COMPOST FERTILIZER FROM POUR-FLUSH WATERSEAL LATRINES

A PUBLIC HEALTH RISK ASSESSMENT

by

Mark Dorfman

UNICEF
Kathmandu, Nepal
September 1986

COMPOST FERTILIZER FROM POUR-FLUSH WATERSEAL LATRINES

A PUBLIC HEALTH RISK ASSESSMENT

by

Mark Dorfman

UNICEF
Kathmandu, Nepal
September 1986

ACKNOWLEDGMENTS

Sincere appreciation for their time and assistance is extended to the staff of East Consult, Inc. and to the Central Laboratory of the Water Supply and Sewerage Corporation.

"Scientists now know that the most fertilizing and effective manure is the human manure... Do you know what these piles of ordure are, those carts of mud carried off at night from the streets, the frightful barrels of the nightman, and the fetid streams of subterranean mud which the pavement conceals from you? All this is a flowering field, it is green grass, it is cattle, it is the satisfied lowing of heavy kine, it is perfumed hay, it is gilded wheat, it is bread on your table, it is warm blood in your veins."

Les Miserables
Victor Hugo (27)

TABLE OF CONTENTS

1. ABSTRACT 1

2. OBJECTIVE 1

3. INTRODUCTION 1

4. METHODOLOGY

Field Sampling 2

Laboratory Analysis 3

5. RESULTS AND DISCUSSION

Effect of Decomposition Time on Roundworm Egg Survival 4

Effect of Waterlogging on the Sanitary Quality of the Compost 8

Effect of Pit Waterlogging on Drinking Water Source Contamination 9

Effect of Ashes on Sanitary Quality of Compost 9

Effect of Pit Location on Internal Physical Conditions 12

6. CONCLUSIONS AND RECOMMENDATIONS

Compost Utilization

Emptying of Pit Contents 13

Post-Treatment of Compost 15

Field Application of Compost 16

Sulabh Latrine Maintenance 17

7. LIMITATIONS OF THIS STUDY 20

8. LIMITATIONS OF A SULABH LATRINE HEALTH IMPACT STUDY 20

APPENDIX 1: SAMPLING PROCEDURES 23

APPENDIX 2: LABORATORY METHODOLOGIES 24

BIBLIOGRAPHY 28

LIST OF TABLES

Table 1: Sampling Site Information.................................. 2

Table 2: Mortality Rate of Roundworm Eggs versus Total Egg Number..... 7

Table 3: Effect of Waterlogging on Roundworm Egg Survival............. 8

Table 4: Effect of Ashes on pH..................................... 10

Table 5: Effect of Pit Location.................................... 12

Table 6: Summary of All Measurements and Observations................ 27

LIST OF FIGURES

Figure 1: Number of Live Eggs per Gram of Compost versus Decomposition Time....................................... 5

Figure 2: Percent of Total Eggs Which are Dead versus Decomposition Time....................................... 6

Figure 3: Effect of Ashes on the Number of Live Eggs per Gram of Compost.. 11

1. ABSTRACT:

Live roundworm eggs were found in 63% of compost samples from double-pit, pour-flush latrines. Therefore, health safety precautions should be followed whenever the resultant compost is handled. Waterlogging of pits did not appear to have an effect on the concentration of surviving eggs, whereas the use of ashes in cleaning the squatting pan did appear to result in an overall decrease in the average number of live eggs per gram of compost.

2. OBJECTIVE:

To determine those factors that enhance or deter the natural removal of pathogenic organisms within double-pit pour-flush latrines (also known as sulabhs), and to provide public health guidelines for the safe handling and utilization of the resultant compost fertilizer.

3. INTRODUCTION:

Composting is a process by which relatively complex substances (ex. night soil, urine, vegetable matter, etc.) are broken down into simpler products (ex. nitrates, phosphates, carbonates, etc.) by the action of naturally occurring micro-organisms. When feces come in contact with soil, the soil bacteria begin to thrive in and decompose the waste (36, 26). Most enteric pathogens (disease causing organisms that live in the human digestive system and are subsequently excreted in feces and urine) will succumb in time to the adverse conditions occurring outside the body. These environmental conditions include temperature, moisture and the competitive and predatory action of other micro-organisms (21, 26, 29).

Time and temperature are the two most important factors contributing to the inactivation of enteric pathogens. Composting in the presence of air (aerobic) will produce temperatures great enough to kill enteric pathogens in a relatively short period of time; however, the air-free (anaerobic) conditions occurring in the sealed pits of pour-flush composting latrines inhibit this lethal temperature rise, and thus a longer period of time is required to render the compost pathogenically benign.

4. METHODOLOGY:

4.1 Field sampling: Compost samples were taken from latrine pits whose contents had been decomposing for anywhere from two weeks to two years. Due to the small number of pits that had actually been filled and left to compost at the time of this study, the total number of sampled pits from eight sites is thirty. Table 1 lists sampling site information. For a detailed report of sampling techniques see Appendix 1.

Table 1: Sampling Site Information

Site Name	Locality	Implementing Org.	# of Pits Sampled
Khokanaa	K'du Valley	UNICEF/MPLD	18
Bhadrapur	East Terai	"	1
Thimi	K'du Valley	EASTAP	3
Bode	"	"	1
Nagadesh	"	"	1
Kirtipur	"	"	2
Lainchur	"	"	1
Dadhikot	"	"	3
			TOTAL = 30

4.2 Laboratory analysis: Ova (eggs) of the helminthic parasite, *Ascaris Lumbricoides* (roundworm), were used as the indicator organism for sanitary quality of each compost sample because:

4.2.1 Generally, prevalence of this disease is high in most developing countries (15, 45), and specifically, roundworm infestation was found to be prevalent in 80% of the population in the town of Khokanaa prior to installation of the sulabh latrines (45).

4.2.2 Roundworm eggs are the most resistant of all enteric pathogens (21, 26, 44, 15) and is considered to be the most suitable indicator organism for this method of waste treatment (15, 29).

4.2.3 Roundworm eggs are relatively easy and quick to enumerate.

4.2.4 They are infective in small doses (15, 52, 19, 10) and there is little immunity built up in the exposed population (15).

Detailed laboratory procedures and a complete tabulation of collected data is given in Appendix 2.

5. RESULTS AND DISCUSSION:

5.1 Effect of decomposition time on the survival of roundworm eggs:

The data collected in this study suggests that even after a two year decomposition time, there is a likelihood that living, infective roundworm eggs will be present in the compost. Therefore, health safety precautions must be adhered to when handling and utilizing the compost fertilizer.

Figure 1 illustrates the relationship between the concentration of live worm eggs and decomposition time. Although there is a steady decrease with time, the average number of live, infective worm eggs that could be present after two years of decomposition is 145 per gram of compost. The literature states that even a single infective egg can cause infection (10, 52, 19). It must be noted that the data points are widely scattered and therefore this investigator suggests continued data collection over the next two years to further substantiate or refute the conclusions reached thus far.

