

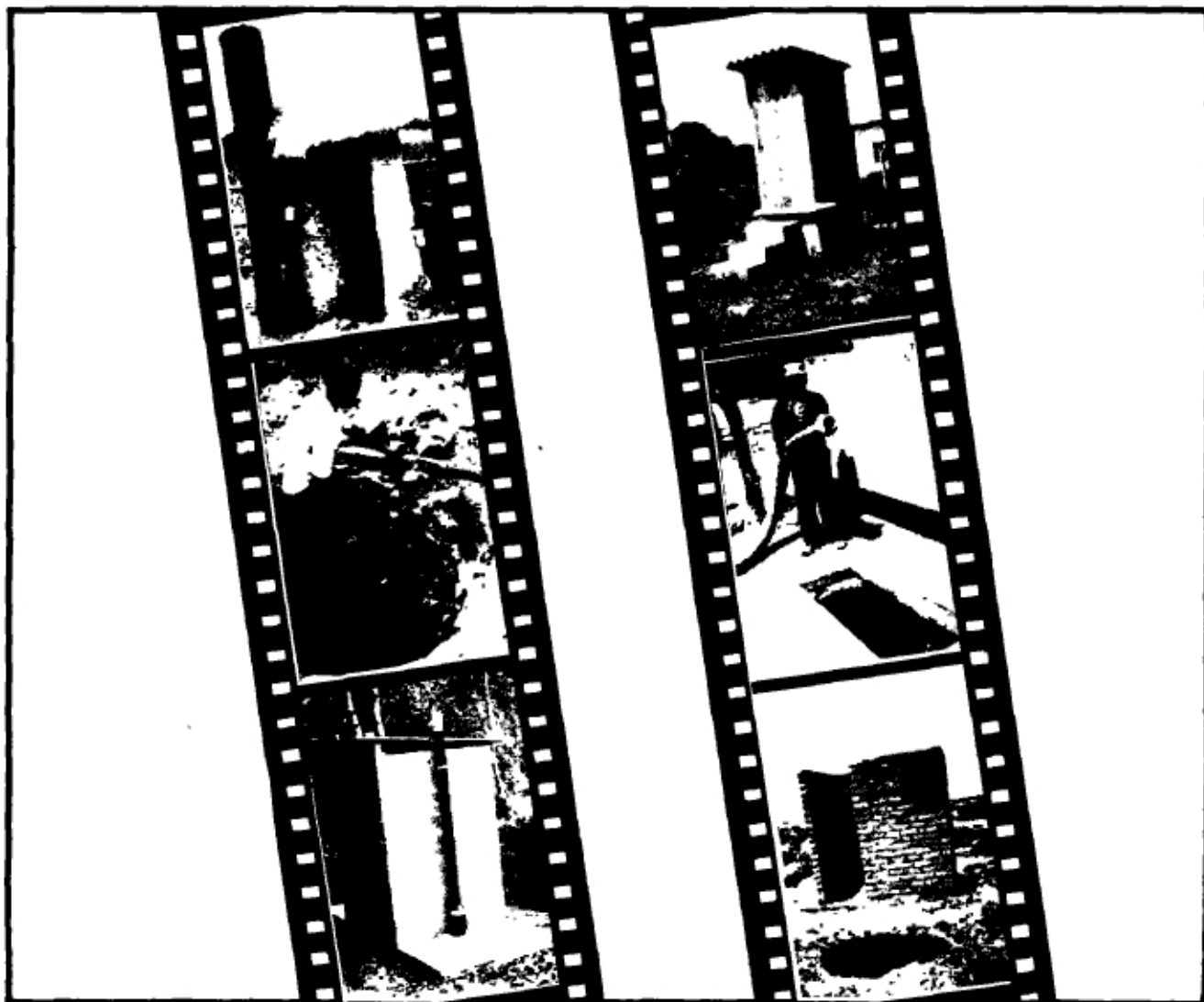
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Ventilated Improved Pit Latrines: Guidelines for the Selection of Design Options

D. Duncan Mara, Technology Advisory Group (TAG)



A joint United Nations Development Programme
and World Bank Contribution to the International
Drinking Water Supply and Sanitation Decade

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PREFACE

This Discussion Paper, prepared by Duncan Mara, is one of the technical outputs of a meeting of TAG ^{1/} staff held in Nairobi, Kenya, during July 9-13, 1984. It seeks to clarify the current state of Ventilated Improved Pit latrine design, which often includes a bewildering set of design options such as single or twin pits, emptiable or non-emptiable, lined or unlined and raised above ground level or unraised. The ability to make a rational choice between these design options should lead to a less wasteful use of resources and enable an adequate and cost-effective sanitation technology to be readily provided to those in need.

This document is being issued on a limited distribution basis to stimulate discussion and elicit ideas and contributions from readers. Comments and suggestions are invited from readers who would like to contribute to the state of the art, particularly on specific issues raised in the paper. Unfortunately, TAG will not be able to respond to every individual reader but hopes to revise this paper in due course to reflect, as appropriate, the comments and contributions received from readers.

