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RESOURCES RECOVERY IN TROPICAL WASTES DISPOSAL: COMPOSTING AND BIOGAS TECHNOLOGIES

1. INTRODUCTION

The major developmental problems facing all developing countries may be summarised as follows :-

- 1) high urban population growth rate (2-5% per year);
- 2) low income (per capita G.N.P. less than \$450);
- 3) high infant mortality (120 deaths per 1000 live births);
- 4) hunger (54grams of protein per day per person);
- 5) low life expectancy (less than 52 years);
- 6) illiteracy (43%) literacy rate;
- 7) lack and inadequate provision of water supply (38% of total population have water supply and a majority of these cannot be supplied more than 60 litres per capita per day) (2)
- 8) lack and inadequate provision of excreta and wastewater disposal facilities (33% of total have some form of excreta disposal facilities, most of which are totally inadequate). (2,3,4,5)

The provision of adequate and appropriate excreta and wastewater disposal facilities can help considerably in redressing some of these problems. However, it may not be readily apparent to many western-trained environmental engineers and health administrators in African countries that excreta disposal systems other than the conventional water-borne sanitation systems (sewerage systems) can fulfill the following requirements:-

- 1) low constructional and operating costs;
- 2) ease of operation and maintenance;
- 3) non-reliance on imported mechanical parts;
- 4) low water requirement;
- 5) less risk of causing surface water pollution;
- 6) good hygiene;

- 7) high user acceptance;
- 8) production of useful by-products (the sale of which can reduce the cost of the facility).

These alternative sanitation systems range from the simple pit latrines to ramifications of conventional sewerage. The systems that encourage the reuse of excreta form the general subject of this paper.

Recycling or reuse of excreta is traditionally practised in many developing countries. The practice, in its insanitary form, has grown out of dire necessity rather than for the primary reasons of environmental control as in the resource-wealthy industrialized countries. The governments of most independent African countries are becoming increasingly aware of the need for massive agricultural development upon which the nutritional level and in certain areas, the very survival of the population depends. The massive investments being made for the construction of irrigation schemes and the increasing amount of chemical fertilizers which are annually imported into several African countries are clear evidence of the high priority being given to agriculture in this part of the world. However, the high cost of chemical fertilizer is not affordable by the peasant or rural farmer. Even when the chemical fertilizers are heavily subsidized and are affordable by the rural farmer, their use may be grossly abused because soil testing services, which will help to identify the deficient nutrients in soils, and the fertilizer best suited to particular crops, are unavailable to him. The demand and consumption of chemical fertilizers are on the increase in several African countries. For instance, additional 400,000 metric tons of fertilizer were imported into Nigeria in 1978 and an additional 700,000 metric tons were expected to be imported in 1979. (6) Per capita consumption of chemical fertilizer in Kenya in 1975 were Potash (0.31kg K₂O) phosphate (2.29kg P₂O₅) and nitrogen (1.51kg N) and the corresponding figures in Ethiopia, a much less developed country than Kenya, were phosphate (0.41kg P₂O₅), and nitrogen (0.29kg N). (7) On the other hand, the per capita yearly nitrogen discharge in human excreta is 5kg; phosphorus is 1.5kg (as P₂O₅); and potassium is 1kg (as K₂O). Micronutrients and organic matter,

which are excellent soil conditioners are also present in human excreta. As shown in Table 1, the fertilizer value of digested excreta (compost) is much lower than that of chemical fertilizer. However in many developing countries only a small percentage of the population are served by waterborne sanitation while a majority have some other kind of facilities or no facility at all.⁽²⁾ The situations in Kenya and Zambia⁽⁹⁾ are summarized in Table 2 and these are reasonably typical of many African Countries. Under these situations, the quantities of fertilizer that can be realised from undiluted human excreta can be very substantial particularly in the rural areas where a majority of the population of the developing countries live. Although composting renders human excreta virtually free of pathogens and the sanitary application of composts as agricultural fertilizers has been widely demonstrated in many developing countries,⁽⁹⁾ there are very few (if any) reported cases of any successful composting systems in operation in Africa. Furthermore, per capita costs of compost toilets have been indicated to be more favourable than those of several other low-cost excreta disposal systems commonly in use in Africa.⁽³⁾

This paper attempts to briefly review composting toilets in Africa since these have very high potential for yielding agricultural "fertilizer" (compost) and suggest factors which should be taken into consideration in the design and operation of these waste reuse systems to make them adaptable to the conditions in rural and peri-urban Africa.

2. COMPOSTING

2.1 Technical Principles

Aerobic composting may be defined as the biochemical decomposition of organic waste materials into relatively stable and odourless compost under aerobic and controlled moist conditions. The complex biochemical processes involved are summarized in Figure 1. The large quantity of heat generated during the process effects the destruction of pathogens and thus renders the process very safe from the public health or disease transmission point of view. The time/temperature relationship for aerobic composting cycle is shown in Figure 2 and it is apparent that a period of at least four months is required for the production of a safe compost.