Perhaps the most important factor in the variance of worm egg concentration at any given decomposition time is the overall health status of the family. A person with a high worm load could excrete as many as 300,000 eggs per gram of feces (15). Figure 2 shows that 87.5% of the samples exhibited a mortality rate of total worm eggs at 95% or more. This increased only slightly with time. Table 2 shows that the mortality rate of roundworm eggs is not necessarily proportional to the total number of eggs present. Therefore, the family that is shedding a greater number of eggs in each gram of feces will require a longer decomposition time in order to render the compost pathogen free.

Figure 1. Number of Live Eggs per Gram of Compost Versus Decompoition Time.

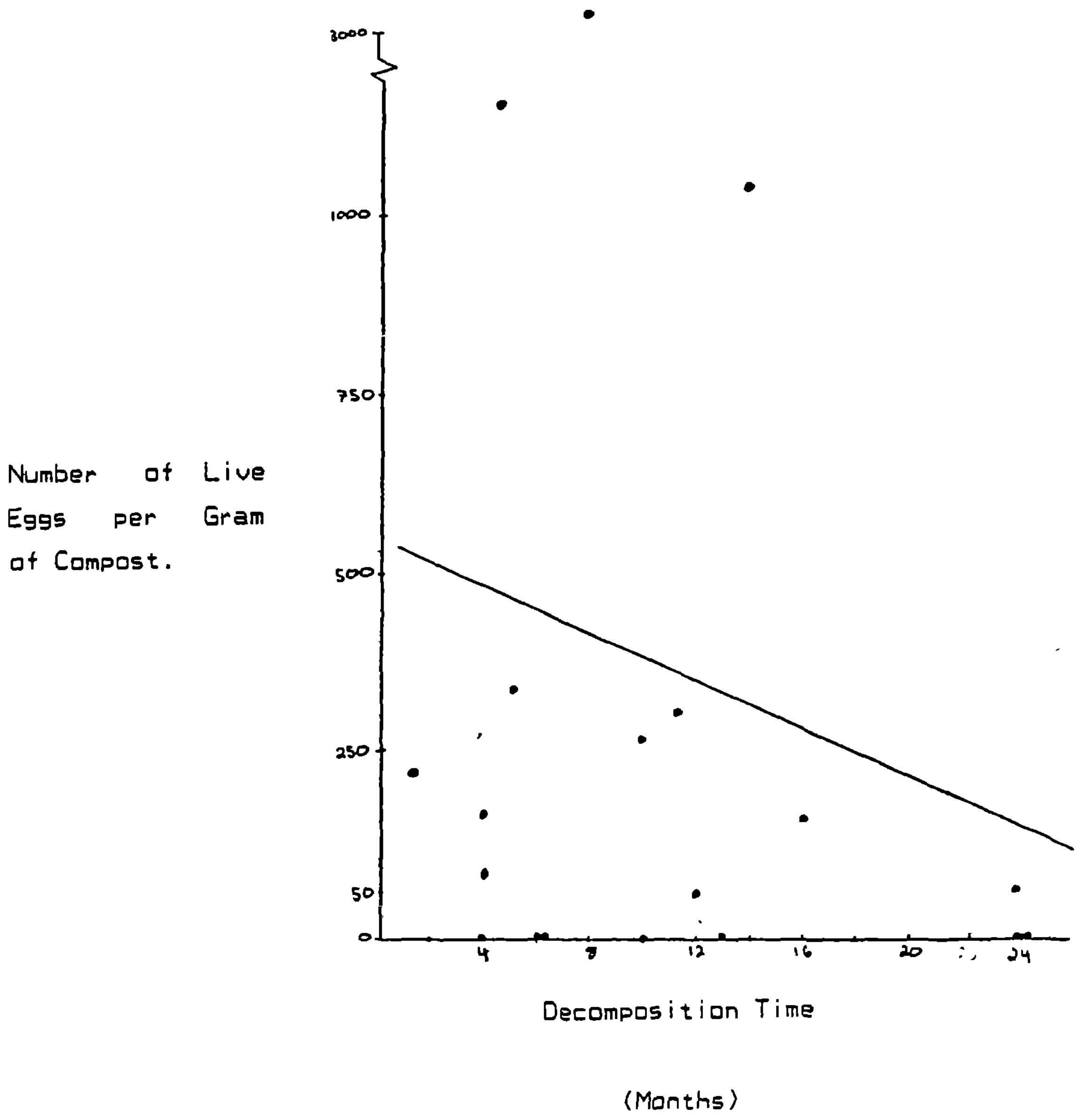


Figure 2: Percent of Total Eggs Which are Dead Versus Decomposition Time.