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Enquiries about the TAG program and the publications available and comments on this and other TAG papers should be addressed to the Project Manager, UNDP Project INT/81/047, Water Supply and Urban Development Department, The World Bank, 1818 H Street, N.W. Washington, DC 20433.

Project Manager

^{1/} TAG: Technology Advisory Group, established under the United Nations Development Programme, UNDP Interregional Project INT/81/047: **Development and Implementation of Low-cost Sanitation Investment Projects** (formerly Global Project GLO/78/006), executed by the World Bank.

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INTRODUCTION

1. The ventilated improved pit (VIP) latrine is now widely recognized as one of the most important, affordable and appropriate on-site sanitation technologies for use in both urban and rural areas of developing countries. The Technology Advisory Group (TAG) has been one of the major agencies responsible for its promotion in several countries (principally in Africa and South America) and has published several Technical Notes describing the design of various types of VIP latrines.^{1/}

2. This Discussion Paper provides guidelines that will enable a design engineer to make a rational selection of the VIP latrine design option most appropriate to the community for which he is responsible. The designer is aiming at a technical choice that will be affordable to the householder and will give the best long-term service at the least cost. It is assumed for the purpose of this paper that a VIP latrine of some sort is the most appropriate sanitation facility for the community under consideration, and also that the reader is aware of how VIP latrines function and how they are able to control odors and insects (these details are covered in the appropriate TAG publications).^{1/} What remains for the designer is to select the type of VIP latrine that is compatible with available resources as well as with the prevailing physical, sociocultural, institutional, economic and financial conditions. In doing so, special emphasis is placed on technology costs and affordability.

3. For convenience, VIP latrine options can be considered as:

- (a) **Design options**, which cover the basic types of VIP latrines.
- (b) **Construction options**, which cover the various ways in which the basic VIP latrine types can be built.

In general, the selection of the most appropriate design option is more critical than the choice of the most suitable construction option. TAG Technical Note No. 13 covers the various construction options (and also design calculations for effective pit volume); therefore, this Discussion Paper is restricted to a consideration only of the various design options.

^{1/}

A complete list of TAG publications is given inside the front cover of this document.