Composting has been thoroughly reviewed in the literature^(10,11) and a wide range of excreta composting technologies are known to be available. In general a composting process is fairly easy to operate provided the following conditions are fulfilled:-

- (1) the initial carbon to nitrogen (C/N) ratio in the organic material is about 30 : 1;
- (2) the initial carbon to phosphorus (C/P) ratio in the organic material is about 100 : 1;

- (3) the moisture content is about 60%;
- (4) there is periodical agitation or "disturbance" of the composting mass;
- (5) the aeration rate through the composting mass is maintained at about 1m^3 air/day/kg volatile solids at initial stages of operation of the system;
- (6) the initial temperature is not greater than about 50°C ;
- (7) the particle sizes of the composting material range from about 10mm to about 80mm;
- (8) pH of the composting mass is maintained between 6.5 and 8.5.

2.2 Composting Toilets

2.2.1 Designs and Performances in Africa.

There are two main types of composting toilets namely the continuous and the batch toilets. The several variations of these two types of composting toilets have recently been reviewed by Winblad⁽¹³⁾ Nimpuno⁽¹⁴⁾ and Kilama.⁽¹⁵⁾

In general, batch composters are of the double vault variety (see figure 3, 4 and 5). One vault is used until it is about 70% full, when it is filled up with earth and sealed, and then the other is used. When the second vault is full, the contents of the first one are removed and may be used as agricultural fertilizer. In order to satisfy the C/N ratio and moisture content requirements, either urine is excluded and ash is added as in the Vietnamese practice (see Figure 5) or organic domestic refuse, wood-chips sawdust or ashes are added to the composting toilet and free percolation of urine into the soil may also be allowed as in the Botswana and Tanzanian trials.^(3, 15, 16)

The exact design and operation of composting toilets in Africa are uncertain because detailed and systematic studies are yet to be conducted. However, Chinese, Vietnamese and Indian experiences^(17,18,19) indicate that batch composting toilets perform very satisfactorily. The study in Tanzania^(3, 15) (which is perhaps the most detailed so far in black Africa) indicate that the batch double-vault composters are versatile but sensitive to misuse. The study⁽¹⁵⁾ suggested that these composters will operate well if plenty of grass or other carbon source are added, if water is not put into them and therefore the moisture content is kept in the range 40 - 55% and if they are used by less than around 15 people. The compost from the vault which was sealed for at least six months contained no more pathogenic organisms than the soil in the same locality. The modified Gopuri (see Figure 4) was recommended for general adoption. The study^(3,15), however, failed to indicate the effect of grass addition on the filling time of the vault or the effect the mode of addition of the grass or the form in which the grass was added (i.e. whether as fresh or dried or burnt grass) on the time required to obtain a safe compost (sealing period of the vault). These factors are bound to affect the rational design

Table 1:- Nutrient Content of a Fertilizer and some "Wastes" (10)

Constituent	Concentration as % of Dry Solid						
	Primary Sludge	Activated Sludge	Digested Sludge	Fertilizer	Farm Compost	Municipal Compost	Nightsoil
Total nitrogen	4.5	6.0	2.0	6.0	0.4	3.5	0.6
Phosphorus as P ₂ O ₅	2.0	2.5	1.5	10.0	0.3	3.5	0.2
Potash as K ₂ O	0.5	0.7	0.5	6.0	0.5	1.8	0.3
Total	7.0	9.2	5.0	22.0	1.2	8.8	1.1

Table 2:- Sanitation Facilities in some African Countries (8,9)

Facility	Urban Zambia (1976)	Rural Zambia (1976)	Lusaka (Zambia) (1976)	Kenya (excluding Nairobi) 1973
Flush toilet	43.9	3.5	37.3	6.0
Sewerage	-	-	-	-
Aqua-Privy	4.8	0.5	1.2	-
Pit latrines	40.1	33.5	53.7	40.0
Bucket	1.3	-	2.7	3.0
None	9.9	62.5	4.7	51.0
Total %	100.00	100.00	100.00	100.00

of batch composters for the rural and peri-urban areas of Africa particularly as grass, weeds and similar plants are the most accessible and affordable biodegradable organic materials which can help maintain the delicate C/N ratio in composters. The Botswana study (3, 16) was much shorter than the Tanzanian study (3, 15) and the major indication from that study (3, 16) is that batch composting toilets might prove very popular particularly if the municipal authorities would be willing to help empty the vaults.