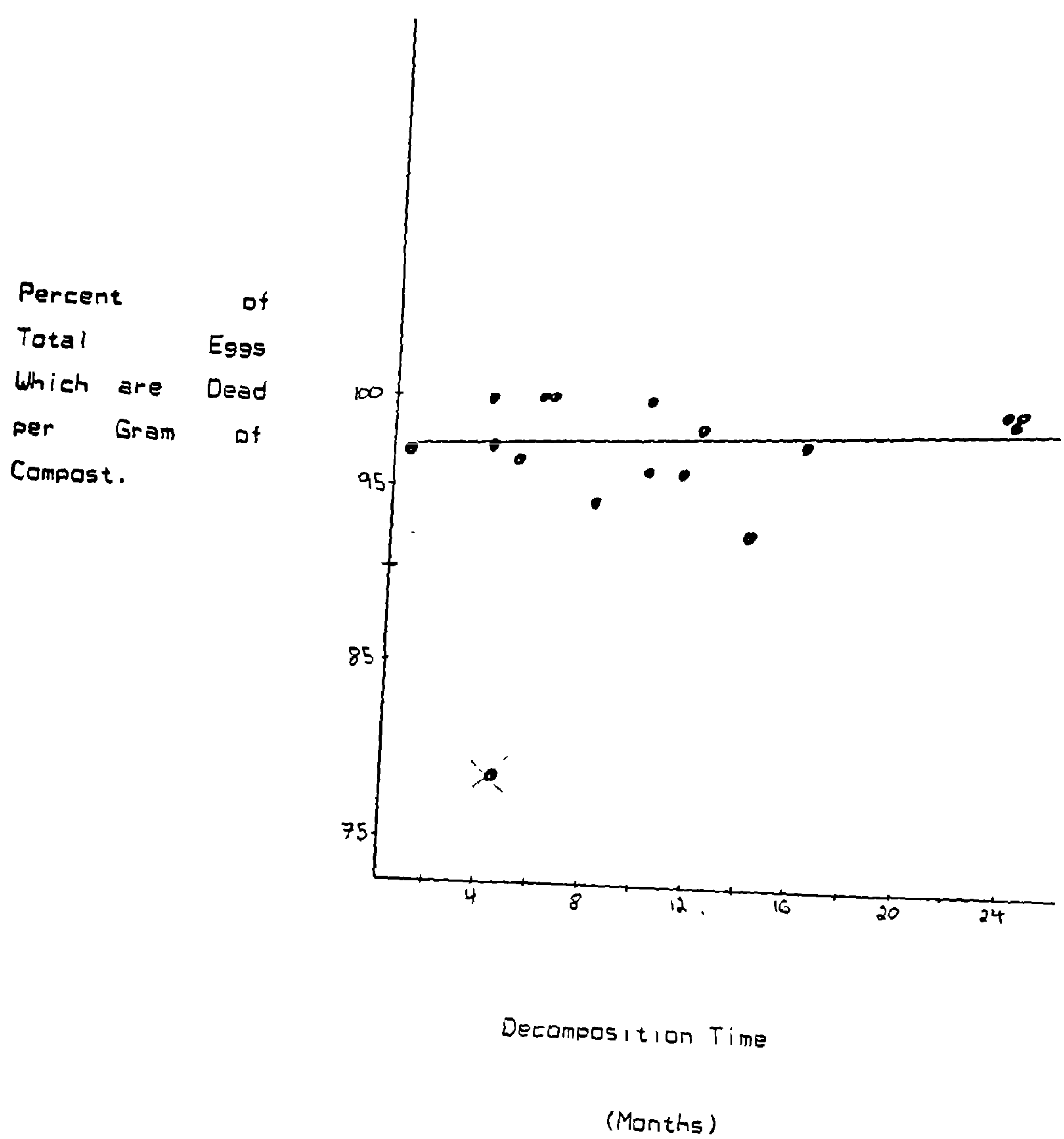


Table 2: Mortality Rate of Roundworm Eggs vs. Total Egg Number:

Total Number of Eggs/Gram of Compost	% Kill
53,538	94.3
16,526	92.6
11,571	100.0
9,071	100.0
9,000	96.3
8,370	99.1
8,000	96.2
7,143	97.0
6,769	97.8
6,211	97.5
5,543	95.9
5,375	100.0
4,621	98.5
3,524	97.4
2,444	100.0
2,143	100.0
1,647	100.0
1,500	100.0

5.2 Effect of waterlogging on the sanitary quality of the compost:

Waterlogging of the compost pit does not appear to have an effect on the overall sanitary quality of the compost. Table 3 shows that the difference in the average percent kill of worm eggs between waterlogged and non-waterlogged pits is not significant. It should be noted that only 21% of pits sampled were not waterlogged, therefore, continued data collection is recommended to further substantiate these conclusions.

Waterlogging of the compost pit causes functional problems in some cases and could render the latrine inoperable. Proper construction ammendments can be used to alleviate this problem in areas where waterlogging occurs (50).

Flooded pits have been observed to yield significantly reduced volumes of solid compost, thereby prolonging the life of the pits (25). This could account for the relatively long fill times reported by the homeowners.

The percent moisture readings for all pits sampled were between 65% and 97%. Anaerobic micro-organisms prevail when moisture content is above 60% (47) indicating that anaerobic conditions are always present in the latrine pits. Anaerobic composting does not reach the lethal temperatures necessary for thermal destruction of pathogens, therefore, decomposition time becomes the most important factor in this type of treatment process.

Table 3: Effect of Waterlogging on Roundworm Egg Survival.

	Average %Kill	# of Samples
Waterlogged Pits	96.3	11
Dry Pits	96.0	3

5.3. Effect of pit waterlogging on drinking water source contamination:

This study was not able to address the problem of waterlogging on the sanitary quality of water sources in areas with sulabh latrines. However, previous studies have revealed the following information: There is a much greater depth of bacterial penetration into the ground water where the water table is in contact with the pit (18). Viruses are able to travel further than fecal bacteria after heavy rains (24). Chemical constituents of the waste leachate, such as nitrates are able to travel futher in the soil than micro-organisms. Since nitrates are a by-product of night soil decomposition and can cause methemaglobinemia (*blue babies*), its presence should be monitored along with fecal bacteria in well water samples in the vicinity of sulabh latrines.

Collection of water quality data prior and subsequent to sulabh installation is recommended in towns which use well water for drinking or other purposes. This type of study was not feasible at the sites surveyed during this evaluation because, 1) all but one of the sites obtained their water from sources outside the town and 2) water quality data measured at that site prior to sulabh installation indicated all wells had already been heavily contaminated with fecal bacteria. This makes it impossible to differentiate possible future water contamination from sulabh waste infiltration.

5.4. Effect of ashes on sanitary quality of compost:

5.4.1. Effect of ashes on worm egg survival:

Figure 3 illustrates the relationship between the number of live worm eggs per gram of compost and decomposition time in households where ashes were said to be used or not used for cleaning the squatting pan. The average number of live eggs at any given time is less when ashes are used. Ashes promote the death of roundworm eggs (35).

5.4.2. Effect of ashes on compost pH:

Table 4 illustrates the difference in pH ranges for those pits where ashes were or were not used to clean the squatting pan. Only those latrines that utilized ashes for cleaning showed a consistent pH at neutral or alkaline levels (pH values below 7 indicate acidic conditions, whereas values above 7 indicate alkaline conditions). Ashes are reported to help neutralize the acid produced by certain anaerobic micro-organisms in the pit (42). Neutral and slightly alkaline pH conditions are desireable for efficient compost production (31).