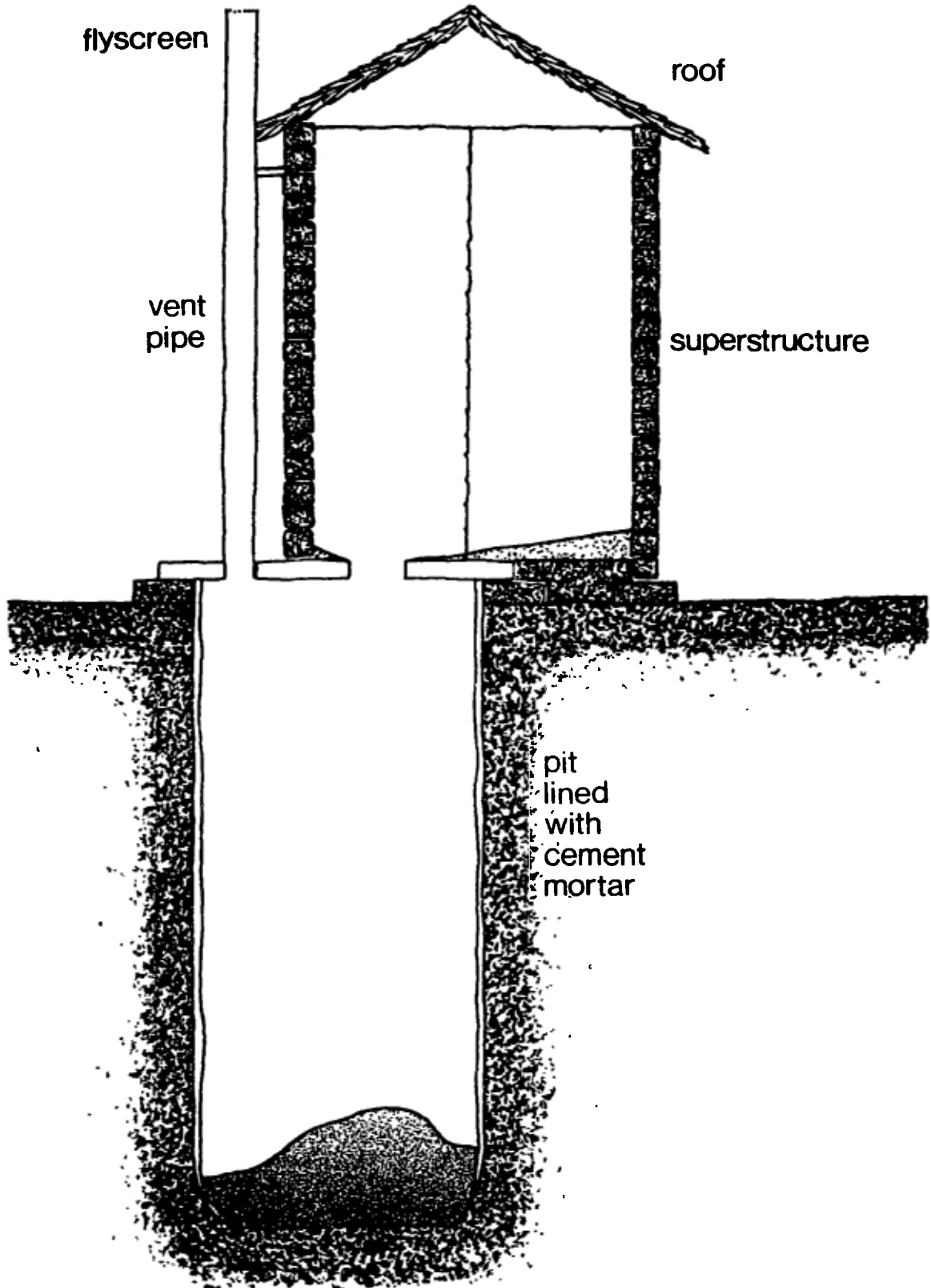


Figure 1. Non-emptiable, unlined and unraised single-pit VIP latrine. This is usually the least expensive design option.

VIP LATRINE DESIGN OPTIONS

4. A VIP latrine may be designed in several ways. For example, it may be a **single-pit** unit or an **alternating twin-pit** system. The latter is always designed as a permanent, **emptiable** facility, whereas the former may or may not be designed to be so. Emptying may be done manually or mechanically by using specially designed vacuum tankers.^{2/} Additionally, pits may or may not need to be **lined** (to prevent structural collapse), and they may be partially **raised** above ground level (to minimize problems in rocky or high groundwater table areas). In high-density areas in Zimbabwe, single-pit VIP latrines with soakaways have been used to prolong the effective life of the latrine. These latrines are largely experimental at this stage; moreover, it is debatable whether they should be classified as VIP latrines or aqua privies without chutes. For these reasons they are not included in the list of options.

Relative costs and affordability

5. The four basic sets of design options considered in this discussion paper are as follows:

- (a) non-emptiable/emptiable;
- (b) non-alternating (single pit)/alternating (double pits);
- (c) unlined/lined; and
- (d) not raised/raised.

The negative option is intentionally given first in each case because it is less expensive than the corresponding positive option. As a result, the least-cost VIP latrine design option is commonly a non-emptiable, unlined, single-pit latrine that is not raised above ground level (Figure 1). This is the option best suited for the lowest income group in a community. At the other extreme is the raised, fully lined, emptiable VIP latrine, which can cost more than twice as much. This is because about 40-50% of the capital costs arise from pit lining, and operation and maintenance costs are always higher for emptiable options. An implication of this is that whenever pit lining becomes imperative, the lowest permissible solids detention period should be chosen so that pit volumes and hence pit lining costs can be minimized to enhance affordability. An even greater impact on affordability can be achieved when there is access to credit.

^{2/} Boesch A., and R. Schertenleib (1985): **Emptying On-Site Excreta Disposal Systems: Field Tests with Mechanized Equipment in Gaborone (Botswana)**, IRCWD-Report No. 03/85



Figure 2. Vacuum tanker specially designed for emptying VIP latrine.

Pit emptying

6. The key points to note about pit emptying are:

- (a) Emptying is **essential** if
 - (i) there is insufficient space available for the relocation of a single-pit VIP latrine when it becomes full; or
 - (ii) an in-house latrine facility (see paragraph 13) is required and affordable.
- (b) Emptying is **desirable** if a shallow pit is required (for example, to minimize pollution of the local groundwater if this is used as a source of supply).
- (c) The main **advantage** of emptying is that it permits the facility to be a permanent one, and one that can be located in-house; a second advantage (which may be important in some societies) is that it makes reuse of the excreta product possible.
- (d) Pit emptying has several **disadvantages**:
 - (i) the purchase, operation and maintenance of specialized pit-emptying equipment may be required, depending upon the community type and the nature of the sludge (Figure 2);
 - (ii) higher operational costs; and
 - (iii) pit lining is required if the pits are to be emptied mechanically; it is highly recommended if they are to be emptied manually.
- (e) **Mechanical emptying** is required to remove the contents of single-pit latrines, which will contain fresh excreta and therefore may also contain viable pathogens.