Continuous composting toilets, differ from the batch or double vault composters in that they allow for the removal of compost from a single chamber (see Figure 3). Although this system seems to have performed satisfactorily in several Scandinavian countries (20, 21) has evaluated the possibility of their adoption in some African countries, continuous composting toilets have been found unsatisfactorily in the two African countries, Botswana and Tanzania where they have been tried. In Botswana (16) the continuous composting toilets were found to suffer considerably from fly and odour nuisance and "dry" composts were rarely produced in any of the systems under trial. They were also found to be sensitive to the degree of user care and the number of users. The Tanzanian investigators (15) pointed out that the sloping floor of this type of toilet required more skill for its construction and also the risk of pathogenic organisms being washed down to the desludging port. A further interesting observation from the Tanzania study (15) is

that there was no significant difference between the continuous composters with and without channels to promote the aeration of the pile. A difference of about 7° in the slope of the floor was also found not to cause a significant difference in performance.

The total annual substructure costs for composters built in Botswana and Tanzania have been summarized as follows (3):-

	<u>Botswana</u>	<u>Tanzania</u>
Batch Composter (lined)	£34	£15
Batch Composter (unlined)	-	£14
Continuous composter	-	£16

The Chinese composting methods which have recently been reviewed by McGarry (19) also appear to offer potential for adoption in the rural and peri-urban areas of Africa. These are reproduced in Figure 6.

2.2.2 Apparent Deficiencies in the Designs and Operations of Composting Toilets in Africa

The designs of the several composters which are being evaluated in Africa (15, 16) have operated satisfactorily in several other countries outside Africa. Operational rather than design factors may, therefore, be more important in ensuring the good performance of composters in tropical Africa.

The shortage of refuse and biodegradable organic materials, which may help to maintain the delicate C/N ratio in the composting mass and also absorb excess moisture, has generally been mentioned as a cause of the poor functioning of composters in the rural and peri-urban areas of Africa. However, grasses, weeds and similar plants are abundant in these areas and what is now most needed is an evaluation of the mode of addition of these readily available biodegradable materials and also the best possible form (whether as fresh, dried or brunt materials) in which to add these materials so that they do not adversely decrease the filling time of the vault or prolong the duration of the composting process.

Water is a common anal cleansing material in several African communities⁽¹⁵⁾ (particularly the moslem community). It is impossible to regulate the quantity of water used by an individual for anal cleansing. This practice may severely hamper the performance of the designs of composters which are currently under trial in Africa.^(15, 16) In communities where there is a prevalent use of water for anal cleaning, one wonders what would be the merits and demerits of the composter design shown in Figure 7. The slatted bed and the sloping floor of this design are clearly attractive features since these will ensure uninterrupted and continuous drainage of urine.

2.2.3 Potential for the Adoption of Compost Toilets in Africa.

Pit latrines are undoubtedly the most prevalent excreta disposal system used in tropical Africa.^(3, 8, 9, 23, 24, 25) A major disadvantage of pit latrines is that, when full, they must be taken out of service and another unit built. Furthermore, pit latrines have very little potential for resource recovery. The operation of pit latrines in some African countries^(9, 23, 24, 25) is such that when a pit is full, it is covered with earth and the new pit is dug adjacent to the filled pit. This mode of operation is somewhat similar to that of a double-vault compost toilet. Thus considering the facts that composting toilets have a high potential for resources recovery and are of comparable cost⁽³⁾ with improved pit latrines, they should be attractive for adoption in tropical Africa.

In both rural and urban areas where crops are grown near the house, and where there are no cultural barriers to reusing human waste products, the compost can be used to improve gardens and also to refill eroded soils. In dense urban areas where people have little or no space for gardening, or in areas where the reuse of human waste products is abhorrent, the "in-yards" disposal of the compost may present a slight problem. This problem is however not insurmountable as the compost can be used on community basis to refill street potholes and such similar purposes.

Composters are demanding in terms of care and attention by the users (fulfilment of the requirements in Section 2.1). The involvement

of the municipal authority at some stages of execution of compost toilet programmes may be inevitable. Composting toilets, particularly the continuous type, are generally too complex for self-help programmes, so that in areas where there are relatively well organised municipal authorities (e.g. East and Central African Countries) these will INITIALLY have to be responsible for organising construction and also plan carefully the financial arrangements by which the users will pay for the system. Users should be encouraged to attempt the construction of future composters when familiarity has been gained with the system and designs standardized. This approach has worked well with the construction of pit latrines in Zambia⁽⁹⁾ and the response of the local user to the construction of ROEC latrine in Botswana⁽²⁶⁾ was very encouraging.

