes in small, single-chambered septic tanks. It is therefore desirable that small household tanks, i.e., those serving, say, less than 20-25 persons,

be provided with two compartments. The inlet compartment should have a capacity of one-half to two-thirds of the total tank capacity, and the liquid capacity of such an inlet compartment should be not less than 1900 l (500 US gal.) for the minimum installation. For the larger tanks, i.e., those serving more than 20-25 persons, the need for compartmenting the tank will depend upon the degree of treatment required by local health authorities and by the degree of permeability of the soil (where this applies). The research cited above shows that there is not much to be gained by an excessive number of partitions, and that a well-designed, single-chambered tank will result in a suspended solids removal efficiency of over 60%.

Outlet and inlet arrangements

Various outlet and inlet devices have been used in septic tanks. Recent experimental research^{39, 40} indicates that the baffle system or the arrangements shown in Fig. 64 and 65 are quite satisfactory and offer simplicity and ease of installation. The depth of penetration of these devices into the tank's liquid is very important, as it influences the volumes of clear space and of sludge accumulation. The research cited above shows that for best results the outlet device should penetrate below the surface to a depth of 40% of the liquid depth. In the case of horizontal, cylindrical tanks, this figure should be reduced to 35%. The inlet baffle or tee should extend 30 cm (12 in.) below water level.

Both devices should permit free ventilation through the tank and through inlet and outlet pipes. They should extend at least 15 cm (6 in.) above the water line and leave at least 2.5 cm (1 in.) clearance below the tank's cover for ventilation purposes. Baffles are usually placed 20-30 cm (8-12 in.) away from the inlet and outlet pipes, whose ends are flush with the tank's walls.

The invert of the inlet pipe should be at an elevation not less than 2.5 cm (1 in.), preferably 7.5 cm (3 in.), above water level. Connexions between two compartments are best made by means of an ell whose lower end does not penetrate into the liquid at a depth lower than the outlet device.

Shape of tank

The shape of the tank is important inasmuch as it influences the velocity of flow through it, the depth of accumulation of sludge, and the presence or absence of stagnant corners. If the tank is too deep, the other dimensions will be small, and a direct current from inlet to outlet will occur, greatly shortening the retention period. If the tank is too shallow, however, the sludge-clear space will be too small, and the effective cross-section of the tank will be unduly reduced. When the width is too great, there will be dead pockets of appreciable size at the corners where little, if any

water movement takes place. Finally, if the tank is too narrow, the velocity of flow will be so great as to interfere with efficient sedimentation. Research³⁹ shows that "in a two-equal-compartment arrangement, there is no difference in performance between rectangular and cylindrical shapes, if equal solids storage capacities are provided". Rectangular tanks should be designed with a length not less than two, but not more than three, times the width. The liquid depth should not be less than 1.2 m (4 ft), but not more than 1.7 m (5.5 ft) in the large tanks. Clearance above the water level is usually 30 cm (12 in.)

Location of tank

The septic tank should be so located as to permit easy drainage from the dwelling and to the effluent disposal system. When the latter makes use of subsurface irrigation, the location of the tank should be such as to ensure that sufficient area is available for disposal of the effluent and that tile lines may be laid on a gentle slope and at a depth not exceeding 75 cm (30 in.) at any point.

Since periodic inspections are necessary, the tank should not be buried more than 30-45 cm (12-18 in.) below ground level. Inspection manholes should preferably be extended to reach ground level. Precautions should be taken to prevent the entrance of surface run-off into the tank.

Because of the possibility of leakage, especially around the inlet and outlet pipes, the tank should be located preferably downhill and at least 15 m (50 ft) away from wells and other sources of water supply.

Construction of tank

Septic tank systems belong to the category of works which require for their construction the direct assistance and supervision of engineers, or at least of experienced construction foremen. No attempt will be made to describe here in detail the steps which should be observed in the actual construction of a tank in a rural community. The following information and data may, however, be useful to the engineer entrusted with the construction of these systems.

Tanks are usually built of concrete, a material which offers a guarantee of strength and imperviousness. Sometimes the bottom and the cover of the tank are made of concrete while the walls are built of bricks, cut-stone, or cement blocks laid with rich cement mortar and plastered (on the inside tank surface) with a 1:3 cement-sand mixture. A concrete mixture of 1:2:4 cement sand-gravel containing 23 l (6 US gal.) of water per bag of cement (94 pounds or 43 kg) should be used. Concrete walls and bottom should not be less than 10 cm (4 in.) thick, with adequate reinforcement.

The tank cover should be strong enough to withstand the weight of earth cover and occasional extra loads. Sectional slabs may be used where the tank is protected against surface water run-off. If not, the cover should be cast monolithically with the walls and raised manholes provided. For small tanks, one manhole placed above the inlet is sufficient. For large tanks, two manholes—one above the inlet and the other above the outlet—are necessary. The minimum size of the manholes should be 50 cm (20 in.) square or 61 cm (24 in.) in diameter.

The circular cover, although more difficult to build than the square or rectangular cover, is sometimes preferred as it cannot fall through the opening in the course of handling and tank-cleaning operations. In an area in India where filariasis was a serious public health problem, it was found that *Culex fatigans*, the local mosquito vector of the disease, was breeding in many septic tanks in households and institutions owing to the fact that the rectangular covers had fallen into the tanks through the manhole covers along their diagonal axis at the time of cleaning and had not been replaced.^a

Concrete septic tanks can be pre-cast either monolithically or in small parts at a central shop and erected quickly in the field. They are also made commercially of metal to which a special coating is applied to prevent corrosion.

Operation and Maintenance of the Septic Tank

As previously indicated, a newly built septic tank should first be filled with water up to outlet level and then should be seeded with several (5 to 8) buckets full of ripe sludge (or decomposing stable manure ripe enough to give off an ammonia odour).

Although the designs recommended provide for desludging about every two years or more, the tank should be inspected every 12-18 months in the case of household installations, and every six months in the case of tanks serving schools and other public institutions. The inspection should be directed towards the determination of :

- (a) the distance from bottom of scum to bottom of outlet (scum-clear space) (see Fig. 64);
- (b) the depth of accumulation of sludge over tank bottom.

The scum-clear space should not be less than 7.5 cm (3 in.), and the total depth of scum and sludge accumulations should not be more than 50 cm (20 in.).

Sludge may be bailed out by means of a long-handled, dipper-type bucket, or it may be pumped out by a specially equipped cesspool-emptying

^a Personal communication from Dr T. R. Rao, Assistant Director of Public Health (Malaria), Bombay State, India

vehicle. Where large tanks are provided with bottom hoppers, cleaning is sometimes done by flushing and pushing the sludge out of the tank towards a drying bed by the hydrostatic head available in the tank. Even if care is taken, undigested sludge is likely to be removed also from the tank in this way. On the other hand, digested sludge is fairly dense and does not flow easily. This procedure is not recommended for application in rural areas.

The scum and sludge removed from ordinary septic tanks will normally contain some undigested portion which is still offensive and potentially dangerous to health. Such sludge should not be used immediately as crop fertilizer, but may be profitably composted along with other organic wastes (garbage, grass clippings, etc.). Otherwise, it should be buried in shallow, 60-cm- (2-ft-) deep trenches. Provision should also be made for more frequent (perhaps every 3 to 6 months) inspections of the distribution box.

In a few instances, local health authorities may require that the effluent from septic tanks or disposal fields be disinfected before discharge into a small stream or public pond. This is especially true of hospital effluent, which is likely to contain live germs of transmissible diseases. Chlorine, as calcium hypochlorite, is commonly used for this purpose and is applied by means of hypochlorinators.

Because of the need for regular, intelligent care to ensure the proper operation of septic tank systems, it is desirable that some persons in the rural community be instructed in their maintenance and repair. Local health authorities should stimulate the formation of "co-operatives" or the setting-up of private concerns willing to undertake the maintenance work. These authorities should also stimulate requests from the people for advice on septic tank construction and maintenance and should be prepared to give technical guidance to all interested persons.

THE DISPOSAL OF EFFLUENT

The quality of septic-tank effluent and the biological processes involved in its purification have already been discussed. One conclusion to be drawn from this discussion is that septic-tank effluent should never be permitted to run in canals and open ditches, or to be disposed over land for the irrigation of crops or into small fishponds without the permission of local health authorities.

In rural areas and small communities, the choice of methods available for treating and disposing of the effluent is usually limited to (a) dilution, (b) seepage pits, (c) subsurface irrigation, (d) filter trenches, (e) sand filters, or (f) trickling filters.

In order to be able to select the method which is most appropriate to the particular location under consideration, it is necessary to determine the nature of the ground, the depth of the ground-water table, the degree of permeability of the soil, the proximity of wells and other water-supply sources, the volume and the rate of renewal of surface water available for dilution (in streams, ponds, and other bodies of water), and the uses made of this surface water (e.g., water supply, fishing, bathing). Among other factors to be considered are the land area available for the disposal works, the proximity of houses, the prevailing directions of the wind, the vegetation cover of the disposal land, and probable future extensions of the system.

The methods of disposal by dilution and by seepage pits have already been described in connexion with the disposal of raw sewage (see pp. 122-125).

Disposal by Subsurface Irrigation

This is the method most often employed in connexion with small septic tanks serving households and institutions. It consists simply of dispersing tank effluent into the top layer of the ground by means of open-jointed drain pipes laid in trenches and covered. In this way the effluent is purified through the action of the aerobic saprophytic bacteria of the soil and percolates away into the ground. It is obvious that this method cannot be used where the subsoil is not porous, where the ground-water table rises to within 1.2 m (4 ft) of the ground surface, or where there is the danger of pollution of water supplies (in fissured limestone formations, for example). In particular, it is not applicable in impervious clay soils and swampy lands.

Percolation tests

In order to calculate the length of pipe required in the disposal field, it is necessary to determine the degree of permeability of the soil by making percolation tests. The method for performing such tests has been recently improved as a result of numerous field investigations.^{3, 39, 40} The following is quoted from Part III of *Studies on household sewage disposal systems* :³⁹

Percolation Test Procedure

“ Because of the great number of factors that may affect a percolation test and the variability that can be expected in the rate-time relationship, it appears unlikely that a short-time procedure can be developed, applicable to all soils and all conditions.

“ It is thought best at this time to concentrate on developing a fundamental and objective test procedure which can be applied to a wide range of soils and which, as has been pointed out, would be essential in clay-type soils. Such a test would also be essential where no experience with test methods or a particular soil is available. As experience is gained, the test might be modified to suit local conditions. The fundamental test might also be used to check modified procedures from time to time.