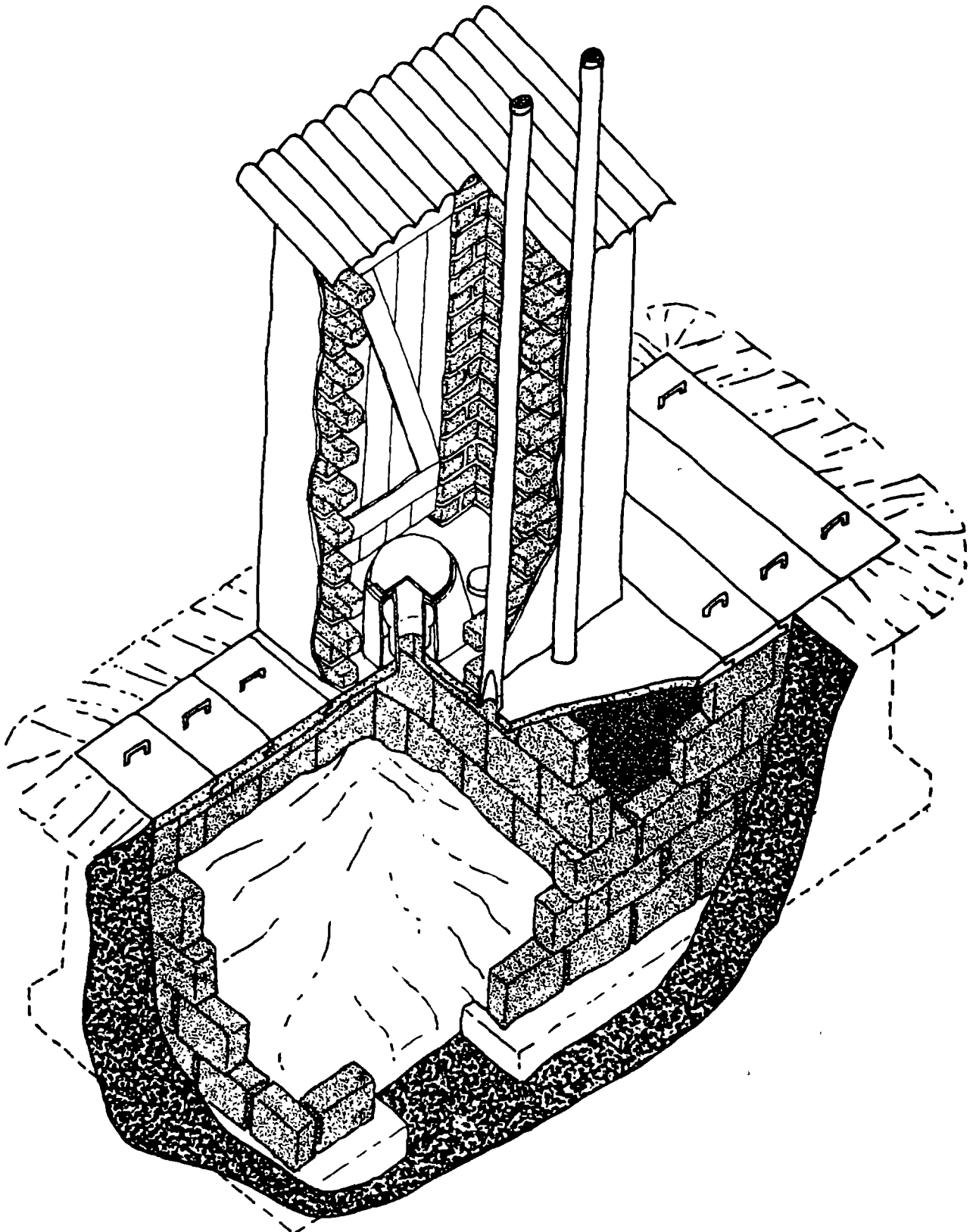


Figure 3. An alternating twin-pit VIP latrine.

- (f) Mechanical emptying requires a high degree of institutional organization, and also well-equipped and well-staffed workshops with good access to spare parts and expendable materials (the possibility of providing these facilities through the private sector as an alternative to the public sector should be borne in mind).
- (g) **Manual emptying** may call for cultural change on the part of the users, and should only be used with alternating twin-pit VIP latrines. It should thus be used only when it is both socially feasible and less expensive than mechanical emptying.

7. Design engineers should seek to optimize the combination of effective pit volume and emptying frequency to arrive at the least-cost solution. This approach requires knowledge of both construction and emptying costs; the former are easy to obtain, but there is little information on the latter. Some order-of-magnitude calculations are given in Annex I.

Alternating pits

8. Alternating twin-pit VIP latrines (Figure 3) should be used where appropriate and cost-effective. They are not required if latrine pits are not to be emptied. The following points should be noted:

- (a) Alternating systems are **essential** if
 - (i) the pits are to be emptied manually;
 - (ii) off-site treatment or hygienic disposal of the emptied pit contents is impracticable; or
 - (iii) excreta reuse is to be practised.
- (b) Alternating systems are **desirable** if
 - (i) very shallow pits (< ca. 1.5 m) are required to avoid groundwater pollution; or
 - (ii) there is unpickable rock at shallow depth and raised single pits are infeasible.
- (c) Alternating systems have several **advantages**:
 - (i) Production of an essentially pathogen-free product that can be handled without risk to public health;



Figure 4. VIP latrine pits lined with rough coral (above) and concrete blocks (below).

- (ii) manual emptying is permissible;
 - (iii) shallower pits can be used so that ground water pollution is more easily avoided;
 - (iv) the alternating cycle permits the restoration of the infiltrative capacity of the pit-soil interface; and
 - (v) greater flexibility in the precise time when the full pit is emptied.
- (d) Alternating systems have the following **disadvantages**:
- (i) capital costs may be higher;
 - (ii) user education may be required to gain acceptability; and
 - (iii) user education is necessary to ensure that both pits are not used simultaneously.