Although users may indicate some feelings of reluctance to emptying their composters (as in Botswana⁽¹⁶⁾) and this may be seen as an area calling for the involvement of the municipal authority,⁽³⁾ it should be remembered that the success rate of African composters has been very low indeed. When real composts have been and are being produced in African composting toilets, this apparent reluctance on the part of the users to empty their composters may greatly decrease. In cases where the reluctance persists, the user may privately arrange for his composter to be emptied as is the practice with the emptying of aqua privies, septic tanks and similar sanitation systems in several West African countries.⁽²⁴⁾ The private contractor may be able to sell the compost to other members of the community who have no objections to using compost as fertilizers (just as cow-dung which is relaised from animals reared by the Fulanis of Northern Nigeria are sold to non-fulani members of the community who use the cow dung on their gardens). On the other hand, the use of the compost for land reclamation purposes should not be ignored.

Unlike the pit latrine, which can be converted to a pour flush toilet,⁽²⁷⁾ there is no potential for economically converting a composting toilet into another type of toilet. However, compost toilets, like the improved ventilated pit latrines, can serve as an economically alternative (reserve) excreta disposal system in established urban areas of Africa where flush toilets have been already installed but where water supply is intermittent and irregular^(23, 24) to ensure the continuous and hygienic functioning of the flush toilet system.

3. SUMMARY

This presentation has attempted to review and assess the potential of compost toilets in Africa. The following observations are made:

- (1) Although composting toilets, of whatever type, requires a considerable amount of conscientious care by the users, double vault composters, which are designed to accept both

excreta and urine and to which organic wastes are added to ensure that the delicate C : N ratio and moisture content requirements are met, will be easier to adapt to the African environment. Designs such as shown in Figure 7 may be developed for wider application.

(2) Although there is usually a shortage of refuse in the rural and peri-urban areas of Africa to ensure the proper operation of compost toilets, there is abundant grass, weeds and similar materials in these areas and these should be suitable substitute for conventional refuse particularly if they are properly added (e.g. used in filling up the compost toilet when 2/3 full or burning the grass and using the resultant ash to cover the excreta after every use.) In fact, this proposal, if successful, will help in the general up-grading of the rural African environment which is often bushy.

(3) Although there is a lack of tradition of using fertilizer and reusing human waste products in agriculture in Africa, and this is generally seen as a drawback in adopting composters, **SUCCESSFUL COMPOSTERS WHICH PRODUCE COMPOSTS WHICH ARE CLEARLY DISTINGUISHABLE FROM HUMAN EXCRETA ARE YET TO FUNCTION IN TROPICAL AFRICA.** Until this happens, it will continue to be a supposition that the use of compost is not likely to be favoured in African agriculture for social and cultural reasons.

(4) Even where composts cannot be used as fertilizers (e.g. in dense urban areas where gardens are unavailable) they can be used in filling street potholes and levelling eroded footpaths, etc.

(5) The unit costs of composters in some African countries (3) is very comparable to the corresponding costs of the ventilated improved pit latrine. Composters, however, do not require to be resiting when full and as a result can serve as an economically alternative (reserve) excreta disposal system in urban areas of Africa where flush toilets have already been installed but where water supply is intermittent and irregular to ensure the continuous and hygienic functioning of the flush toilet system.

(6) The traditional practice of resiting a new pit latrine adjacent to the used pit in several African communities may facilitate the adoption and construction of double vault composting toilets in these communities.

Africa remains a continent riddled with poverty, hunger and a range of chronic debilitating diseases, the transmission of which related to poor environmental conditions and insanitary habits particularly with regard to the disposal of human and animal excrement and community wastes. Whereas the training and outlook of the public health engineer from the resources of wealthy industrialized countries largely tends to emphasize the disposal of wastes in order to upgrade the environment (and as a result improve public

health), the African public health engineer has the additional onus of developing and implementing waste disposal process that will augment the very limited natural resources such as food, fertilizer, and water in his continent. Some possible approaches are summarized in Figure 8.