"The following percolation test is suggested as a fundamental and objective procedure:

"1. *Number and location of tests.* — Six or more tests shall be made in separate test holes spaced uniformly over the proposed absorption field site.

"2. *Type of test hole.* — Dig or bore a hole, with horizontal dimensions of from 4 to 12 inches [10-30 cm] and vertical sides, to the depth of the proposed absorption trench. In order to save time, labor, and volume of water required per test, the holes can be bored with a 4-inch [10-cm] auger.

"3. *Preparation of test hole.* — Carefully scratch the bottom and sides of the hole with a knife blade or sharp pointed instrument, in order to remove any smeared soil surfaces and to provide a natural soil interface into which water may percolate. Remove all loose material from the hole. Add 2 inches [5 cm] of coarse sand or fine gravel to protect the bottom from scouring and sediment.

"4. *Saturation and swelling of the soil.* — Carefully fill the hole with clear water to a minimum depth of 12 inches [30 cm] over the gravel. By refilling if necessary, or by supplying a surplus reservoir of water, such as in an automatic siphon, keep water in the hole for at least 4 hours and preferably overnight. Allow the soil to swell overnight. This saturation procedure insures that the soil is given the opportunity to swell and approach the condition that it will be in during the wettest season of the year. Thus, the test will give comparable results in the same soil whether made in a dry or a wet season.

"In sandy soils containing little or no clay, the swelling procedure is not essential and the test may be made as described under item 5C, after the water from one filling of the hole has completely seeped away.

"5. *Percolation rate measurement.* — With the exception of sandy soils, percolation rate measurements shall be made on the day following the procedure described under item 4, above.

"A. If water remains in the test hole after the overnight swelling period, adjust the depth to approximately 6 inches [15 cm] over the gravel. From a fixed reference point, measure the drop in water level over a 30-minute period. This drop is used to calculate the percolation rate.

"B. If no water remains in the hole after the overnight swelling period, add clear water to bring the depth of water in the hole to approximately 6 inches [15 cm] over the gravel. From a fixed reference point, measure the drop in water level at approximately 30-minute intervals for 4 hours, refilling 6 inches [15 cm] over the gravel as necessary. The drop that occurs during the final 30-minute period is used to calculate the percolation rate. The drops during prior periods provide information for possible modification of the procedure to suit local circumstances.

"C. In sandy soils (or other soils in which the first 6 inches [15 cm] of water seeps away in less than 30 minutes, after the overnight swelling period) the time interval between measurements shall be taken as 10 minutes and the test run for 1 hour. The drop that occurs during the final 10 minutes is used to calculate the percolation rate.

"6. *Additional criteria for judging soil suitability.* — In areas of shallow ground water, the depth to the water table shall be determined. If, for any extended period during the year, the water table is normally at a depth of less than 4 feet [1.2 m], the results of the percolation test should be applied with caution. The case also warrants special consideration if impermeable layers are found at depths of less than 4 feet [1.2 m]."

The effective absorption area required may then be found from the Table X.

TABLE X. ABSORPTION-AREA REQUIREMENTS FOR RESIDENCES AND SCHOOLS *

Percolation rate (time required for water to fall 2.5 cm (1 in.), minutes)	Required absorption area (square metres of absorption trench bottom per person served)	
	residences	schools
2 or less	2.30	0.84
3	2.80	0.93
4	3.25	1.12
5	3.50	1.21
10	4.65	1.67
15	5.35	1.86
30	7.00	2.70
45	8.45	3.10
60	9.30	3.50
Over 60	Unsuitable for shallow absorption system	

* Adapted from table given in *Studies on household sewage disposal systems*.³⁹

As indicated by Table X, a percolation rate of 60 or more is an indication that the soil is unsuitable for effluent disposal by subsurface irrigation. In such a case, the possibility of constructing seepage pits which may penetrate into a deeper, permeable layer of the ground or the use of sand-filter trenches may be considered.

It may be emphasized that effective absorption area means the flat area in the bottom (only) of trenches. Attention is drawn to the fact that the figures given in the Table X are based on a daily flow of 190 l (50 US gal.) of sewage per person in residences. In many parts of the world, the daily flow of sewage will be found to be substantially less than this, in which cases the figures in the table might be reduced on the basis of actual field experience.

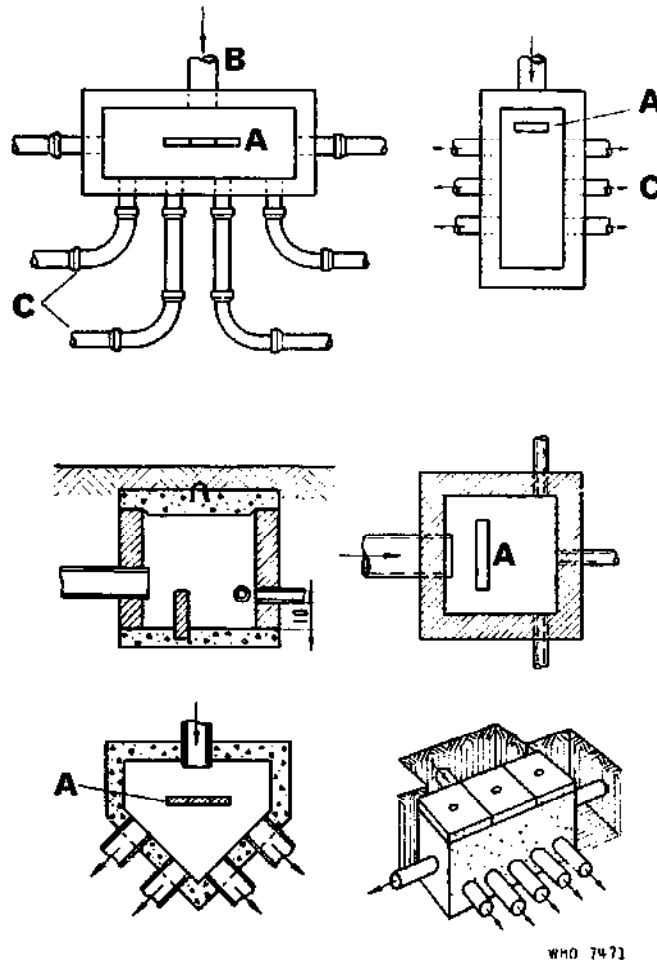
Construction and layout of disposal field

Distribution box

As its name implies, a distribution box is a chamber which ensures an even distribution of the effluent to the subsurface disposal field through the drain pipes (see Fig. 67). If easily accessible, it may also serve as an inspection manhole for checking the amount of suspended matter in the effluent from the septic tank as well as the proper distribution of effluent. It requires care in its design and construction; and, for efficient operation—i.e., the equal distribution of flow among its various outlets—occasional inspection and maintenance are needed. Experience shows that an outlet may become partially obstructed by floating matter from the septic tank,

if the latter needs cleaning, or by other solid matter (twigs, small stones, etc.), which may have fallen accidentally through the manhole. As a result, a portion of the disposal field may be inoperative and the rest overloaded, becoming "sewage sick" within a short time.

FIG. 67. TYPES OF DISTRIBUTION BOX



WHO 7471

Adapted, by permission, from
*Manual of septic-tank practice.*³⁷

- A = Baffle in wood or brick
- B = Inlet from septic tank or dosing chamber
- C = Outlet to absorption lines

The general practice followed in the design of distribution boxes may be described as follows :³⁸

"The inlet pipe should enter at one end of the box about 2 inches [5 cm] above the bottom. Sides of the box should extend approximately 12 inches [30 cm] above the invert of the inlet pipe and the box should be provided with a removable cover. Since frequent inspection is not necessary, the cover of the box may be placed 12 to 18 inches [30 to 46 cm] below the surface of the ground. Drainage lines should be constructed with

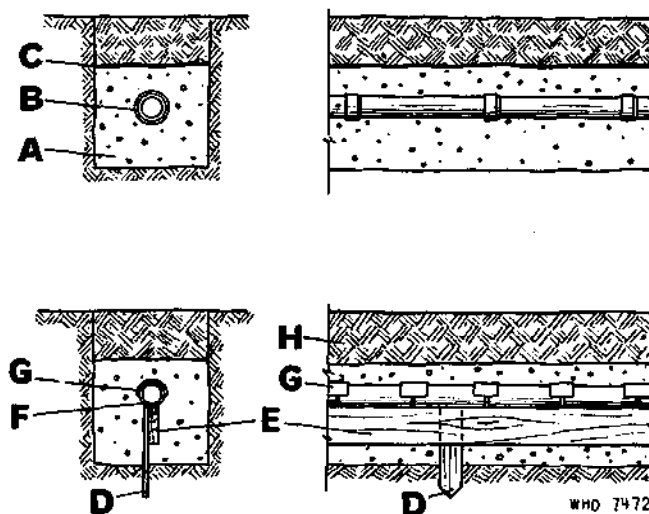
inverts at bottom level of the box or approximately one inch [2.5 cm] above the bottom and all should be set at the same elevation. They should run straight in the desired direction. Horizontal bends should be avoided where possible; when necessary, however, they should be made with tight joints. When set at the same elevation and operating under the same head, pipes all of the same size are more likely to receive an equal flow. Lines may be run from an elevation several inches above the bottom of the box, but care must be taken to insure that all lines leave the box at the same elevation.

"The box need not be more than 18 inches [46 cm] in width, nor longer than is necessary to accommodate drains for effective outlet capacity. Diversion baffle boards should not be installed in distribution boxes on systems serving individual dwellings. However, such construction may prove advisable on systems serving public buildings where constant supervision and maintenance are provided and where the purpose of such baffle boards may be realized. Lines may be shut off at will for repairs or to rest the field when it comes waterlogged, provided a distribution box is installed. Flow diversion devices may be installed in the properly designed distribution box to facilitate rotation of use of the distribution lines where adequate and proper maintenance is assured."

Pipes and trenches for septic-tank effluent

Plain-end tile pipes, 10 cm (4 in.) in diameter and 30-60 cm (12-24 in.) in length, are commonly used (see Fig. 67). Bell and spigot sewer pipe of the same diameter but 61 cm (2 ft) in maximum length may be preferred. A small stone or cement fillet may be used in the bottom of each socket

FIG. 68. ABSORPTION TRENCHES



- A = Coarse gravel surrounding pipe
- B = Bell and spigot pipe
- C = Building or tar paper
- D = Wooden stakes supporting grade board E
- E = Longitudinal boards, nailed to stakes and laid at exact grade selected for absorption lines
- F = Absorption tile pipes resting over grade boards
- G = Tar paper covering upper half of open joints
- H = Earth-tamped backfill

joint to centre the spigot in the bell. Plain-end tiles need a firm support to remain on an even grade and, hence, to effect uniform distribution of the septic-tank effluent. Such a support is provided by means of a flat board—for example, 2.5×10 cm (1×4 in.) in size—which is set on edge and nailed to stakes driven at intervals in the bottom of the trench. The top of the board can be laid accurately to the desired grade (see Fig. 68).