9. There is another alternating system that may often be less expensive than the alternating twin-pit VIP latrine described above: two separate single-pit VIP latrines used as an alternating system. If there is space for two single-pit latrines, one can be constructed initially and used for three to five years (depending on its effective volume and the local rate of solids accumulation). When it is full, its cover slab and superstructure are dismantled and re-erected over a second newly dug pit, which is used for the next three to five years. The first pit, which is sealed with soil, is then emptied and put back into service when the second pit is full. Careful design of the superstructure should ensure that the required dismantling is kept to a minimum and eliminated if the superstructure is sufficiently lightweight (< 150 kg) to permit it to be completely movable. This is particularly applicable in rural areas where the superstructure could be made of material that can be discarded after the shift from one pit to the other.

Lining the pits

10. Lining the pit wall (Figure 4) is sometimes required to provide structural stability to the latrine during its construction, use and emptying. Lining may be made of a variety of materials, including open-joint brickwork, masonry, rot-resistant timber, etc. (further details are given in TAG Technical Note No. 13). Soil stability criteria are given in Annex II. The key features to note about lining are as follows:

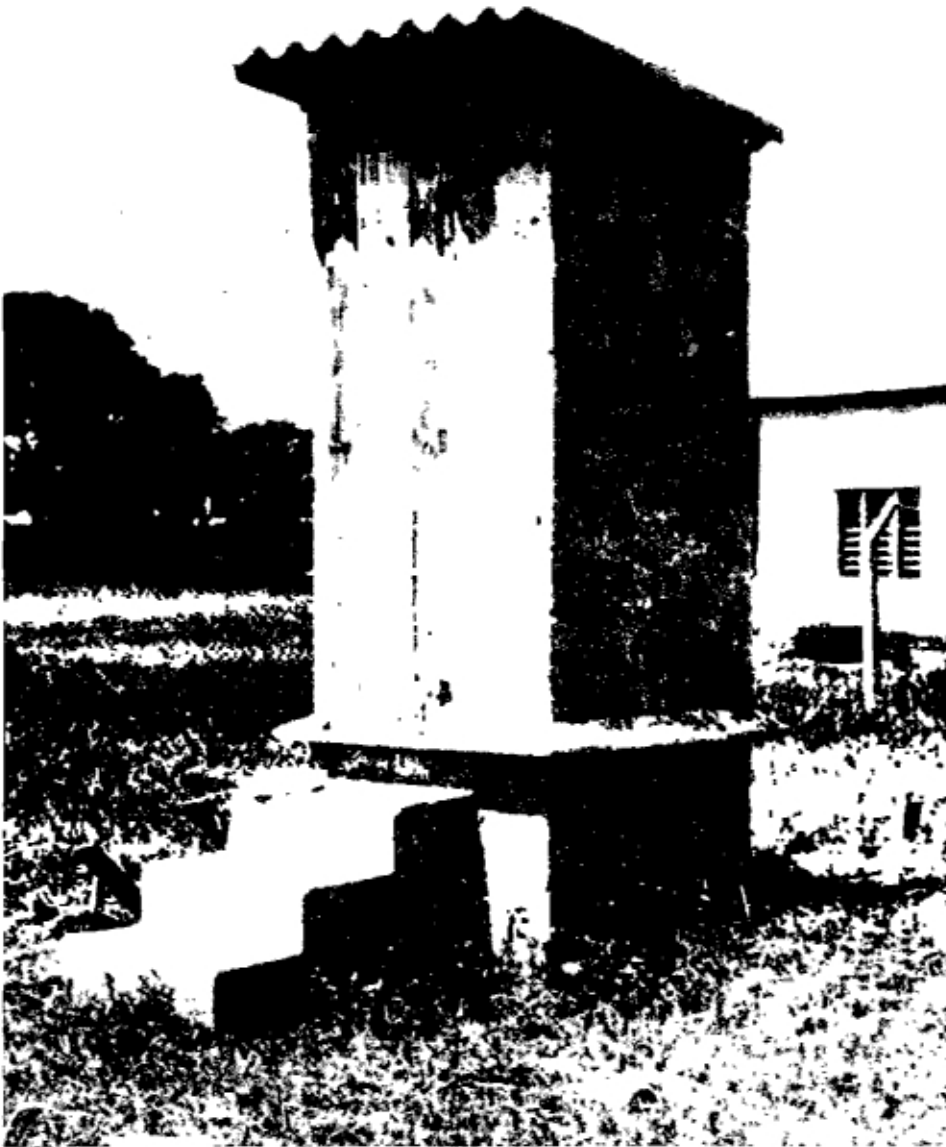


Figure 5. A raised, single-pit VIP latrine.