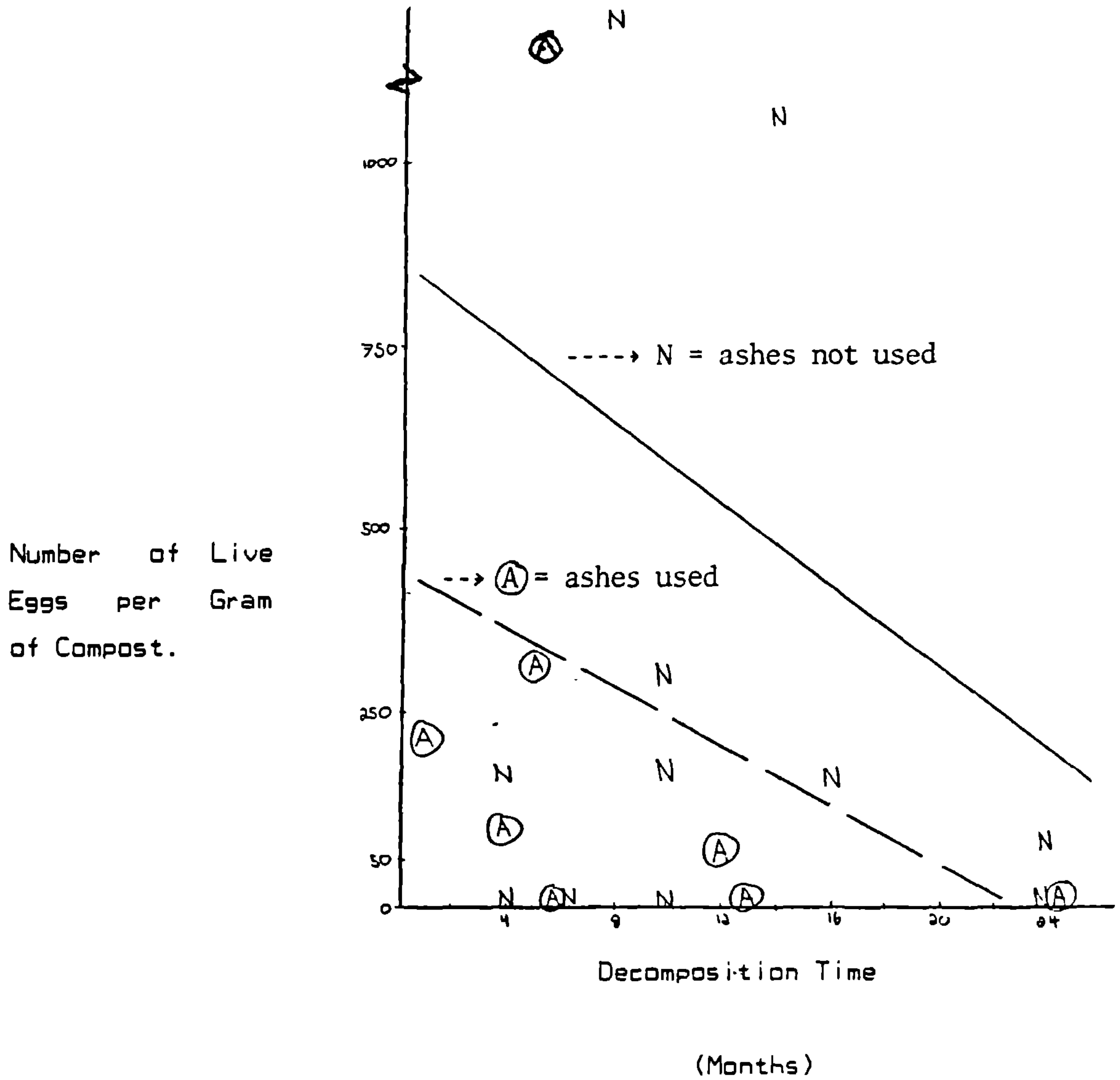
Table 4: Effect of Ashes on pH.

	pH Range
Ashes Used	7 - 7.5
Ashes Not Used	6 - 7.5

5.4.3. Effect of ashes on compost odor:

Empirical analysis suggests that utilization of ashes for pan cleansing has no effect on odor reduction of the compost. Dry ashes are commonly used in eliminating odors, however the moist conditions within the sulabh pit ensure the total saturation of ashes present thereby eliminating their odor absorption capabilities.

Figure 3: Effect of Ashes on the Number of Live Eggs per Gram of Compost.



5.5. Effect of pit location on internal physical conditions:

5.5.1. Compost temperature:

Table 5 shows the temperature ranges measured for pits located inside and outside the home. For complete destruction of pathogens under anaerobic conditions, the temperature must exceed 38°C (44, 15). The maximum temperature measured during the hot, dry season in the Kathmandu Valley did not exceed 21 degrees. A single temperature measurment in the Eastern Terai region during the hottest season was only 30°C. Therefore, location of the ccmpost pit inside or outside the home will not have an effect on the thermal destruction of pathogens in the compost.

5.5.2. Moisture content:

Table 5 shows the range of percent moisture measurements for pits inside and outside the home. Anaerobic conditions prevail at percent moisture levels above 60%, and lethal dessication (drying) occurs at moisture levels below 5% (47). Regardless of pit location, the percent moisture levels are consistently above 60% even in the latter part of the dry season. Therefore, pit location will not have an effect on sanitary quality of the compost in terms of moisture level conditions.

It should also be noted that there were no signs or complaints of odor release from pits that were located within the home.

Table 5: Effect of Pit Location:

Pit Location	Temperature Range °C	% Moisture Range
outside	17 - 21	65 - 97
inside	17 - 19	77 - 96

6. CONCLUSIONS AND RECOMMENDATIONS:

6.1. Compost utilization:

6.1.1. Emptying of pit contents:

6.1.1.1. When:

Based on the results of this study and on a review of the literature, it is suggested that a pit be emptied at least two years after it has been filled and sealed, and during the mid portion of the dry, hot season (April/May in Nepal).

As stated earlier in section 5.1 there is still a risk that viable, infective roundworm eggs will be present in the compost even after two years of decompostion. Previous studies on the survival of roundworm eggs in anaerobic compost have yielded varying results. One investigator claimed total destruction of pathogens in two years (36), while most stated that at least some roundworm eggs may survive for more than one year (15, 21, 47, 40). Roundworm eggs are also reported to live for more than seven years in soils and in drying sludge (15, 33, 13). The resistant strength of roundworm eggs to harsh environmental conditions is further illustrated by the fact that they can survive for a limited time even in wind blown dust (35). The uncertainty of adequate decomposition time in terms of health safety is summed up in the following quote:

> "...storage periods cannot be determined with confidence since related epidimiological evidence is lacking." (21)

Therefore, regardless of decomposition time, health safety precautions must always be adhered to when handling and utilizing the compost. This topic will be elaborated in subsequent sections. It should be noted that total removal of worm eggs from the compost may be an overachievement in that the soil content of viable roundworm eggs is usually high in towns and villages of developing countries (46), therefore the risk of infection through compost handling and utilization must be viewed in relation to other existing routes of infection.

The dry, hot season is best suited for pit emptying because of the lethal effects that sunlight, temperature and dryness have on pathogenic organisms (15). Furthermore, this takes advantage of the farmer's free time before pre-monsoon field work begins.

6.1.1.2. How:

Minimum contact of the hands, feet and clothing with the compost should be emphasized in order to avoid transport of the live eggs into the home. Those emptying the pit should be encouraged to wear shoes or chaples and to thoroughly wash or at least rinse the hands before entering the home. Thorough rinsing was found to remove worm eggs but wiping did not (15). Rubber gloves might be issued but their use by the Nepali villagers is doubtful. To avoid the need to enter the pit for complete removal of the compost, long-handled shovels should be made available in the town.

6.1.2. Post-treatment of compost:

6.1.2.1. Drying:

If space permits, the compost should be spread out in an approximate one inch thickness in a sunny area. A 1.5 inch thickness has been reported to result in total destruction of pathogens, whereas a 3-4 inch thickness will only yield a nominal reduction (22). Experiments conducted during this study showed that total pathogen removal was possible in about two weeks at one inch thickness of compost during the dry season. However, this time period should be extended by at least several days for each heavy rain that occurs during the drying time.