ACKNOWLEDGEMENTS

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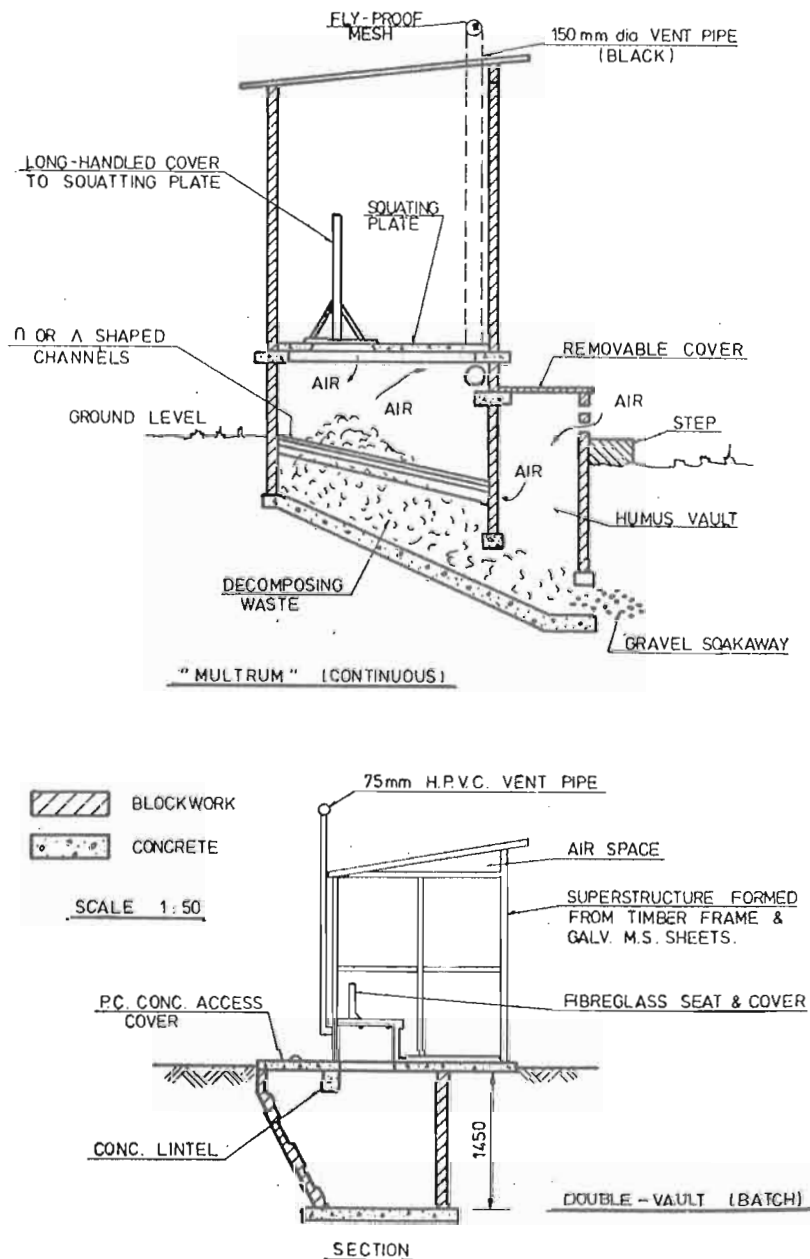


FIG. 3 : COMPOST TOILETS UNDER TRIAL IN BOTSWANA. (16)

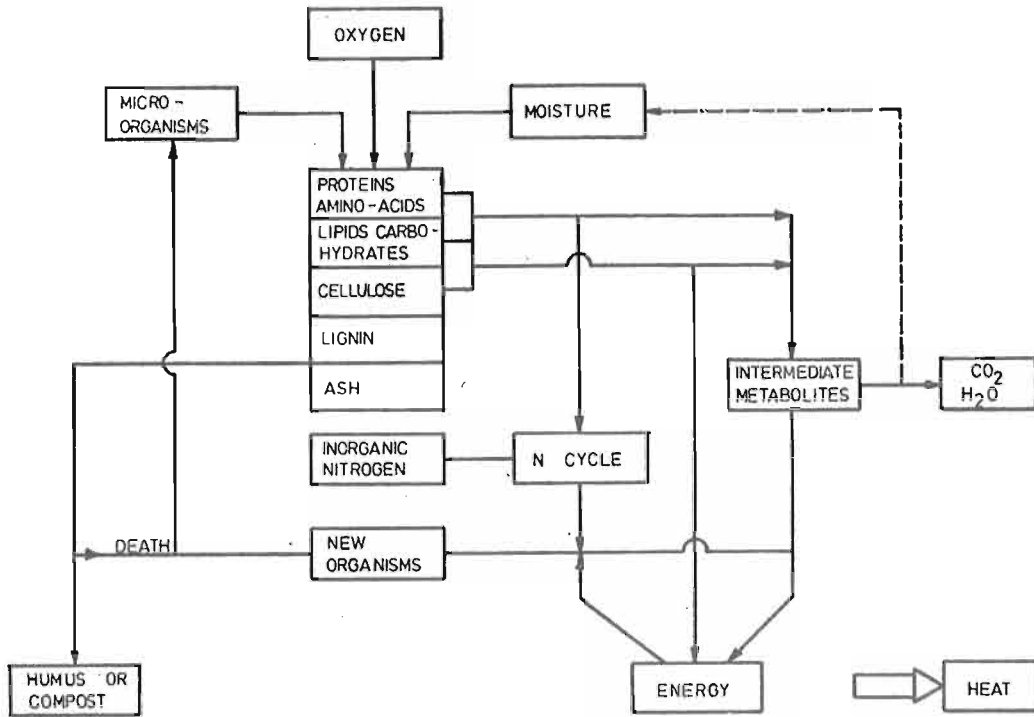


FIG. 1 : BIOCHEMICAL PATHWAYS OF THE COMPOSTING PROCESS.