Both types of pipe are laid in such a way as to leave an open space of 0.6-1.2 cm (0.25-0.50 in.) between pipe lengths for the effluent to run out. When plain-end pipes are used, the upper half of the joint must be covered with a strip of asphalt or tar paper to prevent entrance of fine sand and silt which might interfere with the flow of effluent. Ball and spigot pipes do not require this protection, since the joints are protected by the bell ends. In either case, however, the joints should be covered with at least 5 cm (2 in.) of gravel. Some authors²¹ even recommend that irrigation trenches be filled to the ground surface with filter material (gravel), thereby reducing the risk of silt's entering the drain. The portion of the effluent drain located between the septic tank and the distribution box and a length of, for example, 1.50 m (5 ft) of outlet line from the distribution box should be laid with tight cement joints.

The depth of pipe-inverts should not be less than 30 cm (12 in.) nor more than 75 cm (30 in.). An earth cover of about 30 cm (12 in.) is desirable to protect the pipe against injury. Under roads, or paths followed by heavy agricultural machines, it may be necessary to use cast-iron pipes or strong vitrified sewer-pipes, laid with tight joints, in order to maintain line and grade.

The grade of the disposal pipelines should not be too small or too great: if too flat, only the upper area of the disposal field will receive the effluent; if too steep, there will be a rush of liquid in the upper portion of the pipelines towards the lower portion of the disposal field, which will soon be waterlogged. Experience dictates a slope of 0.16% to 0.32%—i.e., 2-4 in. per 100 ft—with a maximum of 0.5%. In order to maintain such grades on steep-sloping lands, disposal pipes should be laid along the contours of the ground, and changes of direction should be made by means of drop-boxes or terracotta L's laid with cemented joints. At such points special precautions should be taken to cut off the underground flow of sewage which is normally running above the upstream trench bottom and which may cause erosion of the ground around the drop-boxes and terracotta L's. This may be done by filling with well-tamped clay soil the last 30 cm (12 in.) of trench preceding each drop-box or L-pipe.

The size and lengths of trenches required should be calculated on the basis of the figure previously obtained for effective absorption area. The size and minimum spacings recommended may be obtained from the Table XI.³⁸

TABLE XI. SIZE AND MINIMUM SPACING REQUIREMENTS FOR DISPOSAL TRENCHES

Width of trench at bottom (inches)	Depth of trench (inches)	Effective absorption area (sq. ft/ft)	Spacing of tile lines * (feet)
18	18 to 30	1.5	6.0
24	18 to 30	2.0	6.0
30	18 to 36	2.5	7.5
36	24 to 36	3.0	9.0

* A greater spacing is desirable where available area permits.

Trenches should not be too long; otherwise, the effluent will not be evenly distributed over the disposal field. No trench should be longer than 30 m (100 ft). The smallest household disposal system will consist of two trenches 45 cm (18 in.) wide at the bottom and 30 m (100 ft) long, irrespective of calculated findings.

So far as possible, trenches should be laid along straight lines. The herringbone type of layout is no longer used since Y-branches do not, in actual practice, ensure even distribution of the effluent over the disposal field. Parallel lines issuing individually from a common distribution box are now preferred.

After the trenches are dug to the required size and depth, a layer of 15 cm (6 in.) or more of filter material is placed over the bottom. The pipes are then laid to the required grade, as previously described, and are surrounded by more filter material, at least 5 cm (2 in.) thick above the top of the pipe. The rest of the trench is then backfilled with earth. The filter material may be washed gravel, crushed stone, slag, or clean clinker ranging in size from 1.2 cm to 6 cm (0.5 in. to 2.5 in.), although one single size (e.g., 1, 1.5, 2, or 2.5 in.) is sometimes preferred.²¹

Surface run-off should, of course, be diverted away from the disposal field in order to avoid waterlogging of the soil, especially at times of heavy rains.

Finally, trenches should be laid at least 7.5 m (25 ft) away from large trees to avoid blockages due to the penetration of roots into the pipes. For the same reason, the land area above the disposal field should not be cultivated, but may be planted with short-rooted grass.

Seepage pits

Depending upon the layout of the trenches, it is good practice to build one or more seepage pits at the lower ends of the absorption lines, as this serves to catch excess effluent and, possibly, to ventilate the trenches through the piping system. The last 1.5 m (5 ft) of trench preceding the

seepage pit should be filled with well-tamped clay soil in order to stop the flow of sewage above the trench bottom and to prevent erosion.

Pipes and trenches for aqua privies

Subsurface irrigation is also convenient for the disposal of the effluent from aqua privies. The principles of design, the size and types of pipes used, and the width of trench recommended are the same as above indicated. However, the essential difference rests in the fact that the volume of aqua-privy effluent is much smaller than that of septic tanks. As a result, the length and grade to be given to trenches and pipes will differ from those recommended for the disposal of septic-tank effluent. The required length of trench may be calculated from Table XII, which is adapted from figures suggested by Macdonald.²⁹

TABLE XII. REQUIRED ABSORPTION-AREAS FOR AQUA PRIVIES

Percolation rate (time required for water to fall 2.5 cm (1 in.), minutes)	Required absorption area (square metres of absorption trench bottom) for aqua privies serving:		
	10 persons	25 persons	60 persons
2 or less	2.80	5.60	9.80
5	3.75	7.00	11.70
10	4.65	9.80	16.20
15	6.00	11.70	19.50
30	8.00	16.70	25.00
45	9.00	18.00	30.80
60	10.25	19.50	33.50

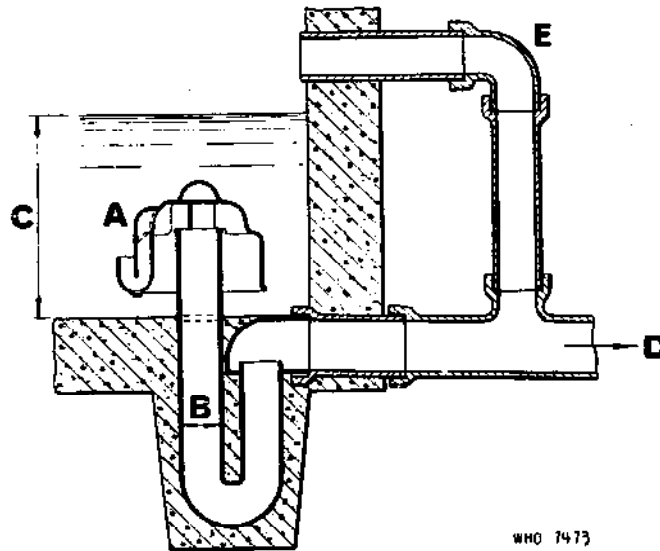
For absorption areas less than 7 m² (75 sq. ft), trenches may be 30 cm (12 in.) wide at the bottom; other trenches should have a bottom width of 45 cm (18 in.). A minimum slope of 1% is recommended.

Dosing Siphons

The importance of the penetration of air into the pores of the subsoil has been previously stressed (p. 129). In order to enable the soil to recover between doses of effluent and to obtain uniform distribution of sewage through the entire distribution line, a dosing chamber equipped with one automatic siphon is recommended for a large septic tank, i.e., one of more than 3785-l (1000-US-gal.) capacity. For tanks having a capacity exceeding 7570-9463 l (2000-2500 US gal.), a dosing chamber equipped with two

siphons is recommended. These siphons will operate alternately, and each will serve half the distribution field. The dosing chambers are usually installed at the outlet of septic tanks, and receive the effluent which accumulates over a calculated period of 2-3 hours before being discharged into the disposal field. (See Fig. 65 and 69.) The effective capacity of these chambers is equivalent to the volume of water required to fill all the disposal pipes from one-half to three-quarters full at one time.

FIG. 69. TYPICAL DOSING SIPHON



- A = Miller siphon
- B = Diameter of siphon, dependent upon population served
- C = Maximum drawing depth of water in dosing chamber
- D = Discharge to distribution box and absorption lines
- E = Overflow pipe

The discharge capacity of the siphon should be less than the capacity of the disposal line leading from it to the subsurface irrigation field. A 10-cm (4-in.) siphon may be used for plants serving 20-40 persons, and a 12.5-cm (5-in.) siphon for those serving up to 100 persons.

Dosing siphons are particularly useful on systems involving sand-filter trenches and sand and trickling filters. They are not usually recommended for small, household types of installations, because of their cost.

Sand-Filter Trenches

Sand-filter trenches may be built in soils which are tight and impervious (clayey soils) and which have a percolation factor exceeding 60. They may also be considered for installation in places where ground water

occasionally rises and reaches a level 90 cm (3 ft) below the ground surface, or when the area available for subsurface irrigation is too small for this purpose.

As shown in Fig. 70, a sand-filter trench is wider than a regular absorption trench and includes :

- (1) an effluent distributing pipe, usually 10 cm (4 in.) in diameter ;
- (2) a sand-filter bed not less than 60 cm (24 in.) deep, preferably 75 cm (30 in.), through which the septic-tank effluent percolates and undergoes biological filtration ;
- (3) an underdrain, also 10 cm (4 in.) in diameter, surrounded by a layer of gravel laid in the bottom of the trench. This underdrain receives the filtered effluent and discharges it into a ditch or similar watercourse. It also prevents the ground water from interfering with the biological processes taking place in the sand bed mentioned above.

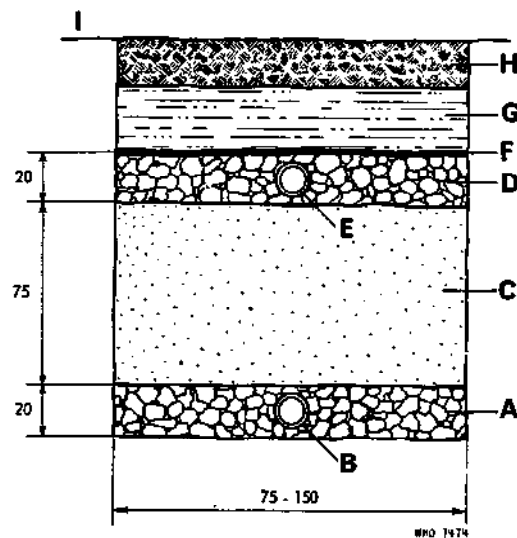
Special care will be needed to ensure that the effluent-distributing pipes are laid on a uniform grade. When grade boards are not used, the sand bed should be flooded to ensure thorough settlement before the distribution pipes are laid.