A complete surface cover of dry ashes at the outset will contain all offensive odors as well as eliminate fly breeding during this time. Furthermore, children and animals should be kept away from the drying compost. Eggs can be transmitted unharmed through dogs, cats, pigs and other animals that ingest the material (15).

6.1.2.2. Aerobic composting:

Mixing the freshly extracted compost in a pile with straw, rice stubble, dry grass, or other available material will initiate the growth of thermophilic (heat-loving) micro-organisms. These organisms will further decompose the compost and produce temperatures within the pile that will kill pathogens in anywhere from one hour to two months (32, 33, 47, 14). To ensure adequate temperatures in all parts of the compost, and to protect from wind, rain, flies, children and animals, the pile should be covered with soil (47) and then with ashes (to conceal odors). If this is done in the hot, dry season, the pile should be left for about one month before transfer to the fields.

6.1.2.3. Chemical additives:

6.1.2.3.1. Chemical fertilizers:

Chemical additives should be used as a supplement to and not in place of the steps described in sections 6.1.2.1. and 6.1.2.2. The addition of chemical fertilizers, such as ammonium sulphate, lime, gypsum, sodium nitrite, and calcium super phosphate, to the compost will further reduce its pathogen content (15, 23).

6.1.2.3.2. Chemical pesticides

PCB, PBB, DDT, Phenyl and other pesticides should not be used. They will contaminate the compost and restrict its usefulness (47, 37).

6.1.3. Field application of compost:

6.1.3.1. When:

Preferrably, compost should be applied to the fields prior to the time when field work and planting is required. There is less health risk if the compost is applied before the early stage of crop growth (33). Compost should not be applied repeatedly throughout the growth season (33) and should not be applied before harvest (15). Human feces and urine do not produce much humus, therefore repeated applications can cause the soil to become compacted, thereby inhibiting proper root development. Night soil compost should be used along with other manures (23).

6.1.3.2. Where:

Compost should not be applied to root or low-lying vegetables (those vegetables that lie on the ground) or to crops eaten raw (12, 35, 21). Furthermore, roundworm egg survival on crops (44, 14) and in soils exceed the growing time of the following vegetables: raddish, spinach, cucumber, carrot, potato, tomato, cauliflower and field beans (21). All homeowners in the town of Khokanaa stated that they planned to use the sulabh compost on the forementioned crops, therefore, health education information is needed during the post implementation phase of this type of sanitation intervention.

Compost would be best suited for fruit trees (since the fruit is never in contact with the soil), crops that have a longer growing season than the previously mentioned vegetables, or on those crops that are well cooked before consumption. However, there is no clear epidemiological evidence of disease risk from crops eaten cooked or those not used for human consumption (12). Therefore, care must always be taken to avoid transfer of worm eggs from the fieldworkers to those who prepare the food in the home (16) by thorough rinsing of hands and vegetables (15).

6.2. Sulabh latrine maintenance: Poorly used and maintained latrines can actually increase transmission of disease (15).

6.2.1. Ensure continuous latrine function:

6.2.1.1. Y-junction:

It is imperative that the Y-junction (point of connection between the drain from the squatting pan and the drains to the the two receiving pits) be properly sealed off to the pit currently not in use. Many existing sulabh latrines were found to be inadequately maintained in this respect. The consequence of an improperly sealed Y-drain is that both pits fill up with fresh night soil simultaneously. When this occurs the latrine must be either put out of use for several years while the pit contents decompose, or fresh night soil must be handled and removed from one of the pits.

6.2.1.2. Waterseal and drains:

Demonstrations of procedures used to clear obstructed waterseals or drains should be performed during the implementation phase of the project. Thereafter, technical personnel should be available in the village to advise and guide the homeowners when this type of obstruction occurs.

In areas where seasonal waterlogging is a problem, the pits should be constructed in such a way as to avoid disfunction of the latrine during that time. Raising the pit several inches above ground level will help in this matter (50).

6.2.2. Health safety:

6.2.2.1. Regular flushing:

Flushing after each use should be promoted to avoid drain clogging, fly and mosquito breeding, and offensive odors within the squatting superstructure. These conditions will not only increase the transmission routes of pathogenic bacteria, viruses, protozoa and helminths, but will also deter people from using the latrine. This is most important in terms of young children since their feces are the most concentrated with organisms that can transmit disease (27) and they are the least likely to use a latrine that is dirty or dark (25). Frequently, sanitation interventions are not successfull because children are not taught to use the facility (15).

6.2.2.2. Regular cleaning of pan area:

Weekly cleaning of the pan area with a handful of ashes and a scrub brush should be promoted in order to eliminate the accumulation of worm eggs on the moist pan surface. Hookworm eggs develop in shady, moist areas and accumulate in dirty squatting pans (35) and can be transferred to the home by flies. Furthermore, ashes will eliminate odors inside the superstructure and improve the quality of the compost (since the ashes will be flushed into the pit).

Disinfectants and pesticides should not be used to clean the squatting pan because they will poison the micro-organisms that carry out the decomopsition process in the pit.

6.2.2.3. Proper slab-cover fit:

The slab covering the compost pit should make a tight seal over the whole pit opening to avoid fly and mosquito breeding and to prevent the escape of odors.

Most latrines visited had an adaquate seal over the pit. In one case, however, the homeowner had removed the slab covers and used them as a thrashing surface for the harvested wheat crop. Health education during the implementation of these latrines would help to avoid such misuse. Smaller slabs were much easier to remove than the larger 1m x 1m slabs used initially.

7. LIMITATIONS OF THIS STUDY:

7.1. Sample number:

The major limitations of this study were the small number of pits that had been previously filled and sealed for composting, and the scatter of the data collected. Although conclusions and recommendations were drawn from collected data and observations, it is suggested that sampling and analysis of the compost be continued over the next two years so as to uphold or ammend the results and conclusions reached in this evaluation

7.2 Sample location:

The applicability of this study's results should be limited to projects in the middle hill regions of Nepal. The continued sampling program should include sulabh latrines built in the terai.

8. LIMITATIONS OF A SULABH LATRINE HEALTH IMPACT STUDY:

The ICCDR/B Workshop, "Measuring the Health Impact of Water Supply and Sanitation" (Bangaladesh, November 1983) concludes that:

> "...the complexity of health impact is such that isolated effects from interventions of water supply and/or sanitation are nearly impossible to single out."

8.1. Methodological problems:

A review of eleven health impact studies in which helminth infestation was used as the health status indicator reveals the following problem areas (6):

8.1.1. Confounding variables:

Confounding variables such as nutrition, socio-economic status, education and general environmental conditions, must be taken into account when trying to correlate the presence of a sanitation intervention and the health impact indicator. For example, an improvement or decline in the overall health of the population at the time of the study may be due to a simultaneous change in one or more of the forementioned areas, rather than from the sanitation intervention in question.

A deworming campaign at the outset of the study might lead some individuals to continue the deworming practice whenever illness occurs, thereby confounding the study results.