- (a) Lining is **essential** if
 - (i) the pit is to be emptied mechanically;
 - (ii) the soil is unstable; or
 - (iii) the pit penetrates the groundwater table.
- (b) Lining is **desirable** if
 - (i) the pit is to be emptied manually;
 - (ii) "bucket showers" are to be taken in the latrine;
 - (iii) the superstructure has to be heavy; or
 - (iv) the latrine has to be raised.
- (c) Lining has several **advantages**:
 - (i) increased structural stability of the latrine;
 - (ii) the pit can be emptied mechanically; and
 - (iii) the pit can support a heavy superstructure.
- (d) Lining has the following **disadvantages**:
 - (i) increased construction costs; and
 - (ii) construction difficulties in areas of permanently high groundwater.

11. If the pit has to be lined, then the designer should seriously consider whether or not the pit should be emptiable (paragraphs 6 and 7), as lined single-pit latrines have the potential to be permanent.

Raising

12. Raised VIP latrines (Figure 5) are those in which the cover slab is raised above the ground level by more than a single course of brickwork. If raising is necessary then it should be by the minimum amount possible. The following points should be noted:

- (a) Raising is **essential** when the groundwater is, either permanently or seasonally, within 0.3 m of the ground surface, or if there is unpickable rock at very shallow depths.

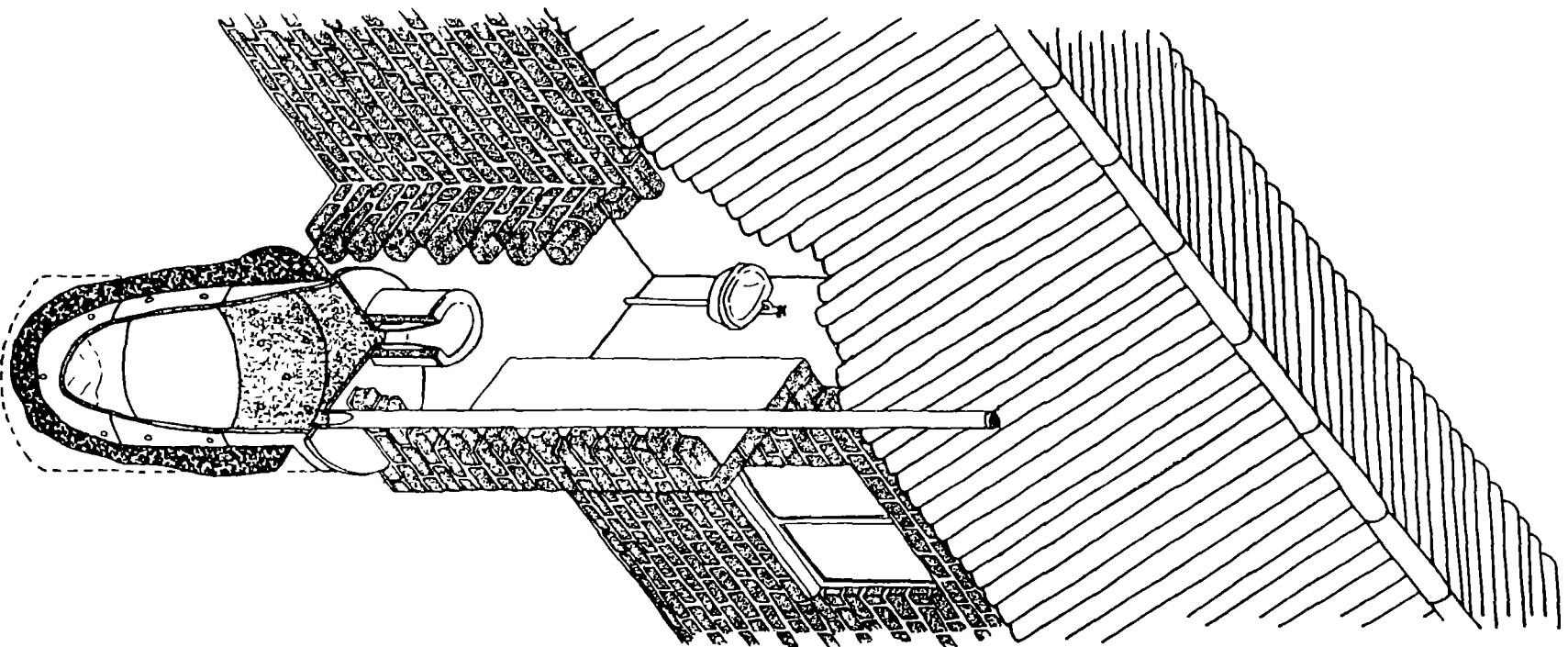


Figure 6. An in-house, emptyable and lined single-pit VIP latrine.

- (b) Raising has the **advantage** of permitting VIP latrines to be used in areas of high rock or high groundwater table.
- (c) Raising often has the **disadvantage** of increasing construction costs.
- (d) Raised VIP latrines normally require fully lined pits.