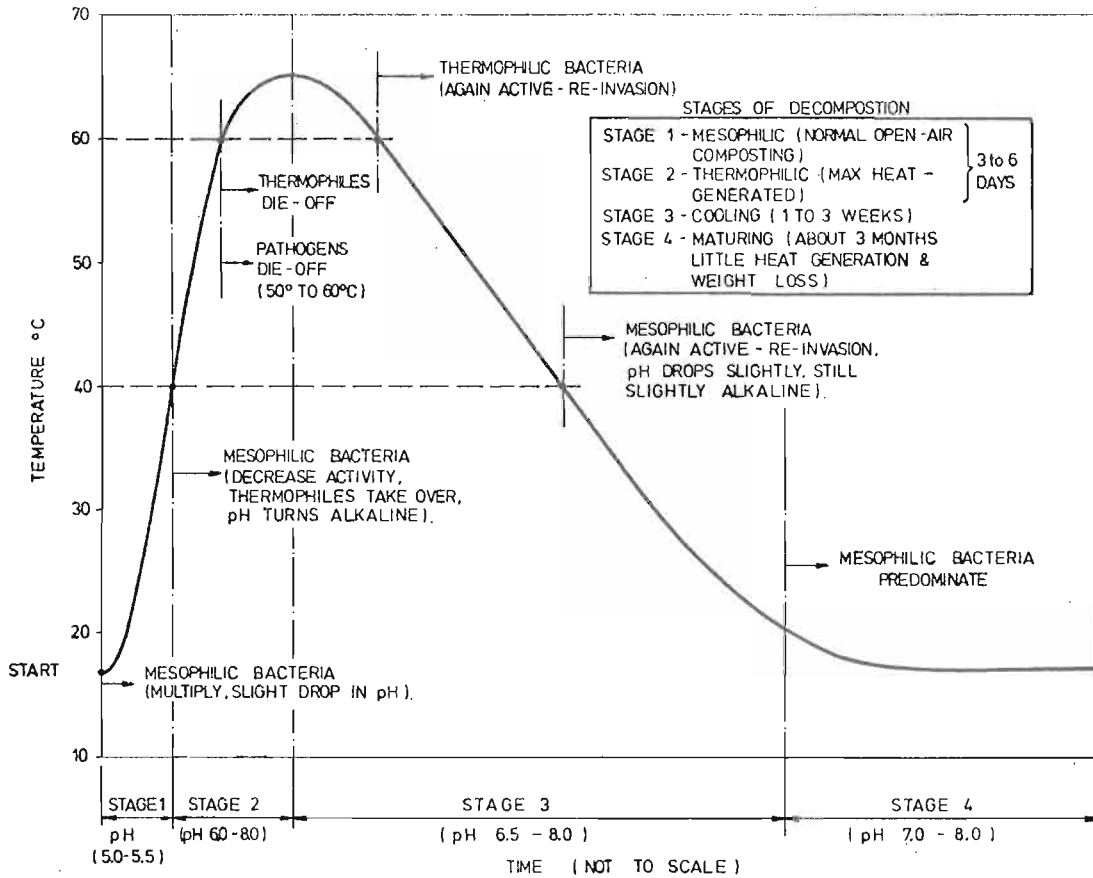


FIG. 2 : TYPICAL TIME / TEMPERATURE RELATIONSHIP FOR AEROBIC COMPOSTING CYCLE.

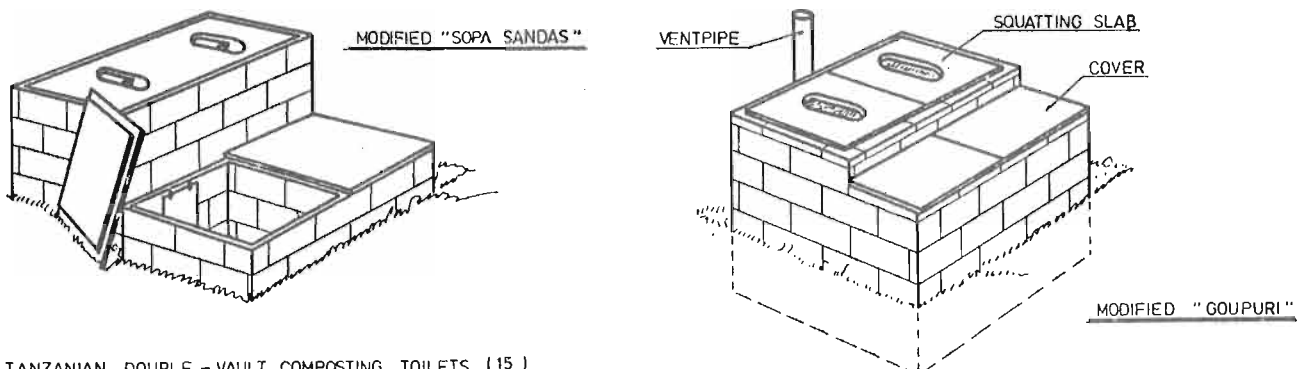


FIG. 4 : TANZANIAN DOUBLE - VAULT COMPOSTING TOILETS. (15)