In the Kathmandu Valley, most of the eligible male population travel to the city for work and schooling. Infections obtained outside the village cannot be differentiated from those occurring within the village.

It has been documented that the immediate surroundings of the home present a great health problem especially in terms of the presence of roundworm eggs in the soil. Roundworm eggs survive for more than seven years in soil (15, 33, 13). This route of infection will persist for at least several years following sulabh implementation.

Although these are difficult obstacles to overcome, they might be reduced somewhat by selection of a representative control group and/or a large randomly selected population. The confounding variables should be clearly defined and measured throughout the study.

8.1.2. Failure to record facility usage:

Defecation practices must be recorded, especially of children. Usage is important to directly correlate any improvements in health with the sanitation intervention. Since roundworm eggs survive for many years in soils, this infection route can continue to be viable years after the sanitation intervention has been implemented.

APPENDIX 1: SAMPLING PROCEDURES:

1. Compost sampling:

Compost samples were taken from latrine pits that had been properly sealed off from the squatting pan effluent. After several modifications the procedures used are as follows:

1.1. Remove soil or other material stored on top of slab.

1.2. Remove slab cover from pit.

1.3. Use a sturdy stick that has been rinsed off with clean water (water that has been filtered through a thickness of cotton to remove eggs)

1.4. Penetrate at least five inches below the surface and move the stick around a small area.

1.5. Bring up a small quantity of compost and place into a thoroughly rinsed container. Sterilization is not necessary for microscopic analysis of roundworm eggs.

1.6. Make field measurements.

2. Field measurements:

2.1. Immediately measure temperature of the sample with a thermometer.

2.1. Measure pH of the sample with pH pa er.

3. Field observations:

3.1. Note the color, consistency and odor of the compost.

3.2. Note what is used to clean the squatting pan, and how often.

3.3. Note compost time.

3.4. Note soil conditions and waterlogging tendencies.

APPPENDIX 2. LABORATORY METHODOLOGIES:

2.1. Percent moisture determination procedures:

2.1.1. Weigh an empty crucible that has been oven dried and cooled in a dessicator. = (A)

2.1.2. Place a portion of the compost sample into the weighed crucible. Re-weigh. = (B)

2.1.3. Keep in a 103°C oven for 24 hours.

2.1.4. After 24 hours, remove from the oven and cool in a dessicator. Re-weigh. = (C)

2.1.5. Percent moisture = $\frac{(B) - (C)}{(B) - (A)} \times 100$

2.2. Selection of indicator organism:

2.2.1. Roundworm eggs:

Roundworm eggs were selected because of their prevalence in the population, their survivablilty relative to all other enteric pathogens, and the ease in which they are detected and counted.

2.2.2. Coliform bacteria:

Coliform bacteria were rejected as an indicator organism because they die before roundworm eggs (15, 33, 21), turbidity of compost samples suppress the gas forming ability of the coliform organisms in the MPN test and clogs the filters of the MF test, and high populations of other micro-organisms present in the compost suppress coliform growth (33).

2.3. Microscopic determination of roundworm eggs:

2.3.1. Procedures:

2.3.1.1. Weigh dry, clean bottle. = (A)

2.3.1.2. Add portion of sample.

2.3.1.3. Re-weigh. = (B)

2.3.1.4. Sample weight (S) = (B) - (A)

2.3.1.5. Mix with as little saline water as possible to produce a slurry that will allow one drop of the mixture to flow out of an eye dropper onto a microscope slide. Note the volume of saline water used = (V)

2.3.1.6. Put one drop of the mixture (0.05 ml) onto a microscope slide and cover with a cover slip.

2.3.1.7. Scan the entire slide under 100X power.

2.3.1.8. Use the criteria listed in section 2.3.2. to determine roundworm viability. Note the total number of eggs seen = (T), and the number of live eggs seen = (N)

2.3.1.9. Live eggs per gram of compost = $\frac{(N)}{(0.05ml)} \times \frac{(V)}{(S)}$

2.3.1.10. Percent kill =

$$\frac{(T) - (N)}{(T)} \times 100$$

2.3.2. Morphological criteria for roundworm egg viability (32):

2.3.2.1. Live eggs:

Living roundworm eggs have the following caharacteristics:

-oval shape.
-approximately 60 x 45 microns.
-grey/white, yellow/brown or yellow/green
-may be decorticated.
-shell is formed by two or three oval shaped rings.
-within the shell there is a round egg cell.
-crescent shaped transparent spaces at each end between egg cell and egg shell, sometimes as thin as a line.
-multi-cellular stage shows overlap of similarly shaped cells within egg cell.
-larval stage is in the shape of: S, 8, 6 or 2.

2.3.2.2. Dead eggs:

Dead roundworm eggs have at least one of the following characteristics:

-both sides of the egg cell are closely connected to the egg shell. No visible space.
-one side is dilapidated and forms a crack.
-vacuole present in the crescent shaped space regardless of number or size.
-both of the crescent shaped spaces are filled with granular cells. Granules are distributed unevenly and there is no space.
-circular spaces appear inside the cell.
-spotted granules inside the egg cell are not clear, or mixed with cell fluid, look turbid and coagulated and fill up the whole egg shell.
-egg cell is contracted.