In-house latrines

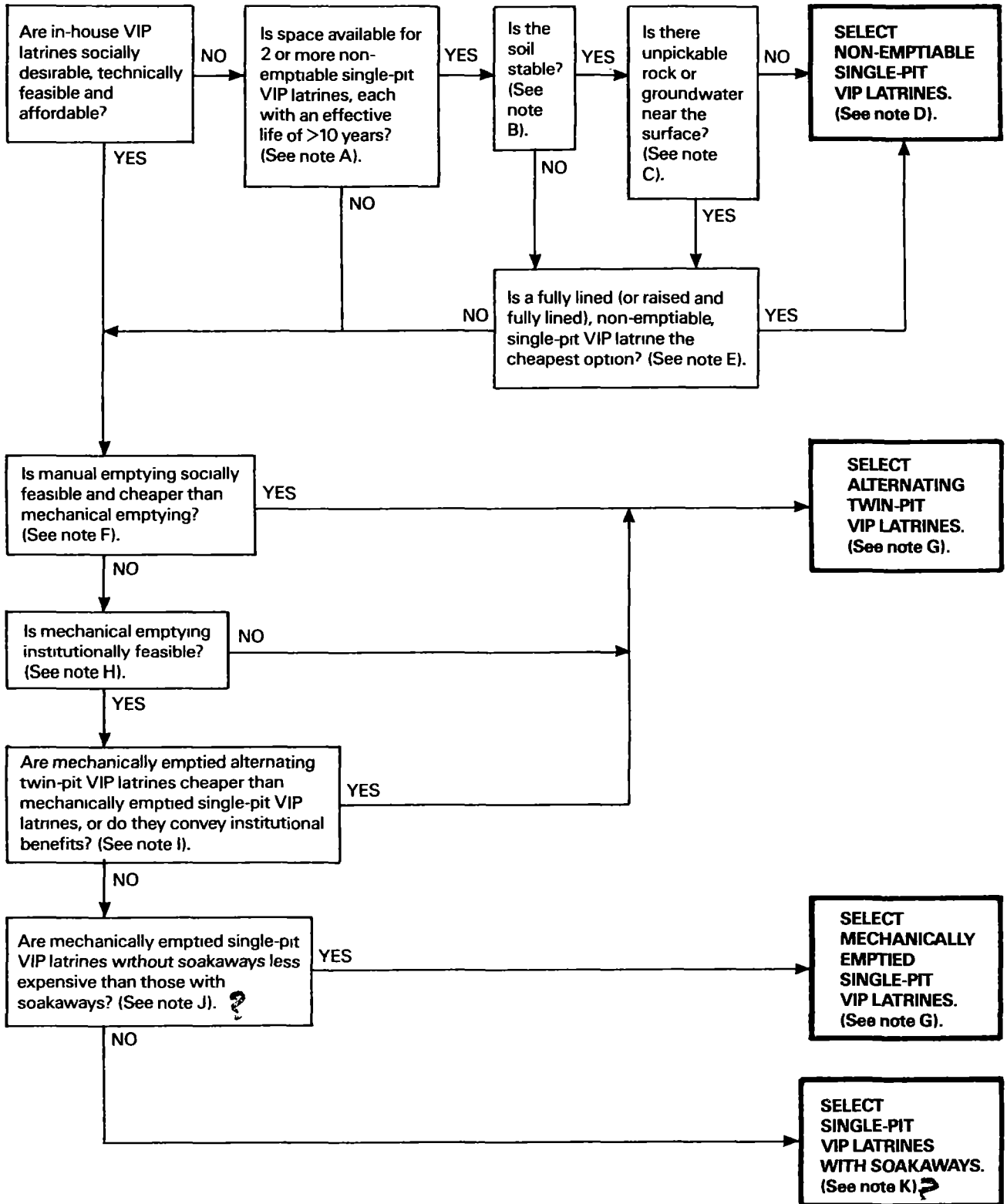
13. VIP latrines are commonly thought of as external sanitation facilities, or "outhouses," but this is not necessarily correct. Recent developments in the cities of Kumasi (Ghana) and Olinda (Brazil) (see TAG Technical Note No. 13) have shown that the superstructure of the latrine may be an integral part of the house (Figure 6); the excreta fall into an offset pit that is partially under the house but mainly outside of it so as to provide access for emptying. Thus in-house VIP latrines are technically feasible and design engineers should always consider this option in urban areas; discussions with the community will indicate if they are socially desirable and affordable. The following points should be noted:

- (a) In-house VIP latrines are permanent, emptiable facilities that may be either single-pit units with mechanical emptying or alternating twin-pit systems with manual or mechanical emptying.
- (b) In-house VIP latrines are generally more convenient and so will usually encourage latrine usage.
- (c) In high density areas, in-house VIP latrines may be the only feasible VIP design option due to a lack of space for external units (in Olinda, Brazil, in-house VIP latrines were installed in an urban slum area with a density of 500 people per hectare; the installation of in-house latrines required space previously used for other purposes, but householders made this available once they were convinced that improving sanitation was essential).
- (d) In-house latrines may have the advantage of slightly decreasing capital costs, particularly when a suitable closet already exists as part of a house.