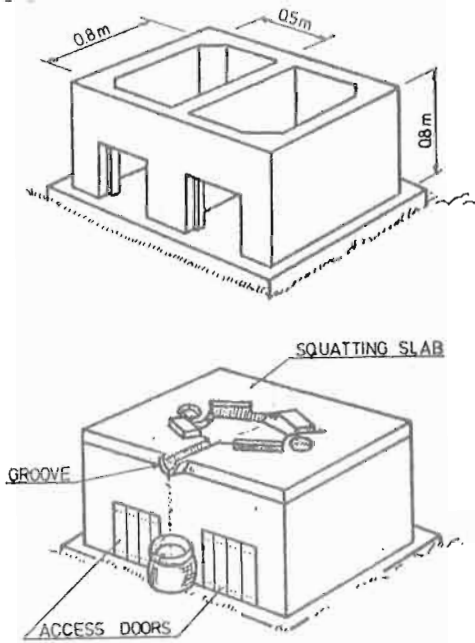
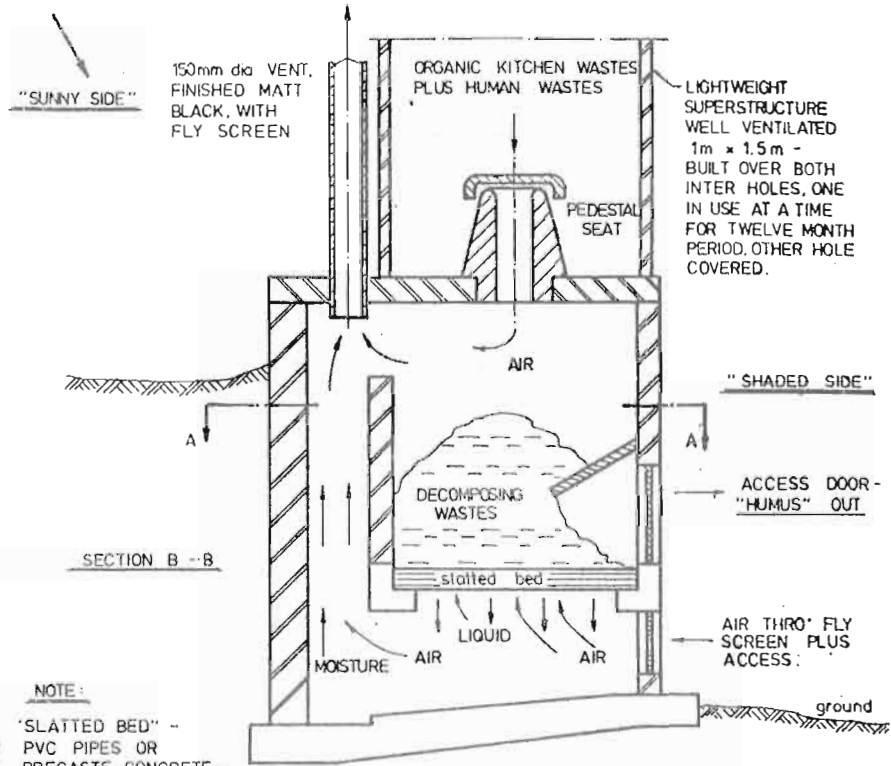


FIG 5 VIETNAMESE DOUBLE - VAULT COMPOSTING TOILETS. (20)



NOTE:
 "SLATTED BED" - PVC PIPES OR PRECASTE CONCRETE - CLOSE SPACED (10 mm GAPS MAX)