Clean, coarse sand should be used as filtering material, as fine sand will be quickly clogged and will lead to failure of the system.

The distribution piping and the underdrains may be built of the same pipes as are used for the construction of the standard absorption trenches already described, i.e., plain-end tile pipes or bell and spigot sewer pipes. Long, perforated pipes have the advantage of maintaining the desired grade, and may be preferred for use in the distribution of septic-tank effluent over the sand bed. The slope of the effluent distribution pipes may be the same as that previously mentioned for standard absorption trenches, while the slope of underdrains may be as much as 1%.

The loading rate for sand-filter trenches is estimated at about 38 l per m² (1 US gal. per sq. ft) per day of filter surface.

FIG. 70. SAND-FILTER TRENCH



Adapted, by permission, from *Manual of septic-tank practice*.²⁷

- A = Coarse gravel or crushed stone
- B = Underdrain for collection of filtered effluent
- C = Coarse filter sand
- D = Coarse gravel or crushed stone
- E = Effluent distributing pipe, made of tiles or of perforated long pipes
- F = Building or tar paper
- G = Backfill, tamped in moist layers 15 cm (6 in.) thick
- H = Top soil
- I = Original ground-level

Sand-filter trenches usually produce a highly purified effluent which may be disposed of in open ditches or streams. There is, however, no certainty that the filtered effluent is bacteriologically safe. When the receiving stream is used as a source for domestic water-supply, the effluent should be chlorinated. In any case, sand-filter trenches should never be constructed without the prior approval of the local health department.

Sand Filters

Subsurface sand filters

Subsurface sand filters operate under the same principles as sand-filter trenches. They "constitute a maximal artificial development of the filtering capacity of the subsurface [soil]".¹³ The area required for filtration, as found by the engineering design, is dug up to the required depth and is filled in artificially with coarse sand, after the effluent distribution pipes and the underdrains have been placed. (See Fig. 71.) The loading rate for subsurface sand filters and the pipes used are the same as those mentioned above for sand-filter trenches. Their effluents compare favourably with the effluents from filter trenches and may be disposed of in the same manner.

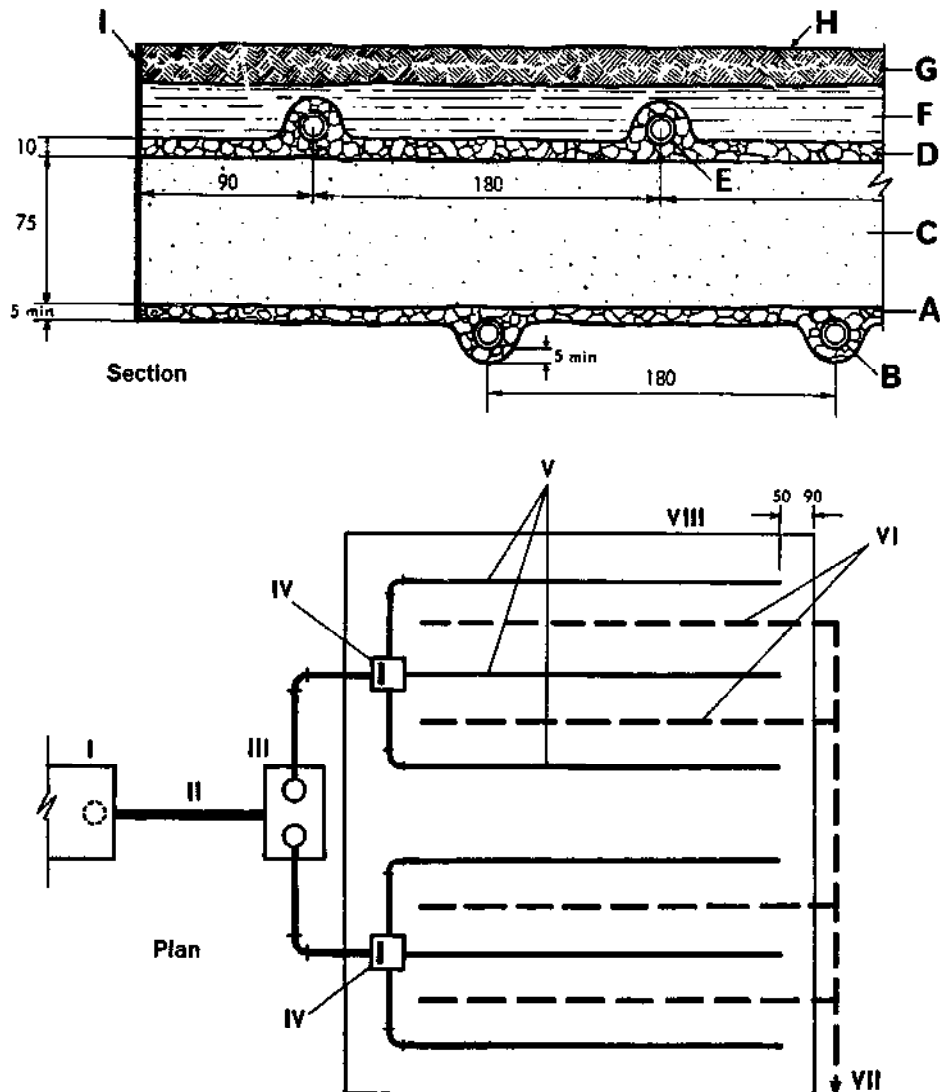
For large installations, subsurface sand filters are likely to be cheaper than filter trenches and should be selected over the trench system when dosing siphons must be installed. Siphons have the advantage of ensuring adequate dosage and of providing a long rest-period for the filter sand. Dosing tanks equipped with single siphons should be installed where the total filter area exceeds 17 m² (1800 sq. ft) and where the distribution pipes exceed 90 m (300 ft). When the length of these pipes is greater than 245 m (800 ft), the filter bed should be divided into two or more sections and dosed separately by alternating siphons.³³ Lining of the bed (or beds) is not necessary except in very wet, soft soil.

Subsurface sand filters, like sand-filter trenches, may be built in most rural areas of the world. They require no attention. However, since they cannot be maintained, they eventually become clogged and must be rebuilt.

Open sand filters

In areas where the ground water remains permanently close to the ground surface, or where subsoil conditions are unfavourable (e.g., rock formations) for the construction of disposal systems already described, open sand filters may be considered. These filters are built above ground or partly below ground as the local circumstances dictate. In both instances, masonry or concrete walls are needed to support the sides and to retain the sand. Earth embankments may also be used for the same purpose.

FIG. 71. SUBSURFACE SAND FILTER



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Measurements shown are in centimetres.

Section :

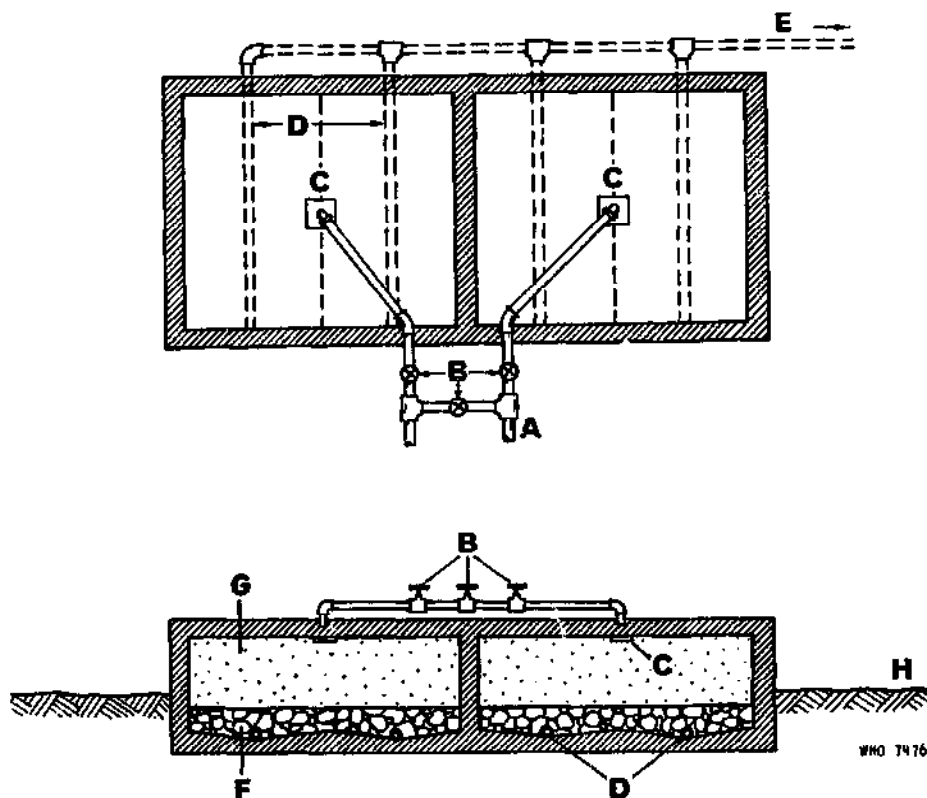
- A = Coarse gravel or crushed stone
- B = Underdrain for collection of filtered effluent
- C = Coarse filter sand
- D = Coarse gravel or crushed stone
- E = Effluent distributing pipes made of tiles or of perforated pipes
- F = Backfill, tamped in moist layers 15 cm (6 in.) thick
- G = Top soil
- H = Original ground-level
- I = End line of subsurface filter

Plan:

- I = Septic tank
- II = Discharge line
- III = Siphon chamber
- IV = Distribution boxes
- V = Effluent distributing pipes (= E in section)
- VI = Underdrain for collection of filtered effluent (= B in section)
- VII = Collection pipe to final point
- VIII = Limits of subsurface filter

In open sand filters, purification of the septic-tank effluent is due to the action of aerobic bacteria in the interstices of the sand bed and to mechanical straining. Since these bacteria require oxygen in order to survive, the filters are usually operated intermittently so that air is drawn into the filter bed during the intervals between dosing. For this reason, these filters are frequently referred to as intermittent sand filters. If properly constructed and operated, open sand filters produce an effluent of high and stable quality.