Selection algorithm

14. A simple algorithm for the selection of the most appropriate VIP latrine design option is given on page 14.

VIP LATRINE DESIGN SELECTION ALGORITHM



Notes to Selection Algorithm

- A. Space for relocation of non-emptiable, single-pit VIP latrines is usually available in rural areas and low-density urban areas. The designer should consider the "alternating single-pit" option discussed in paragraph 9.
- B. As defined in Annex II.
- C. Unpickable rock within 1 m or groundwater within 0.3 m either permanently or seasonally.
- D. The pit will require lining if the answer to question 2 is "no," and both lining and raising if the answer to question 3 is "yes."
- E. The designer should compare the alternative of smaller, emptiable pits.
- F. Mechanical emptying is a broad term and covers, for example, manually operated diaphragm pumps that could be mounted on an animal-drawn cart, which also carries a small sludge tank as well as more sophisticated vacuum truck systems.
- G. The pits will generally require lining and also raising if the groundwater table is high (as defined in note C above). Use manual emptying if feasible for alternating twin-pits but mechanical emptying always for single-pits.
- H. Is there an institutional capability for organizing regular pit-emptying and vehicle maintenance programs? Are spare parts, fuel and other expendable items available?
- I. The designer, in seeking to answer the above question, should consider various emptying frequencies--for example, alternating twin-pits with two-, three-, and four-year cycles and single-pits with three-, five- and ten-year cycles. Institutional benefits include flexible emptying time, no treatment costs and instant reuse of the excreta product.

LATRINE EMPTYING COSTS

1. The use of modern, powerful vacuum tankers for emptying VIP latrines is often thought to be very expensive. While it is true that few reliable field data are available to calculate emptying costs with any precision (this is essentially because work has only recently begun on the design and fabrication of suitable tankers), it is nonetheless possible to make "order of magnitude" estimates of the costs involved.

2. Let it be supposed for a community of 6,000 households that a suitable vacuum tanker (such as the BREVAC^{1/}) has a c.i.f. cost of US\$75,000, and that it can service 10 VIP latrines a day for 200 days per year. One such tanker can thus service (10 x 200), or 2,000 latrines annually.

3. If the tanker is assumed to have operating and maintenance costs of US\$30,000 per year, and if the tanker is written off after three years (which is unlikely in practice but serves to increase the costs in this illustration), then the total annualized cost for emptying 2,000 pits each year out of 6,000 pits assumed to be designed for emptying on a three-year cycle is as follows:

Vacuum tanker (@ US\$75,000 amortized at 12% over 3 years)	US\$31,200
O & M cost	US\$30,000
TOTAL ANNUAL COSTS	US\$61,200

This is equivalent to an annual household (latrine) cost of (US\$61,200/6000), that is, US\$10.2, or a monthly payment of US\$0.85. This is not likely to be unaffordable. Since the tanker can reasonably be expected to last more than three years, and since its operating and maintenance costs are likely to be much less than US\$30,000 per year, the actual cost to the householder will probably be even less than US\$0.85 per month.^{2/} These order-of-magnitude calculations therefore indicate that mechanical emptying of VIP latrines is likely to be economically feasible in urban areas, provided the off-shore costs (in foreign currency) are affordable.

1/ "BREVAC: a Mechanized Method of Emptying Sanitation Chambers," BRE Information Paper No. 84, Building Research Establishment, Watford, England, 1984.

2/ Estimated costs of pit-emptying in Brazil are reported to be US\$0.40-0.50 (1985 dollars) per household per month.

SOIL STABILITY CRITERIA

1. This Annex describes three alternative, simple field tests for soil stability. On the basis of these tests, the designer of VIP latrines can decide whether a pit needs to be fully lined, as described in paragraph 18 above.

Test A

2. This is the simplest test. Soil samples are taken by hand auguring; one sample should be taken every 50 cm to a depth of 3 m. Each sample is then hand-rolled to form a rough cylinder of approximately 2 cm diameter and 5 cm long. After sun-drying for two days or, preferably, oven-drying for two hours at 100 C, the sample is gently crushed between one's thumb and fingers. Unstable (cohesionless) soils crush easily, whereas stable (cohesive) soils do not. This test requires some experience, and it is therefore a good idea to practise the test on soils of known particle size distribution and undrained shear strength.

Test B

3. This is the standard soil mechanics measurement of particle size distribution.^{1/} A soil can be considered stable if it contains more than 30% clay (< 0.002 mm). It is simpler to measure the combined sand and silt fraction (> 0.002 mm), which should not therefore exceed 70%.

Test C

4. This test is the measurement of the undrained shear strength of soil samples and is thus applicable only to cohesive soils. It is done in the field by the standard soil mechanics vane test procedure.^{1/} Soils with an undrained shear strength of less than 15 kN/m² are likely to be able to support normal superstructure and coverslab loads (which may exceed 20 kN). As a reasonable precaution, pits excavated in soils with an undrained shear strength of less than 20kN/m² should be fully lined.

^{1/} This is described in, for example, British Standard BS 2004:1972.