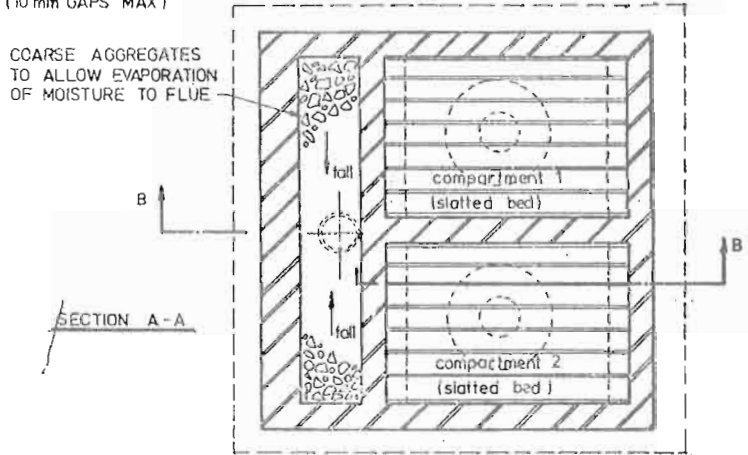
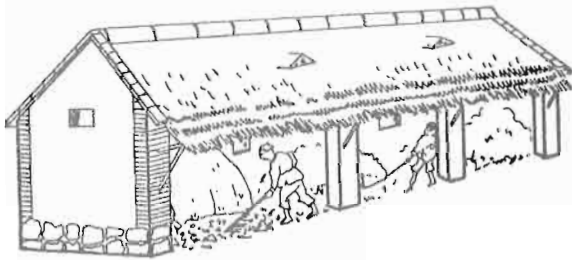
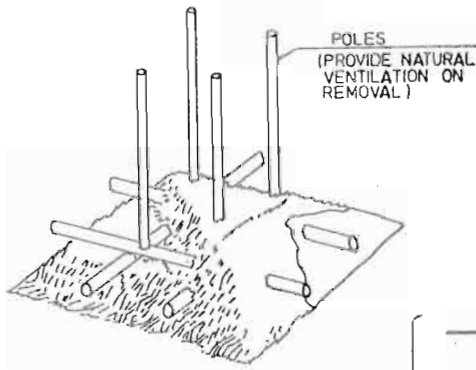


FIG 7 DOUBLE - VAULT COMPOSTING TOILET (PROPOSED DESIGN)



A THE GRANULAR FERTILIZER STORAGE SHED.



B. THE THERMOPHILIC, OR FOUR-COMBINED-IN-ONE METHOD OF AEROBIC COMPOSTING.

FIG. 6 CHINESE COMPOSTING METHODS. (19)

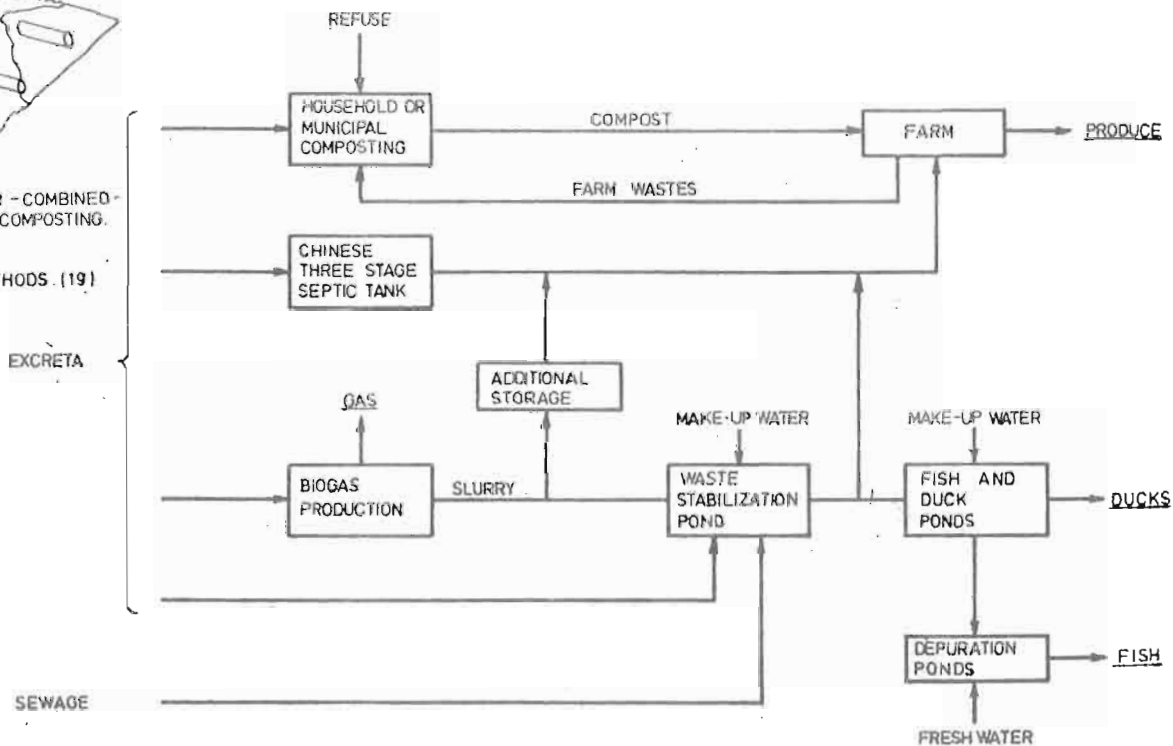


FIG. 8 : INTEGRATED WASTE REUSE PROCESSES (27)