Table 6: Summary of All Measurements and Observations

HOMEOWNER'S NAME	PANCHAYAT	WARD #	COMPOST TIME (MONTHS)	SAMPLE DATE (mo/day 1986)	TOTAL NUMBER OF ROUNDWORM EGGS per gm compost	seen under micro	NUMBER OF LIVE EGGS (a) per gm compost	(b) seen under micro	% KILL (c)	GRAMS of SAMPL (d)	mls (e)	NUMBER OF LIVE EGGS OF TRICHURIS (f) per gm compost	seen under micro	% H2O (g)	(h)	(i)	(j)	ASH USE (k)	PIT (l)	(m)	TEMP C	pH	SOIL TYPE (n)	(o)	COMMENTS
Kancha	Khokanaa	4	0.5	4/07	*	*	*	*	*	*	*	*	*	195	*	*	*	NO		*	17	6.0	*	*	
Bridi Man	″	1	1	4/22	55,046	132	*	*	*	4.8	100	0	0	194	g/b	+++	FRO	″	0	NON	20	7.0	*	*	clean, sunnyyard
R.M. Kila	Bode	4	1	7/24	7,143	100	214	3	97.0	2.8	10	71	1	*	″	+	THK	YES	0	″	*	*	BAD	WL	clean house
Kool Ratna	Khokanaa	6	1	4/07	*	*	*	*	*	*	*	*	*	189	*	+++	FRO	″	0	*	17	7.5	*	*	″
PradanPanch	″	4	1	4/15	*	*	*	*	*	*	*	*	*	181	g/b	+++	″	NO	0	NON	20	7.0	*	*	″
SyamBahadur	Kirtipur	*	2	5/01	8,807	33	*	*	*	7.5	100	0	0	179	″	++	THK	″	0	*	19	7.0	*	*	
Ram Bahadur	Khokanaa	4	3	4/20	20,139	41	*	*	*	4.1	100	0	0	177	″	+++	″	″	1	SOL	19	6.5	*	*	clean house
BhimBahadur	″	1	3	4/22	3,145	17	*	*	*	10.5	100	0	0	194	″	++	LOS	″	0	STR	21	7.0	*	WL	clean courtyard
AsaMaharjan	″	6	4	4/07	*	*	*	*	*	*	*	*	*	178	*	*	*	″	0	″	19	7.5	*	*	″
Sudesh	Thimi	4	4	6/30	3,524	76	95	2	97.4	4.2	10	95	2	185	g/b	++	THK	YES	0	NON	*	*	*	WD	
Ratna Lal	Khokanaa	6	4	7/28	9,071	127	0	0	100.0	2.8	10	143	2	*	*	*	*	NO	0	*	*	*	*	WL	2HookwrmOvaSeen
Ram Lal	″	2	4.5	7/12	6,000	42	1,286	9	78.6	2.8	20	0	0	197	g/b	++	LOS	YES	0	NON	*	*	GOOD	WL	
KrisnaKumar	Nagadesh	5	5	7/24	9,000	135	333	5	96.3	3.0	10	133	2	*	″	+	THK	″	0	″	*	*	BAD	WD	
ChandrPrasd	Thimi	3	6	6/30	5,375	43	0	0	100.0	1.6	10	0	0	182	blk	+++	″	″	0	″	*	*	*	WL	
Ram Bahadur	Khokanaa	4	6	7/21	6,211	118	158	3	97.5	3.8	10	53	1	*	*	*	*	*	*	*	*	*	*	*	
Mohan Shyam	″	4	6	7/28	1,647	28	0	0	100.0	3.4	10	53	1	*	*	++	*	NO	1	SOL	*	*	*	*	clean house
MadanKrisna	″	3	8	4/27	53,538	82	3,077	5	94.3	1.3	40	0	0	*	blk	++	THK	″	0	NON	18	7.0	GOOD	*	
Man. Biswas	Bhadrapur	9	10	6/08	5,543	93	229	4	95.9	3.5	10	0	0	*	″	++	LOS	″	0	″	30	7.0	*	WL	pit raise 1ft
Dev Bahadur	Khokanaa	6	10	4/20	11,571	27	0	0	100.0	1.4	30	0	0	174	g/b	+++	THK	″	0	″	17	7.0	*	WL	nearKitchnWaste
Babu Lal	″	9	11	5/11	17,260	81	*	*	*	*	100	*	*	179	″	++	″	″	0	″	19	6.0	GOOD	WD	dryDrainAdjacnt
BridiKrisna	″	6	11.5	7/28	8,000	104	308	4	96.2	2.6	10	462	6	*	*	*	*	″	0	″	18	7.0	″	WL	1HookwrmOvaSeen
Sidhi	″	5	12	4/15	*	*	*	*	*	*	100	*	*	178	g/b	++	THK	″	1	SOL	18	7.0	*	WL	
Babu Ram	″	1	12	4/22	7,800	51	*	*	*	13.0	100	0	0	196	″	++	″	″	1	″	19	7.0	*	WD	clean house
Jogat Man	Thimi	2	12	6/30	4,621	67	69	1	98.5	2.9	10	69	1	186	″	+++	LOS	YES	0	NON	*	*	*	WL	both pits WL
PraganPanch	Dadhikot	6	13	5/06	2,143	15	0	0	100.0	1.4	10	0	0	181	blk	+++	″	″	0	″	19	7.0	*	WL	
GanesBahadr	Khokanaa	3	14	4/27	16,526	157	1,053	10	92.6	1.9	10	0	0	183	g/b	+++	THK	NO	0	″	18	7.0	*	WL	both pits WL
BhadowBsnet	Dadhikot	9	16	5/06	6,769	44	154	1	97.8	1.3	10	462	3	177	″	+++	″	*	0	*	21	7.0	*	*	
HeraBahadur	Kirtipur	*	24	4/26	8,370	112	74	1	99.1	2.7	10	0	0	179	″	+	″	NO	0	SOL	20	7.0	*	*	roundpit design
RamHariKrki	Dadhikot	6	24	5/06	1,500	4	0	0	100.0	1.6	30	190	1	165	blk	+	LOS	YES	0	NON	19	7.0	*	WL	pitAdjacntDrain
NuchchaRatn	Lainchur	29	24	5/27	2,444	22	0	0	100.0	1.8	10	0	0	181	g/b	+	″	NO	0	KW	20	7.0	*	WL	

(a) See section 2.3.1.9, Appendix 2.

(b) See section 2.3.1.8., Appendix 2
A value of zero indicates that the concentration of live eggs is below the detection limit of this testing technique. It does not necessarily mean that there are absolutely no live eggs in the compost.

(c) See section 2.3.1.10., Appendix 2

(d) See section 2.3.1.4, Appendix 2

(e) See section 2.3.1.5, Appendix 2

(f) Trichuris (whipworm) eggs were seen in some samples, but their viability was not determined. Whipworm eggs are less resistant to lethal conditions than are roundworm eggs

(g) See section 2.1., Appendix 2

(h) g/b=green/brown, blk=black

(i) +++=strong odor, ++=moderate, +=slight odor

(j) Consistency of compost: FRO=frothy, THK=thick, LOS=loose.

(k) See section 3.2, Appendix 1.

(l) Pit location: I=inside home, O=outside home

(m) Material stored on top of slab. NON=none, SOL=soil, STR=straw, KW=kitchen waste

(n) In terms of ability to let water drain

(o) Pit drainage. WD=well drained, WL=waterlogged

* = data not collected.

BIBLIOGRAPHY

1 Bauma, J., "New Concepts in Soil Survey Interpretations for On-Site Disposal of Septic Tank Effluent", Soil Science Society of America Proceedings, Vol. 38, No. 6, Nov/Dec 1974.

2 Benenson, A.S., "Control of Communicable Diseases in Man", APHA, 13th ed., 1981.

3 Bhaskaran, T.R., B.K. Gosh Roy, M.A. Sampathkumaran, I. Radhakrishnan, D.B. Mukherjee, "Studies on the Survival of Pathogens in Nightsoil Compost", Indian Journal of Agricultural Science, Vol. 27, No.1, 1957.

4 Bhaskaran, T.R., "Low Cost Water Seal Pour-Flush Leaching Pit Latrines in Urban Communities - Pollution Studies", UNDP Global Project GLO/78/006, New Delhi, July 1982.