FIG. 72. OPEN SAND FILTER



Adapted, by permission, from *Manual of septic-tank practice*.³⁷

- A = Cast-iron pipe lines from dosing chamber
- B = Control valves, allowing for cleaning and repairs of filter beds without interrupting operation
- C = Concrete splash slabs; top surfaces are left in rough state
- D = Underdrains, laid 1.8 m (6 ft) or more apart, with open joints to receive filtered effluent
- E = Collector to disposal. Pipes laid with tight joints
- F = Coarse gravel or crushed stone
- G = Coarse filter sand, 75-106 cm (30-42 in.) thick
- H = Original ground-level

Open sand filters are usually divided into two or more compartments in order to facilitate regular cleaning of the beds and to regulate operation (see Fig. 72). As in the case of subsurface sand filters and of filter trenches,

a bed of clean coarse sand 75-105 cm (30-42 in.) thick, underlaid with gravel will be used. Sand material possessing an effective size of 0.2-0.4 mm and a uniformity coefficient of 4.0 will give satisfactory performance. (By effective size is meant the size of the sand particle that is coarser than 10% by weight of the material. The uniformity coefficient is found by determining the size of the particle that is coarser than 60% by weight of the material and by dividing that size by the effective size.)

In small installations, the underdrainage system and the effluent distribution pipes may be arranged in the manner shown in Fig. 72. The larger systems are built and operated on the principles of municipal sand filters.

The loading rates for open sand filters are greater than those allowed for subsurface sand filters. They depend primarily upon the degree of treatment achieved in the septic tanks, the size of the sand particles used, and, also, the temperature. Loading rates applicable in warm climates are higher than those allowable in temperate and northern countries. As an example, the loading rates on open sand filters with uniformity coefficients not over 4.0 recommended for application in the USA are as follows, in litres per m² per day : ³⁷

Region	Effective size of sand				
	0.2 mm	0.3 mm	0.4 mm	0.5 mm	0.6 mm
Southern USA . .	378 000	493 000	606 000	682 000	756 000
Northern USA . .	300 000	378 000	455 000	530 000	606 000

The intermittent operation of open sand-filter beds is usually achieved by the use of dosing siphons. Depending upon the volume of sewage to be treated, these siphons are operated in such a manner as to supply one dose per day or a single dose in several days. Most commonly one to four doses per day are provided, the bed being covered each time to a depth of 5-8 cm (2-3 in.). The best practice calls for the installation in the same chamber of two siphons operating alternately and discharging upon different beds.

Open sand filters need not be covered in most instances. However, in order to prevent odours and nuisances which may arise when operation is deficient, or to avoid freezing in northern climates, it may be necessary to cover the beds of sand with a layer of 15 cm (6 in.) of earth.

The great disadvantage of these filters lies in the fact that they require considerable attention. Constant maintenance and cleaning of the sand surface are required ; otherwise, the ventilation of the beds is interrupted, and the nitrifying bacteria die away. Cleaning is done by raking the beds and, when necessary, by removing the top 2.5 cm (1 in.) of dirty sand. This sand is washed and returned to the bed in order to maintain the depth of the filter bed.

Because of the care needed in their construction and, especially, in their operation, open sand filters are recommended only for use in communities which can afford the services of competent sanitary engineers and sewage-plant operators. The advice and approval of the local health department should be sought prior to their construction.

Trickling Filters

Trickling filters, also called percolating filters, are used as a means of secondary treatment of septic tank effluent in the more economically favoured rural areas, where sanitary engineering advice may be obtained for the construction and operation of such units. In this method the effluent is trickled intermittently through a thick bed of crushed stone, metallurgical coke, lath, or even brush (twigs cleaned of leaves and bound in bundles). (See Fig. 73.)

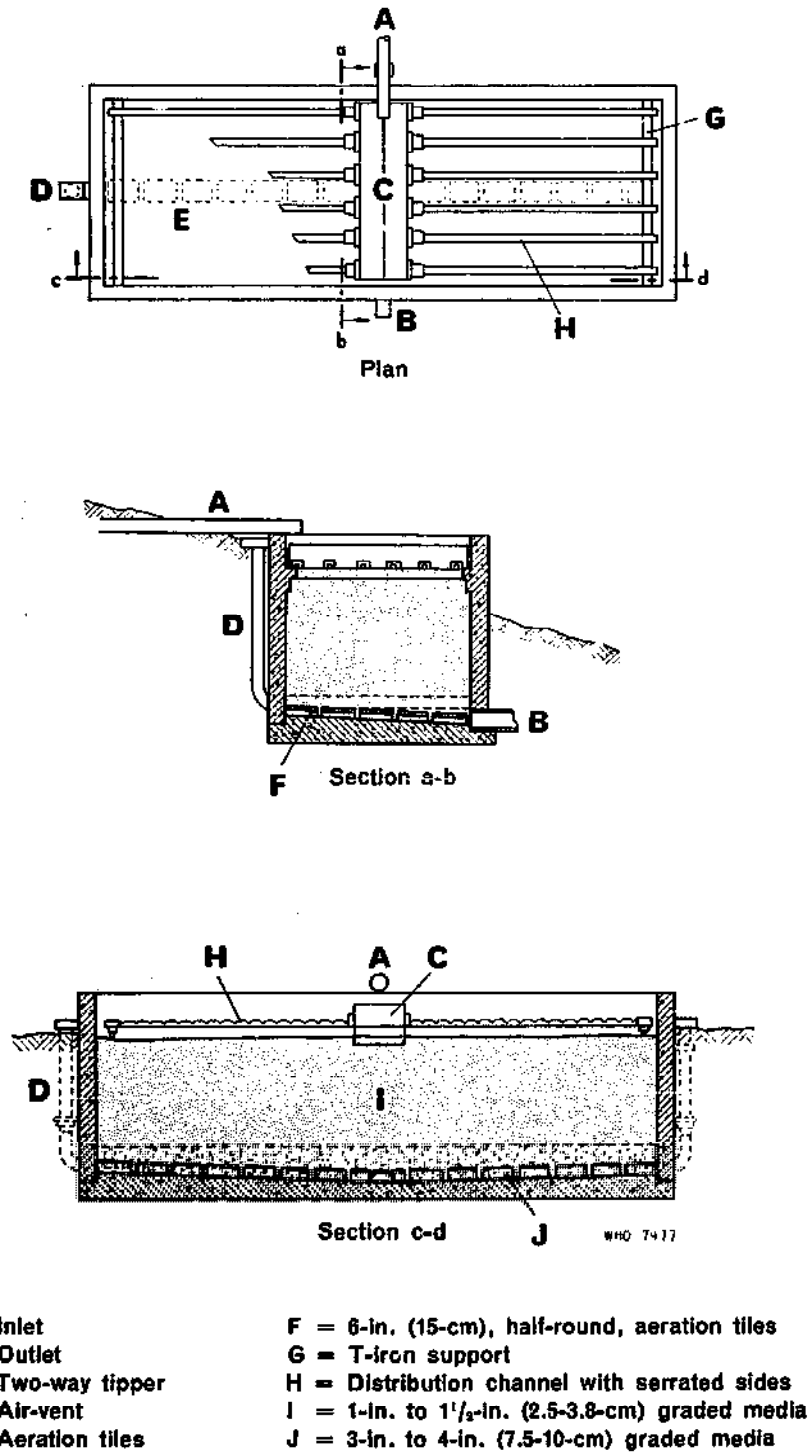
The rate of application of sewage to small installations is governed by the volume and strength of the sewage to be treated. In the USA the rates recommended range from 175 000 US gal. to 225 000 US gal. per acre per day for each foot of depth of bed²⁰ (i.e., 558 l to 718 l per m³ of filter medium). In the United Kingdom of Great Britain and Northern Ireland, where the domestic sewage is usually stronger than in the USA due to a smaller per person consumption of water, a figure of 45 Imp. gal. per cubic yard of filter bed (268 l per m³ of filter bed) is recommended for design purposes by the Royal Commission on Sewage Disposal.

The depth of a trickling filter bed usually varies from 2 m to 3 m (6 ft to 10 ft). The bed should consist of clean, durable material of the quality mentioned above, and the stones should have angular shape and rough surfaces. In such a filter, air must circulate freely in order to maintain the zoogloea which thrive over the stones in the presence of oxygen. The larger stones, 8-10 cm (3-4 in.) in size, will form a layer 15-20 cm (6-8 in.) thick at the bottom of the bed; the smaller stones (not less than 2.5 cm or 1 in. in size) will make up the filter bed.

In small trickling filters, distribution of the septic-tank effluent over the bed is accomplished by means of static distributors fed intermittently by a tip trough or a dosing siphon (see Fig. 73). The tip trough allows admission of the sewage to half of the bed at a time. It is usually not more than 4.20 m (14 ft) in length and serves a filter area not more than 1.50 m (5 ft) wide on either side of the trough. Trickling filters larger than this require additional tip troughs. However, the latter should not be used when the bed exceeds 47 m² (500 sq. ft) in area.³⁰

The distributors may be made of cast iron, concrete, or plain 2.5 × 7.5 cm (1 × 3 in.) boards. Cast iron and concrete distributors often assume the shape of channels whose bottoms are perforated with small holes, or

FIG. 73. SMALL TRICKLING FILTER



whose sides are notched at close intervals in order to let the sewage out in the form of rivulets above the bed.

Trickling filter units should be constructed of concrete or other suitable materials and should be located at least 45 m (150 ft) away from human habitations. Such filters are usually uncovered and are likely to produce odours. Also, they breed large numbers of a small, moth-like fly of the genus *Psychoda*, which may be carried away by the wind into human habitations. *Psychoda* flies do not bite but are a serious nuisance to man. They are controlled by operating the filters for a while at a very high rate of filtration, thus reducing by sloughing the thickness of the zoogloal film in which the fly larvae develop. Chlorinated lime may also be applied once a week to the bed with similar results.

The effluent of trickling filters normally contains humus-like materials which, in large installations, are removed by passing the effluent through a secondary settling tank. In small systems serving, for example, less than 100 persons and where the effluent can be disposed of without nuisance or danger to sources of domestic water-supply, humus tanks are usually not provided. When needed, such tanks should have a detention period of four hours and be designed like a septic tank, except for the cover. The floors of these tanks are designed to slope down to a sump at the inlet end to permit periodic removal of sludge by scoops or by pumps.

EXCRETA DISPOSAL PROGRAMMES FOR RURAL AREAS

THE PLANNING OF EXCRETA DISPOSAL PROGRAMMES

Essential Elements

In planning an excreta disposal programme for rural areas, it is important to remember that such a scheme should be considered only as a part of a general sanitation plan for the country concerned. An excreta disposal programme is not an end in itself and, even if successful, cannot be expected, alone, to produce a considerable reduction in morbidity and mortality due to enteric infections. Often a long-range plan of general sanitation does not exist either because there are still doubts among health officials as to the benefits of sanitation, or because these officials do not have the knowledge and the desire to face the sanitation problem, which in many countries assumes staggering proportions.