5 Bickel, F., Solid Waste Management Project, Kathmandu. Personal Communication.

6 Blum, D., R.G. Feachem, "Measuring the Impact of Water Supply and Sanitation Investments on Diarrhoeal Diseases: Problems of Methodology", International Journal of Epidemiology, Vol. 12, No. 3, Oxford Univ. Press, U.K., 1983

7 Cairncross, S., J.F. Cliff, "Water and Health in Mueda, Mozambique."

8 Carroll, R.F., "Affordable Sanitation for Developing Countries.", Building Research Establishment, U.K. 1982

9 Cram, E., "The Effect of Various Treatment Processes on the Survival of Helminth Ova and Protozoan Cysts in Sewage", Sewage Works Journal, Vol. 15, 1943.

10 Drake, M., British Military Hospital, Public Health Laboratory, Dharan Personal Communication.

11 Edwards, P., "Aquâculture: A Component of Low Cost Sanitation Technology", Integrated Resource Recovery, W.B. Technical Paper No. 36, April 1985.

12 Ellis, H.M., W.E. Gilbertson, O. Jagg, D.A. Okun, H.I. Shuval, J. Summer "Problems in Community Wastes and Management", No. 38, Geneva, WHO, 1969

13 Feachem, R., M. McGarry, D. Mara, "Water Wastes and Health in Hot Climates" John Wiley, New York, 1977

14 Feachem, R.G., D.J., Bradley, H. Garelick, D.D. Mara, "Appropriate Technology for Water Supply and Sanitation - Health Aspects of Excreta and Sullage Management - A State of the Art Review" Vol. 3, World Bank, Dec. 1980.

15 Feachem, R.G., D.J. Bradley, H. Garelick, D.D. Mara, "Sanitation and Disease - Health Aspects of Excreta and Wastewater Management", World Bank, New York 1983.

16 Flintoff, F., "Management of Solid Wastes in Developing Countires." WHO Regional Publications, S.E. Asia Series No. 1, 1984.

17 Gotaas, H.B., "Composting", WHO Monograph Series No. 31, Geneva 1956.

18 "Groundwater and Wells", Library of Congress No. 66-29629, Saint Paul Minn, USA, 1975.

19 "Guidelines for Drinking Water Quality", WHO, 1984

20 Gunn, R.A., Ballance R.C., "Maximizing Benefits to Health" WHO, ETS/83.7, Geneva.

21 "Health Aspects of Nightsoil and Sludge Use in Agriculture and Aquaculture." IRCWD News, No. 23, WHO, Dec. 1985.

22 Hogg, E.S., "A Preliminary Study of Ova and Cysts in Cynda Digested Sludge" Journal of Proc. Inst. Sewage Purification, Part 1, South African Branch, 1950.

23 "Human Feces, Urine and Their Utilization", ENSIC Script/370 Version 3, ISBN-974-8200-22-1, A.I.T., Bangkok, 1981.

24 "Human Viruses in Water, Wastewater and Soil", Tech. Report No. 639, WHO 1979.

25 Joshi, P.C., EASTAP, Personal Communication.

26 Kawata, K., "Environmental Sanitation in India", Department of Social and Preventative Medicine, Christian Medical College, Luchiana, Punjab, March 1963

27 Kawata, K., W.N. Cramer, W.D. Burge, "Composting Destroys Pathogens in Sewage Solids", ENSIC 340014 Abstracts, 1979, Water and Sewage Works, 1977.

28 King, M., "A Medical Laboratory for Developing Countries", Oxford University Press, London 1973

29 Krige, P.R., "A Survey of the Pathogenic Organisms and Helminthic Ova in Composts and Sewage Sludge", J. Inst. Sewage Purification, 1964

30 Lewis, W.J., S.S.D. Foster, B.S. Draser, "The Risk of Ground Water Pollution be On-Site Sanitation in Developing Countries" Lit. Review, IRCWD No. 01/82;

31 Mara, D.D., "Sewage Treatment in Hot Climates", Wiley, Chichester, U.K. 1976

32 McGarry, M.G., J. Stainforth, "Compost, Fertilizer and Biogas Production from Human and Farm Wastes in the People's Republic of China", IDRC-TS8e

33 McJunkin, "Water and Human Health" USAID, AID/DSAN - C- 0063, July 1982

34 Otis, R.J., W.C. Boyle, "On Site Disposal of Small Water Flows", Small Scale Waste Management Project, University of Wisconsin, Madison, 1977

35 Pacey, A., "Sanitation in Developing Countries", Oxfam, John Wiley, New York 1978

36 Pathak, B., A. Prakashan, "Sulabh Sauchalaya", Calcutta, 1981

37 Patel, I., "Safai Margdarshika (A Guide Book of Sanitation)", Udyogshala Press, Delhi 1970

38 Polprasert, C., S. Wangsuphachart, S Muttamara, "Composting Nightsoil and Water Hyacinth in the Tropics." Compost Science/Land Utilization March/April 1980

39 "Recycling of Solid Wastes", Environmental Sanitation Reviews, ENSIC, ISSN 0125-5088, No. 13/14, Sept. 1984

40 Reeves, J.B., "Sanitary Aspects of Composted Sewage Sludge and Sawdust", Sewage and Industrial Wastes, Vol. 31, No. 5, May 1959

41 "Report of the Internatinal Seminar on Low-Cost Techniques for Disposal of Human Wastes in urban Communities", Calcutta, Feb. 1980

42 Rodale, J.I., "The Complete Book of Composting", Rodale Books, Inc., Emmaus, Pa., 1960

43 Roy, A.K., "Manual on the Design, Construction and Maintenance of Low Cost Pour-Flush Waterseal Latrines in India", World Bank, TAG-TN-10, 1984

44 Rudolfs, W., L.L. Falk, R.A. Ragotzkie, "Literature Review on the Occurence and Survival of Enteric, Pathogenic and Related Organisms in Soil, Water, Sewage, Sludges and on Vegetation", Field Study on Ascaris eggs, Sew. and Ind. Wastes 1950

45 "Sanitation Education in Khokanaa", Baseline Survey, Vol. I, New ERA, Kathmandu, Jan. 1983

46 "Sanitation: Why and How", Recommendations of the National Sanitation Seminar, Kathmandu, Nepal, Sept. 1981

47 Shuval, H.I., C.G. Gunnerson, D.S. Julius, "Appropriate Technologies for Water Supply and Sanitation - Nightsoil Composting", Vol. 10, World Bank, Washington, D.C., Dec. 1981

48 "Water Qualtiy Surveys", WHO/UNESCO, 1978

49 Winbland, "Sanitation Without Water", UNO, SIDA, Stockholm, 1978

50 Wolz, C., "Evaluation of the Semi-Urban Sanitation Project - Engineering Aspects", UNICEF, Kathmandu, Nepal 1986

51 "World Water", Sept. 1984

52 "World Water", Nov. 1985

53 Ziebell, W.A., J.L. Anderson, I. Bauma, E. McCoy, "Fecal Bacteria: Removal from Sewage by Soild", American Society of Agricultural Engineers. No. 75-2579