As a result of experience acquired in many parts of the world, Baity ^a has suggested that the governments concerned might take the following progressive steps :

1. Recognize the real benefits of sanitation to the health and well-being of their people.
2. Establish a sanitation unit within the national health service of the country, commensurate with the country's needs and resources, and staff it with personnel competent to plan and direct all phases of work in this field.
3. Integrate sanitation properly with other public health undertakings, and see that "first things come first" in the assignment of priorities.
4. Develop a long-range plan of sanitation for the country as a whole, into which projects and programmes may be logically fitted as to time and place.
5. Realize that it is possible to do *something* helpful in environmental sanitation under any conditions and under any budget—and that the simplest things are usually the most important.
6. Select a point of beginning, always the most difficult step in such an undertaking, and outline an orderly progression of work and objectives.

^a Baity, H. G. (1956) *The sanitary sceptics—Shall we condemn them or teach them?* Unpublished working document WHO/Env.San./93)

In most countries of the world the disposal of human wastes should constitute an important part of any long-range plan for sanitation development and might well be a desirable starting-point for such an undertaking. Once a decision has been made as to the proper time and place for an excreta disposal programme, the following elements might be considered in planning :

- (a) preparation of necessary staff ;
- (b) initiation of a community sanitary survey ;
- (c) selection of the type, or types, of units to be built ;
- (d) study of the possibility of a pilot project in the area under consideration ;
- (e) estimate of costs ;
- (f) health education of the population ;
- (g) programme and schedule of construction ;
- (h) maintenance of the installations ;
- (i) appraisal of results and promotion of further sanitation development ; and
- (j) establishment of sanitary regulations.

Preparation of Staff

The planning and execution of any programme of environmental sanitation require the services of technically qualified professional and non-professional staff. This is particularly true in the case of excreta disposal programmes for rural areas and small communities. It is desirable that in every country specialists in environmental sanitation be placed at an appropriate level within the health administration and that they be made responsible for the formulation and development of programmes relating to their competence. One of their functions should be to undertake, in co-operation with medical and other health personnel, a close study of the status of rural sanitation and the staff required for its improvement. Such a study would be expected to provide the facts on which a programme, however simple, could be based, and to lead to decisions as to the means whereby it could be implemented.⁴⁴ The assistance of these specialists should be made available to local health services when necessary for the solution of difficult problems.

At the local (or district) level, there will be a need for well-trained public health (or sanitary) inspectors, who will be directly in charge of the execution of the programme. These officers will be assisted by a number of health assistants and health aides posted in rural towns and

villages. The possibility of organizing village-level workers on a voluntary basis may also be considered as a part of a self-help movement within each community.

In rural excreta disposal programmes, the quality and quantity of the sanitation work performed are directly related to the quality of the supervising personnel. It is therefore important to give considerable attention, before a programme starts, to the proper training of the sanitation staff which will carry it out. This applies particularly to the health assistants and health aides, who will be in closest daily contact with the population. The training scheme should be founded on a careful analysis of the functions to be performed by such staff. This matter will be studied further in the next chapter.

Community Sanitary Surveys

In most rural areas, community sanitary surveys are usually necessary to obtain first-hand information concerning local sanitary conditions and needs. Such surveys, undertaken with the participation of local leaders of the community, will be of immense help in programme planning and evaluation. Depending upon the particular situation at hand, they may cover the following factors in part or in whole.

A. *Description of area*

- (1) location, topography, climate, character, communications, maps ;
- (2) geology and hydrology, with particular reference to nature of top and underground layers of the soil, its porosity, presence and abundance of ground water (if any), direction of flow, level of ground-water table, its appearance and potability, estimation of yields of springs, rivers, and so on ;
- (3) population—number, constitution by age-groups and sex, density, growth ;
- (4) industries and agriculture, with particular reference to irrigation, drainage, and soil fertilizing practices ;

B. *Medical and sanitary data*

- (1) general health of the population, with special emphasis on communicable diseases and on intestinal infections, helminth infestations, and trachoma and acute conjunctivitis in infants and children ;
- (2) vital statistics, mortality and morbidity data ;
- (3) health and sanitary administration, with reference to organization, personnel, budget, and activities of voluntary or other agencies in the field of sanitation ;

(4) existing sanitary conditions in the area, with reference to description of private and public latrines, their distribution and use ; to wells, springs, and other systems of water supply (including such information as number of persons served by piped water-supplies, and by wells, the consumption and uses of water, number of dwellings with private water supply, etc) ; to wastes collection, disposal, and composting ; to milk and food sanitation ; to insects (flies, fleas, lice, mosquitos) ; to health aspects and standards of housing ; and to school sanitation.

(5) sociological and cultural patterns, with particular reference to community and family organization, leadership ; customs, beliefs, and habits bearing on personal hygiene and community sanitation ; present methods (if any) of health education of the public.

C. Resources available

(1) general economic level of the population ; average income *per caput* ;

(2) co-operation expected from agricultural, educational, and other agencies or groups for training and health education of the public ;

(3) housing and vehicle transport for programme, vehicle and equipment repair and maintenance facilities ; sources of power (electricity, fuel) ;

(4) local construction materials and their costs ;

(5) local craftsmen and wages ;

(6) potential resources for self-help.

This information has an important bearing on the project and makes it possible to draft a reasonably accurate cost estimate. Such a survey is a useful educational tool and also serves to acquaint the sanitation personnel with the families and with their customs, beliefs, interests, and attitudes. In short, it helps to prepare a "social map" of the community.

Health Education of the Population

In all programmes involving the disposal of human wastes, especially those undertaken in a rural environment, health education plays a most important role and should be one of the earliest considerations. It is through a well-planned and active programme of health education that health authorities will be able to secure the understanding, support, and participation of the rural population. This fact, which has already been discussed, cannot be overstressed.

Broadly speaking, the purposes of the educational programme should be :

(a) to create a desire for the improvement of excretory habits, or more generally, to create interest in, and awareness of, health problems which may be solved through improvement of personal, family, and community sanitation practices ;

(b) to help people determine what changes are needed and desirable for improving sanitation and how they can be implemented ;

(c) to encourage people to put into practice good habits of personal hygiene, as well as those measures which will serve to improve personal, home, and community sanitary conditions ;

(d) to foster those learning experiences which would feature the people's participation and self-help in solving sanitation and related health problems ;

(e) to provide instruction in the designs, materials, and methods involved in building and maintaining proper installations ;

(f) to secure sustained interest and participation in a community programme of environmental health improvement.

In carrying out such a programme in rural areas and small communities, it is desirable to utilize to the fullest extent the assistance of the available local, provincial, and national personnel with skills and experience in family and group education methods, organization of village committees and councils, conduct of training courses for village leaders and school groups, and production and use of simple teaching aids and visual materials. In some countries there may be one or more persons with full or partial training in health education of the public. There may also be experienced leaders in adult education, rural development work, social work, rural education, religious leadership, agricultural extension work, and others whose collaboration should be sought and who may prove to be of considerable help to the sanitation personnel in planning and carrying out educational activities with family, school, and village groups.

Selection and Design of the Units

These subjects have already been covered in the previous sections. However, it might be worth while to reiterate here the fact that the choice of installation must be made in the light of: (1) what the community needs and is prepared to accept; (2) what the community can afford, giving due consideration to basic health criteria (p. 39); and (3) what the community can maintain in the future. The word that should describe

the design chosen is *soundness*. It does not mean luxurious or poor, expensive or cheap. It does mean the best possible installation at a cost which the particular community can afford.

The selection of units has a direct bearing on the success or failure of the excreta disposal programme. From the beginning, the technical aspects of the scheme must provide for a certain degree of flexibility because, once the programme is organized and started around a single type of installation, it is difficult to switch to another type and to "sell" it to the people.

Pilot Projects

When it is not possible, from the findings of the sanitary survey, to arrive at a safe conclusion regarding the type or types of units, their costs, and the construction procedure to be used, a pilot project should be carried out first. This method offers the quickest and most economical way of discovering the answers to these questions. Pilot projects are often desirable and may be undertaken especially in conjunction with the training of the sanitation personnel which will ultimately be employed in the programme. The use of such projects for demonstration purposes has also proved to be valuable in many countries in "selling" the programme to the people concerned.

The Estimate of Cost and Budget

It is quite possible that rural sanitation work has often failed because of inadequate cost estimates and budget. It is, indeed, exceedingly difficult to prepare cost estimates for projects that are new and drawn up mostly from unreliable information. The estimate of cost should be true, honest, and correct. If the basic data are poor, this should be made abundantly clear to those officials who will decide on budget matters. Health administrators throughout the world are predominantly medical people who cannot be expected to understand in detail the engineering phases of construction work. They are often confused when a project runs out of funds long before completion, and this may shake their confidence in the whole sanitation programme. To avoid this situation, it is important that every effort be made to prepare the best possible estimates of cost, based on complete field information and making generous allowances for unknown factors. The total sum required may appear staggering when all the figures are added up, but it is much better in the long run to accept the more difficult job of promoting a rural sanitation project that seems to be expensive beforehand than to try to justify a budget increase halfway through.

Construction

On the basis of data gathered in the course of the community sanitary survey, a decision should first be made whether construction will be carried out (1) by a well-organized campaign conducted by the health department, (2) by the family with guidance only from the sanitary (public health) inspector, or (3) by a combination of these two methods, involving the aid of the health department and the participation of the family in the form of labour or materials, or both. As pointed out before, the third method yields by far the best and longest-lasting results. If method 1 or 3 is decided upon, it should be possible to draw up a fairly detailed programme of construction of the projected facilities.

The programme of construction would indicate such things as the rural districts which should be tackled first; the proposed schedule of construction; the distribution and organization of construction gangs; the list and plan of utilization of available construction materials (donated or otherwise), equipment, and transport; and the organization and location of field warehouses and shops, etc. The construction programme should be flexible enough, however, to cope with unforeseen difficulties, such as those which may be created by unstable ground formations, high ground-water level, or low permeability of soils.

Experience shows that in the early stages progress will be slow, even though the units selected may be easy to build. Construction will then pick up momentum and go through a period of major activity until 75%-80% of the units are completed. Then it will again slow down.

Depending upon circumstances, resistance of certain groups to the excreta disposal programme may be anticipated; this should be taken into account in drawing up or revising the construction schedule.

Maintenance of Installations

When the tempo of construction slows down following the installation of most of the units projected, attention may be shifted to another rural district or community. The permanent staff member (sanitary inspector or health assistant) should pick up the work from there with whatever help may be needed from his immediate supervisor. He should continue his efforts to persuade the last persons still holding out to build sanitary installations and should undertake periodic visits to the homes where units have been built to ensure that these are properly used and maintained. Inspection and maintenance are necessary, since neglected installations may lose much of their value and may even constitute potential hazards to the community they are intended to serve. Provision should be made, right at the planning stage, for regular follow-up by sanitation personnel permanently stationed in the area.

Appraisal of Results and Promotion of Further Sanitation Development

In planning a programme of rural sanitation, it is desirable to keep in mind the need for an evaluation of results upon the completion of construction activities or at a later date. The medical and sanitary data collected in the course of the pre-operative sanitary survey of the area should, if adequate and sufficiently reliable, provide a good basis for an objective appraisal of the results of the programme. In some cases it may be necessary to select for comparison purposes another area, similar in character, in which comparable sanitation work is not being carried out. This comparison area should be surveyed in the same manner and, as far as possible, at the same time.

Measurements of the results may be by either direct or indirect means. Direct measures, which are to be preferred when applicable, involve the analysis of death-rates of specific age-groups of the population or the study of morbidity returns and the results of special morbidity surveys. Data on infant mortality due to specific diarrhoeal diseases are often selected for studying the present status of sanitary conditions in an area. However, Macdonald^a states that death-rates for the ages 1 to 15 years are a most delicate index of the amount of infective diseases in the population and are the first to respond to sanitation programmes. He also found that the range in death-rates for the age-group 1 to 4 is particularly sensitive and less influenced by standards of maternal and child care and public education. On the other hand, crude death-rates are generally unreliable and may not reflect a successful rural sanitation programme at all.

The study of morbidity returns may often lead to fallacious conclusions since, depending upon local conditions, such returns may be influenced by several factors, among which are inadequate records of notifiable diseases, standards of diagnosis, and others. Objective measurements by special morbidity surveys covering the faecal-borne diseases are very desirable. Particular attention should be paid to prevalence of these diseases in infancy and childhood.

Indirect measures involve observations of changes in the environment which may indicate that rural health must have been improved as a result of the sanitation programme. They do not provide direct evidence of health improvement; for this reason they are less desirable from a technical standpoint. However indirect measurement is often the only way of appraising the results of rural sanitation programmes, especially in primitive or unorganized areas and where a complete medical team is not available

^a Macdonald, G. (1953) *The appraisal of the results of rural sanitation programmes* (Unpublished working document WHO/Env. San./37)

for making morbidity surveys. The data upon which indirect measurement is based are those which are normally collected in the course of community sanitary surveys.

Both pre- and post-operative community sanitary surveys will point to the need for further sanitation work in the area and will yield valuable information upon which future programmes may be based. These may have to be deferred for a while because of lack of funds or the necessity for preliminary stimulation of the interest of the local population. In the latter case, much will depend upon the initiative, the zeal, and the ability in public relations of the sanitation and other personnel in promoting new health and sanitation ideas among the population.

Sanitary Regulations

Basic legislation is necessary in order to enable a public health agency to initiate and develop activities in the field of public health and sanitation. Such legislation is normally passed by a legislature, a parliament, or a similar official legislative body of a country or state. The collection in an orderly manner of legislative acts in the form of public health or sanitary codes is done from time to time by the public health agency. Basic, or enabling, legislation is confined to statements of broad principles, responsibilities, and penalties. On the basis of such legislation, the public health agency concerned is in a position to formulate and issue more detailed rules, regulations, and standards relating to the organization and operation of local health work and to procedures for carrying it out. Also, ordinances dealing with such matters as the source of food and milk, the health and sanitation practices of persons who come in contact with them, the sanitary nature of processing equipment, the sanitary quality of water, and so on, may be issued by the public health agency in order to explain or qualify in detail the basic legislation enacted.

An existing sanitary code in a country may exert a strong influence upon the nature and content of a rural excreta disposal programme under planning. If the sanitary regulations are outdated or too elaborate or exacting, they may have too much of a restricting influence upon both the technical and administrative aspects of the programme. Such regulations defeat their own purpose and are usually ignored by the population. When suitably drafted, regulations are useful in helping to ensure a basic minimum of sanitary safeguards and the elimination of potential health hazards, especially in densely inhabited communities or industrialized rural areas. They usually deal with, and prescribe standards for, such matters as the prevention of soil and water pollution; the disposal of human and animal wastes; the hygienic aspects of housing; the protection of milk and other food supplies; the control of arthropod, rodent, and mollusc hosts of disease; and the use of surface waters.

When elaborating sanitary regulations, it is important to keep in mind the following principles,²⁸ which have been set forth for milk, but which apply as well to all sanitary legislation :

1. No regulation should be made which cannot be enforced.
2. No law can be enforced without the co-operation of most of the persons concerned.

Rules and regulations applying to excreta disposal in rural areas should be reasonable and no more drastic than is necessary ; above all, they should adhere to basic principles of sanitation. Only in this way can they be applicable at the same time to several (or all) rural areas within a given country. It is important to consider every contingency which may occur within the foreseeable future, and the best way to do so is to consult the people for whose benefit the regulations are formulated. While the experience of others may be useful in drafting new regulations, it is always a mistake to adopt the regulations of another country without making some necessary modifications.

On the need for the co-operation of the people in the enforcement of legislation, Lethem²⁸ has written :

" No form of control can be effective without the support of most of the people concerned, backed by an enlightened public opinion. Hence, *education must precede legislation* ; in fact, it might be described as the father of legislation. The lower the standard of education, the greater the need for careful preparation before new regulations can be introduced and enforced. It is better to start in a small way and work up, than to introduce a multiplicity of rules and raise a wall of opposition, which makes enforcement difficult. Legislation alone cannot improve hygiene. To launch regulations without first preparing the way, is like sowing seed without first ploughing the ground. Old traditions die hard, and bad habits are not easy to change."

This statement applies particularly well to excreta disposal programmes, which are designed to effect desirable changes in people's attitudes and practices. In this field public health instruction is more important than compulsion, and sanitary inspection should not aim at the enforcement of regulations by means of sanctions. Instead, it should be directed away from that concept.

TRAINING AND FUNCTION OF THE SANITATION STAFF

Categories of Personnel Required

Sanitation programmes in general, and rural excreta disposal schemes in particular, require for successful planning and execution a number of competent sanitary staff at various levels of responsibility. This staff includes public health (or sanitary) engineers, health (or sanitary) inspectors, health assistants, health aides, and village workers.

It is quite probable that rural sanitation work has been carried out in many parts of the world without sanitary engineers, but not without sanitary engineering.^a Often medical officers of health, assisted by health inspectors, are responsible for all phases of sanitation. However, experience has repeatedly shown that, because of the multiple engineering aspects involved, engineers trained in the sanitary sciences are needed at the highest possible level of the health services for the formulation, administration, and development of sanitation programmes, including rural schemes. On this subject, the WHO Expert Committee on Environmental Sanitation⁴³ stated :

“ The assumption, perhaps too widely made, that underdeveloped regions are not prepared for the services of the best-trained specialists in environmental sanitation can readily be contested. Countries of minimum resources are most in need of the highest expert service available, both for diagnosis of need and for planning of solutions. The relegation of these functions to less-adequately prepared persons results from a great misunderstanding of the complexity of the problems in environmental sanitation encountered in areas of low economic level. These problems require for their solution the impact of high intelligence, training, and experience, even when the number of persons possessing such qualifications is necessarily a minimum. It is unsound practice literally to send a boy to do a man's job.”

Apart from a few public health (or sanitary) engineers, the numbers and types of the other officers to be trained will be governed, according to circumstances in countries, by : (a) the background education of the potential recruits, (b) the ability and capacity of the training establishment to train different grades simultaneously, and (c) the pattern of the health services, if any, into which the new staff will be integrated.

Whether a new training programme is aimed at producing sanitarians (health inspectors, assistants, and aides, as listed above) for general sanitation work, or for a specific rural sanitation scheme, it is perhaps preferable not to dissipate teaching resources, but to concentrate all efforts on producing a single type of sanitarian. In the case of rural sanitation programmes, the greatest need is usually for sanitarians of the “ health assistant ” or “ health aide ” levels. Such personnel are assigned to rural towns and villages, and work under the supervision of health inspectors who are posted in district headquarters.

Village workers are trained within the rural areas concerned, not necessarily in the same training school as the sanitarians. The training of such workers is directed towards the stimulation of the self-help movement, of which sanitation is only one of several elements. Village workers are usually trained to do specific jobs, such as latrine or well construction, or maintenance of hand pumps or other equipment.

^a The term “ sanitary engineering ” includes the public health aspects of all environmental conditions and situations the control of which is based upon engineering principles and the application of scientific knowledge. The terms “ sanitary engineer ” and “ public health engineer ”, as used in this monograph, are interchangeable.

In addition to sanitation staff, foremen and workers must be trained in the construction practices and procedures adopted for field application in the excreta disposal scheme.

Function of Sanitation Personnel

The nature and scope of the training of the rural sanitation worker engaged in the excreta disposal programme depend primarily upon the function which he will be expected to discharge. Sometimes training schemes are initiated without a clear understanding of what sort of health worker is wanted and what jobs the sanitarians are expected to perform. As a result, the sanitarian produced under such training is likely to be disoriented and dissatisfied when confronted with rural problems and situations for which he finds himself unfit, and he may decide to quit the job, thus creating an undesirable turnover of laboriously trained staff.

In order to determine the functions of the future sanitarians, it is necessary to study such matters as the national sanitation plan (if one exists) of the country concerned, the present organization and responsibilities of health services and municipal administrations, and the country's general health and sanitary conditions to which attention will have to be paid in the future. The duties of the various categories of sanitarians may be described in general terms as :

(1) making preliminary surveys of a district, recording its sanitary conditions, and participating in the formulation of a plan of action for their improvement ;

(2) carrying out programmes of practical sanitation based on 1 above ;

(3) establishing good relations with the public, and educating the public in health matters ;

(4) maintaining active collaboration in all of the duties mentioned above with other services whose activities have a bearing on environmental sanitation.

The health (or sanitary) inspector must be able to perform all these duties. The work of the health assistant will be concerned mainly with item 2, and he should perform duties 1, 3, and 4 under direct supervision. The health aide should be limited to duties under 2. This distribution of functions among the sanitation staff will, in most cases, be well suited to the execution of programmes of excreta disposal in rural areas.

Conditions of Service

In planning a training scheme for sanitarians, it is necessary to consider the future conditions of service, including such matters as the possibility of personnel rotation from urban to rural areas and *vice versa*, the scales

of pay and allowances which will be granted to this sanitation personnel, and their chances for promotion. Since the duties of sanitarians range over a broad field of activities, their status and emoluments should compare favourably with the pay in similar professions. These should preferably include periodic within-grade increases for satisfactory performance and promotions to higher grades, eventually to supervisory positions. In rural sanitation programmes, the need for supervisors will arise at a relatively early date and will be more and more pressing as the activities expand. The supervisory positions should be filled from the ranks of the inspectors. While at the beginning these promotions may be made on a somewhat informal basis, they should eventually become a part of the personnel policy of the health departments concerned. In some countries a system of rewards for good work has been found to be desirable to help maintain a high morale among the staff and to reduce turnover.

Selection of Trainees

A discussion of this subject raises several questions of an economic, educational, and social character. Men of high calibre and education will almost always perform the best work in sanitation; but, of course, they are usually the most difficult to recruit, and demand higher salaries than those which may be offered to them. On the other hand, people willing to accept very low pay are often incapable of sustaining the effort and interest necessary for the long-range success of rural sanitation undertakings. It is therefore necessary to study the local scene and to offer scales of pay and allowances sufficient to attract "trainable" persons.

The level of general education of the potential recruits may be another stumbling-block. It is desirable to investigate the curricula of local schools as well as the teaching methods used in these schools. The information obtained will point to certain gaps in general education which need to be filled before technical subjects can be taught. It has been suggested that : ⁴³

(a) the educational background of health inspectors should be the equivalent of some twelve years of education from the beginning, and should be sufficient to permit them to matriculate at a university ;

(b) the educational standard for health assistants should be the equivalent of at least seven to eight years of education from the beginning, or in some countries to that of the highest class in the elementary school ;

(c) in the case of health aides, the standard of education may be elementary, comprising reasonable competence in reading, writing, and simple arithmetic.

It is always wise to choose men from the small towns and villages where the rural sanitation work is to be done. These men are accustomed to rural life and are not apt to get discouraged too quickly when facing the challenges of the job. Staff turnover is always greater among persons recruited from cities, even though the cities may be within the same general area or province concerned. Family status of recruits is also an important factor to consider. A good rule is to start training single men (for they are much more mobile), or at least to keep married sanitarians in the towns from which they were recruited. The suggestion has been made that women might be trained as sanitarians who could perform duties in places inaccessible to men. In addition to the above-mentioned qualifications, sanitarians should be selected among persons exhibiting good character, personality, and integrity.

Training

It is desirable that sanitarians should be trained within the country concerned and, preferably, at a centre located within a region possessing the same general characteristics as the rural area where the sanitation programme will be developed. Facilities such as health centres and laboratories, hospitals, water and sewage works, and refuse disposal and other sanitary installations should be available for the practical demonstration and training of the students. In fact, most of the duties of sanitarians are of a practical nature, and their training should therefore be essentially operational. Much of the teaching should take place outside the classroom during field visits and inspections, and the theoretical lectures should relate as much as possible to field applications. Such training will aim at developing the trainees' abilities in observation, criticism, and constructive suggestions. Particular care should be taken to stress the future advisory and teaching role of the sanitarian and to combat the idea of police-power inspection.

In reviewing the literature on the subject of training of sanitarians, it is noted that the duration and contents of courses differ widely throughout the world: training courses vary from five weeks to three years, and the course material from application of simple sanitary measures through class work and closely supervised field exercises to academic work of university calibre with field training in health departments. This might well be expected, for each training course has been developed in the light of the customs, history, needs, and health programmes of the country concerned. The WHO Expert Committee on Environmental Sanitation⁴³ has suggested courses which might be included in the training programmes for various categories of sanitarians (see Annex 1, p. 175).

Unless one has had long teaching experience, the first training course and the beginning work in community sanitation in rural underdeveloped areas are likely to be more enlightening to the teacher and administrator than to the students. With a large class and a long course, the investment of resources—e.g., for school buildings, transportation facilities for students, demonstration and library materials, and equipment—is apt to be considerable ; yet it is difficult to foresee all the personnel needs of the sanitation programme, as well as the reaction of the students to the courses presented. For these reasons a pilot type of training school may be desirable in the first instance under such a situation. After the sanitation work has been going on for a while, the needs for personnel and for a particular type of training will be better defined, the less capable students and staff will have been weeded out, and it will then be possible to readjust the training programme accordingly.

Another advantage in starting the training scheme on a small scale is the aid this gives to good supervision and leadership of the trainees, particularly from the standpoint of the supervisor. It is fallacious to believe that the sanitarians, upon the completion of a short training course, are capable of solving all kinds of problems. The majority of them will be going into the field with considerable uncertainty and, if left by themselves too long a time at the beginning of their career, may either fail or get off on the wrong track. To avoid this, it is necessary for the supervisor to visit them frequently.

This feeling of uncertainty on the part of the sanitarians can also be considerably reduced if their training has prepared them to do a limited number of jobs very well—a point which cannot be emphasized too much. It is not wise to give the trainees a great deal of vague, theoretical notions and to expect them to go out into the field and be successful. Such training is bound to lead to failures ; and, what is worse, the sanitation programme itself may fail or receive an irreparable setback. The training should be highly objective and should be designed to make the men confident and aware of where to start, how to start, and where to go.

A compendium of the lectures and field notes should be given to the new sanitarians at the end of the course. This will serve them as a reference on problems which often arise and for which there is no clear-cut solution.

In most instances, training courses are initiated under the conduct of teachers selected from among existing health department personnel. However, it is acknowledged that the training of sanitarians is an exacting task which requires at least a nucleus of full-time and experienced teachers, preferably possessing previous knowledge of teaching principles. Such teachers should be able to develop training manuals written in the local language and adapted to local problems and to the educational level of trainees. Foreign books should be used only as references.

In planning the training programme, provision should also be made for various extension activities designed to widen the influence of the school, to establish a link between the teaching staff and the health activities in the territory, and to encourage and follow up the work of the former students.^a The following types of activity are suggested :

(a) Team-work in varied regions, possibly under the supervision of the teaching staff. This may be a very desirable activity immediately after the course, where the qualifying students are young and inexperienced, or where the governments have insufficient health staff to provide the necessary supervision.

(b) Refresher courses. Such courses give everyone a chance to develop, and offer encouragement to the sanitarians, who feel that the health department is paying attention to their welfare. The sanitarians do not have to absorb much new material at any one sitting, and the engineer can develop the sanitation programme more objectively in the light of what his whole staff can learn and contribute in such courses.

(c) Conferences, seminars, dealing with one or two special topics.

(d) Health weeks, with the participation of schools and the public.

(e) Promotion courses, preparing lower-level sanitarians for upgrading.

Utilization of Sanitarians

Proper utilization of sanitation personnel is as important as their training, and should be based on the principle that each sanitarian should fill a position fitted to his grade and training. To sanitarians who are beginning rural or community sanitation work there is nothing so important as success ; and success will come much more easily and quickly if the scheme provides for concentration on objectives limited in number and scope to what the sanitarian can achieve at any one time. Such a technique is the surest and quickest way to get to a broader programme. A latrine project is excellent as an initial objective, provided the health department is prepared to contribute leadership and its proper share of funds, materials, and supervision, the last by means of sanitarians assigned to each community.

It is important that the sanitarian be assured at all times of the full material and moral support of the health authorities. This is especially true in the initial stages of his work in a new area. He will need encouragement and recognition from his superiors. Above all, his talents should not be misused by making him a " Jack of all trades ".

^a Slater, A. R. F. (1956) *The planning of training programmes for sanitation personnel* (Unpublished working document WHO/Env.San./98)

ANNEXES

Annex 1

EDUCATION AND TRAINING OF SANITARIANS *

Sanitarians

Health inspector

A large part of the training of the health inspector should consist of practical demonstrations with a period of experience in a health department. The course should be so designed that the subjects may be expanded to higher stages to enable the health inspector, with further study, to advance, if he is suitable and so desires, to the academic course. He should be imbued with a spirit of inquiry and enthusiasm for public health ideals. The basic idea is to educate and train a good general practitioner of environmental sanitation.

The courses of study should include the elements of the following subjects: mathematics, physics, chemistry, bacteriology, parasitology, epidemiology, anatomy, and physiology; the control of communicable diseases; disinfection and disinfestation; water-supply and treatment; sewerage and sewage treatment; the collection and disposal of refuse and excreta; insect and rodent control; factory inspection; building construction, including drainage, septic tanks, soakage pits, and the like; and the drawing and examination of simple plans. The health inspector should be instructed in the inspection of meat and food-stuffs and the procuring of samples for analysis, and be able to deal with special sanitary problems in places such as hospitals, schools, airports, mines, etc. He should also receive instruction in public health administration, statistics, legislation, and legal procedure.

Health assistant

The education and training of the health assistant should be designed so that he may play an important part in environmental sanitation in urban and rural areas under suitable direction. The course of study should provide ample time for practical demonstrations. The subjects taught should include: very elementary anatomy and physiology; mensuration, simple geometry, simple arithmetic, and sketching; general hygiene, causes of disease, and sanitation, including air, water, and food. The course should provide some instruction in communicable diseases, disinfection and disinfestation, case investigation and control methods,

* Reproduced from the second report of the WHO Expert Committee on Environmental Sanitation.⁴³

elementary medical entomology and elementary helminthology, collection and disposal of refuse and night-soil, with some information on the more complex sewerage, sewage disposal, and water-supply systems. The health assistant should also be instructed in food inspection, with visits to food production establishments; in nutrition; in rodent and insect control; in the use of artisan's tools and the construction of latrines and privies; and in personal hygiene. He should be encouraged to promote health education in rural communities.

Health aide

Under suitable direction the health aide would be a valuable person in the promotion of rural sanitation. His instruction, therefore, should include a knowledge of sanitary work as applied to rural areas, such as the raising of the standard of housing, the improvement of rural water-supplies, and refuse and excreta collection and disposal. The course should include elementary understanding of the factors concerned in the spread of the common communicable diseases in relation to sanitation. It should also include the preparation of simple hygiene reports and the keeping of a diary. The health aide should be able to recognize local insect pests and rodents and be instructed in disinfection and disinfection. He should be able to construct simple sanitary works.

Voluntary Leaders for Mobilization of Self-Help

The people in this category cannot spare the time for long and formal education far away from their homes. Short but intensive training for about two weeks has been tried and found sufficient.

The curriculum should be simple and practical. Besides explaining the causes and mode of communication of the most important diseases prevailing in the area, the curriculum should emphasize the need for personal hygiene, sanitation of the environment, and maternal and child care. It should also provide data on, and point out sources of, materials and skilled service that may be available to the local people for improving the environment, and for constructing sanitary facilities such as wells for safe water-supplies, or sanitary latrines.

The trainee will have to be taught in the language of the locality. In the case of volunteers and village schoolmasters, the period of training should be so chosen as to interfere least with their normal business.

After receiving training, the volunteers and trained teachers should be the chosen repositories of confidence of the local health-authorities in those matters which come reasonably within their competence, for example, the issue of insecticides.

Annex 2

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